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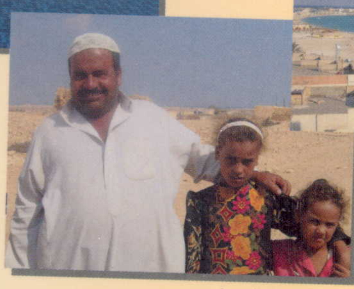
SUSTAINABLE MANAGEMENT OF MARGINAL DRYLANDS

Application of indigenous knowledge for coastal drylands

Edited by
Zafar Adeel



Proceedings of a
Joint UNU-UNESCO-ICARDA
International Workshop
Alexandria, Egypt
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UNITED NATIONS UNIVERSITY
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Preface

Hydrological studies show that there is abundant water on earth, as 75% of the earth is water and only 25% is land surface. If all the water was readily available for human use, the earth would not face water problems, especially in terms of quantity. The problem at hand is that most of the freshwater is currently inaccessible for human use; the largest fraction is frozen in the polar ice caps, and the remainder is present as soil moisture, or lies deep underground in groundwater aquifers. As a result, less than 1% of the world's freshwater, or about 0.012% of all the water on Earth, is readily accessible for direct human use in lakes, rivers, reservoirs and those underground sources that are shallow enough to be tapped at an affordable cost. Only this small amount is regularly renewed by rain and snowfall, and therefore available on a sustainable basis.

Population increase is one of the significant factors contributing to water problems. Millions of people are added to the earth every year intensifying pressure on natural resources. In the year 2000, the global population increased by 77 million and reached a total of 6.1 billion, and in the year 2001 reached 6.2 billion (based on statistics from *Vital Signs*, 2001 and 2002). Water consumption for agriculture is the highest of all because of expansion of irrigated areas in an effort to ensure food security. This, when coupled with human activities for economic growth and changes in lifestyles, increases the magnitude of global water crises.

The increase in population necessitates us to look into how it translates into impacts on water availability. The WHO (2000) report noted that 693 million people in Asia have no access to water and the number is 300 in Africa. The World Resources Institute noted that 2.3 billion people around the world live in water stressed countries where the per capita water availability is less than 1,777m^3. It is estimated that those who will live in water stressed situation will reach 3.4 billion by 2025.

The United Nations University (UNU) contributes to solving global pressing problems through research and training. The focus is on developing countries and the approach employed by UNU in the course of implementation is multidisciplinary and holistic. We realize that the increasing scarcity of water in the dry regions –

comprising arid, semi-arid and dry subhumid areas – is a major constraint for development. Our networking and research activities focus on innovative and practical ways to manage water resources, while facilitating South-South collaboration. UNU has conducted a number of workshops on issues related to sustainable management of natural resources (mainly land and water) in the Drylands. These include: New Technologies to Combat Desertification (1998 Tehran, Iran); Water Management in Arid Zones (1999 Mednine, Tunisia); Water Management in Central Asia (2000 Aleppo, Syria); Integrated Land Management in Dry Areas (2001 Beijing, China); and Sustainable Management of Marginal Drylands (2002 Alexandria, Egypt).

The focus of this workshop was on reclamation or rehabilitation of the fragile ecosystems in marginal drylands. We think that the output from the workshop, summarized in this book, can be an important contribution to human development and improvement of the quality of in these regions.

Prof. Motoyuki Suzuki
Vice Rector, ESD
United Nations University

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Opening Address by
H.E. Dr. Mahmoud Abu-Zeid

Minister of Water Resources and Irrigation, Egypt

Distinguished Experts, Colleagues and Friends
Ladies and Gentlemen

I am very pleased to have this opportunity to participate in this international workshop on Sustainable Management of Marginal Drylands. I would like to express my most sincere thanks to the United Nations University together with UNESCO and ICARDA for co-sponsoring this very important specialized workshop and allow me to welcome you all in the beautiful city of Alexandria. I would like also to thank Dr. I. Serageldin for hosting this event at the great Library of Alexandria.

In my brief comments this morning I would like to highlight some views about three important questions related to the subject of the workshop, first what marginal drylands means to us in Egypt, second what are the issues threatening its sustainable management, and third what are the suitable corrective measures to secure its sustainability.

But before getting into this, let me brief quickly about some features of the water resources in Egypt and the strategies we are developing for its management. Egypt, as you know, is an arid country and probably very few other countries in the world depend upon a single source of water supply as Egypt does on the river Nile. More than 95 percent of our water supply comes from the Nile. Before the construction of the High Aswan Dam (HAD) Nile waters used to flood the valley and the Delta annually, defining its irrigation system and cropping patterns through thousands of years. With the construction of the HAD in 1964 and its full operation in 1968, irrigation water become available all year round. The water system is still under adjustment to optimally exploit the potential benefits of this change. Virtually all the available water is currently being used.

Egypt has no effective rainfall except in a narrow strip along the northern coastal areas where a relative insignificant rain-fed agriculture is practiced. The groundwater reservoirs underlying the

Nile Valley and the Delta are also entirely dependent on seepage of irrigation water diverted from the Nile. They do not constitute an additional source of supply. Some limited renewable and non-renewable groundwater resources occur in the Nubian Sandstones of the west Desert and in Sinai.

Water management strategies have always focused on developing new supplies to satisfy the ever-increasing demands from all sectors and on building infrastructure to convey and distribute these supplies to different users. Till recently, very little attention was given to reduce the demand or to improve the water quality. Now, almost all the supplies have been developed, demand and quality management evolved as the complementary solutions to solve many demand requirements.

Demand management seeks to optimize the allocation of available water at any particular time to the competing user groups. Quality management seeks to maintain the usability of the resource by controlling pollution. Environment protection has become a major focus of water management in Egypt. However, preserving the ecology of the water system should not prevent its development for the benefit of other sectors. A compromise can easily be reached if the spirit of cooperation prevails during the planning and management activities.

Egypt is developing its water resources management strategies in a more integrated manner in the sense of looking at the water scarcity from all its different views. Current policies of water resources management look at the whole set of technical, economic, institutional, managerial, legal, and operational activities required to plan, develop, operate, and manage the water resources system on both national and local scales.

Sustainability is one of the major objectives of these policies in the sense that the utilization of resources by future generations should not be limited by the use of current generations in any way. Suggested projects and programs do not necessarily have to serve only one sector. A project can be multi-purpose; it can serve reclaiming new lands, build new communities and industries and generate hydropower while conserving the ecological system for both human and habitats.

Back to the topic of the workshop, the marginal drylands are areas within the watershed of desert valley that may be inhabited and used for agriculture or other development activities. The marginal lands along the Mediterranean Northern Coast include extensive cultivated areas that provide food for local communities living in these remote arid and semi-arid zones.

These coastal regions are presently identified as one of the most promising priority areas for development due to their comparative characteristics, including a good road network and moderate climate. However, these regions are suffering from low potential water resources and are classified as dry. This has dictated proper and accurate assessment of available water resources and suitable development activities.

The coastal regions in Egypt, and also marginal lands in Sinai and New Valley drylands, are considered important assets constituting major economic resources and essential social backbone for many Bedouin tribes. Previous generations have conveyed great deal of knowledge concerning traditional methods of securing water resources in such marginal drylands. These methods help in the protection of the drylands against erosion and in securing sufficient water supplies to local communities.

Among the traditional methods for providing and maintaining water supplies to marginal drylands are: Roman wells, cisterns, storage tanks, the use of recharging dams and check embankments to replenish aquifers, and locating of cultivated areas at the foot of sand dune slopes closed to the down stream sides of underground water flows.

Management of the marginal drylands cannot be achieved without studying carefully the issues threatening its sustainability. Some of these issues are as follows:

- Coastal erosion
- Rising sea levels
- Overpopulation that exceeds the natural carrying capacities of dryland areas
- Short sighted development activities
- Competition between agriculture and other forms of development

- Lack of water resources and deterioration of its quality
- Desertification and sand dune invasion

The following approaches have been used in Egypt to avoid some of these problems:

1. Enhancing present irrigation technology through in-depth studies of key issues, including:
   - Indigenous traditional technologies for water supply in arid zones; and
   - Water conservation measures including the selection of crop varieties with low water consumptions and the use of drip and sprinkler irrigation techniques.
2. Adopting integrated concepts for the planning and management of the entire coastal zone.
3. Transporting water from the Nile through lined canals and/or closed conduits to selected dryland locations suffering from water shortages.
4. Raising public awareness for environmental preservation measures.
5. Adopting transparent policies for the development of coastal zones.
6. Encouraging stakeholder participation in the decision- making process.
7. Encouraging young graduates to move to marginal dryland through the provision of soft loans.

Ladies and gentlemen, I would like to thank you for choosing Egypt to hold this workshop in, ad I am very much confident that the workshop, by your active participation and contribution, will stimulate discussions and formulate recommendations and guidelines.

It is with this spirit that I am pleased to welcome you once more in Alexandria and wish you a pleasant stay.

Welcome Message by Dr. Ismail Serageldin

Director, Bibliotheca Alexandrina, Egypt

It is a pleasure to welcome you to the Bibliotheca Alexandrina, whose role is not merely as a library, a large repository of books, but as a center of dialogue. With its extensive conference facilities, the Bibliotheca seeks to become partners with eminent institutions of learning as they engage in important discussions. It is for such international collaboration that the Bibliotheca Alexandrina was created, and so it is a pleasure to welcome ICARDA, UNESCO, and UNU, groups that are close to my heart, to discuss a topic that is also close to my heart.

For years, I have been responsible for many programs in international agricultural research. Though tropical agriculture and issues of temperate zone are well known and the most studied of issues in agricultural management, drylands are the crucible in which we deal with the harsh interface between man and environment. Populations that depend on dryland agriculture are both poor and vulnerable.

What we know of climate change is all indicative that warming will increase and the spread of dry areas and drylands will continue to grow, as will the problems of drought and desertification. This is a most important issue in managing agriculture in a time of climate change where greater and greater fluctuations will place greater and greater numbers of people at risk, especially in respect to the areas of rain-fed agriculture that are going to become increasingly arid in the years to come. The topics of this workshop are not merely special topics in agriculture management - they are topics of vital importance.

Egypt itself is one of the driest countries in the world. Rightly named, "Gift of the Nile," the great river without which Egypt would remain a barren desert, Egyptians for 5000 years have been supremely aware of the value of each drop of water. Water plays a central role in our life, persona, and consciousness. So, from the bottom of my heart, I welcome you all to the land of Egypt, to collaborate in finding better ways to sustainably manage the marginal drylands. Let us lay the foundations for a better future for some of the most vulnerable populations on earth.

Foreword

The marginal dryland ecosystems are fragile, being dependent on limited water resources that cannot meet the needs for optimum production. Despite being limited, the amount of water allocated for agriculture is decreasing because of the increasing demand from urban population and development projects, and industry. Population pressure and land degradation are further contributing to the deterioration of the health of these ecosystems, and leading to increased poverty and hunger. The challenge of protecting the health and productivity of these ecosystems is, indeed, huge and calls for a concerted global effort.

This workshop was a step in the right direction. Organized by UNU, UNESCO and ICARDA, it brought together leading scientists from across the world to take stock of the progress achieved and develop a plan for future course of collaborative action. The message from the workshop deliberations was clear: we just cannot sit and watch the marginal dryland ecosystems continue to degrade and finally collapse. The need to address the problems of these ecosystems is urgent, and the time to act is now.

Fortunately, we now have new tools of research, including biotechnology, remote sensing, geographic information systems and computer expert systems, which promise hope in meeting the challenges at a faster speed. Innovative technologies have become available to safeguard the health of these ecosystems, particularly those that allow improved water management and increased water-use efficiency, and better land management. There is, however, a need to complement these advances with indigenous knowledge to ensure that human beings and nature work in harmony. Community involvement holds the key to halt the degradation of these ecosystems and increase their productivity.

ICARDA in collaboration with UNU and UNESCO will continue to generate international support for marginal drylands agricultural research, and transfer the promising technologies to farmers through the respective national programs.

We were fortunate that this workshop was inaugurated by Dr. Ismail Serageldin, the Director of Bibliotheca Alexandrina, a distinguished international scientist whose contributions to research and development are known world wide.

I hope this volume will be useful to all those involved in marginal dryland agricultural research and development.

Prof. Dr. Adel El Beltagy
Director General
ICARDA

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Role of UNESCO in Sustainable Water Management in Drylands:
The Case of the Arab Region

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Introduction

Most of the Arab countries are located in arid and semi-arid zones known for their scanty annual rainfall, very high rates of evaporation and consequently extremely insufficient renewable water resources. Sustainable Management of Water resources is a must as water scarcity is becoming more and more a development constraint impeding the economic growth of many countries in the region.

International Hydrological Programme

The International Hydrological Program of the UNESCO (IHP) is a vehicle through which Member States can upgrade their knowledge of the water cycle and thereby increase their capacity to better manage and develop their water resources (UNESCO, 1996; UNESCO, 2000). It aims at the improvement of the scientific and technological basis for the development of methods for the rational management of water resources.

In UNESCO, the current concentration areas of IHP in the Arab Region are Groundwater Protection and Rainfall Water Management, with special emphasis on Wadi Hydrology (Attia and Fadlelmawla, 2000). Concentration areas are selected during the regional meeting of Arab IHP National Committees, held each biennium. Activities in the Arab Region include both research and training.

The sixth phase of IHP strives to minimize the risks to vulnerable water resources systems, taking fully into account social challenges and interactions and developing appropriate approaches for sound water management. Assessing the global time and space distribution of freshwater availability and use, developing approaches to reduce the vulnerability of hydrosystems and their supporting ecosystems and improving water resources management for vulnerable areas are among the main objectives. Capacity-building and water education and training, as well as institutional development (with emphasis in the use of information and communication technologies for water resources research and training) are reinforced, and the social and ethical views of water users are incorporated into the development of conflict prevention and resolution.

UNESCO's Regional Activities

Many extra budgetary projects are initiated in UCO: the UNESCO/Flanders Funds-In-Trust Project on "Capacity Building and Training on Environmental Planning and Management" in Palestine. A FRIEND (Flow Regimes from International Experimental and Network Data Sets) Project for the river Nile is recently launched. FRIEND is one of IHP's success stories which is considered as a cross-cutting theme in IHP-VI. The FRIEND/Nile project has selected various research projects, being carried out by research groups with members of all riparian Nile countries.

The urgent need for comprehensive assessment of the world's freshwater has been emphasized by the UN Commission on Sustainable Development. It urged a collective initiative to this effect. This led to the launch of the UN system-wide World Water Assessment Programme (WWAP) led by UNESCO, which aims to improve the assessments of the state of world water resources and their response to the pressure posed by escalating human demands, as well as by factors related to global change.

Therefore, UNESCO Cairo Office is implementing efficiently the themes of the IHP relevant to the Arab Region. It is taking the lead in groundwater protection and dryland hydrology through two concentration areas of groundwater protection and wadi hydrology, respectively. The strategy is to consolidate efforts between various national, regional and international agencies in these areas to address these themes. Human resources development and capacity building has been a prime objective of UCO activities. A Regional Center for Training and Water Studies (RCTWS) of Arid and Semi-arid Zones in Egypt was established under the auspices of UNESCO since January 2002, for 6 years. The establishment of the center is an important landmark in the UNESCO activities in arid and semi-arid regions in particular in the Arab states and Nile basin countries. In all its activities, UCO is actively following the UNESCO approach of result based management.

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Lessons Learnt from Development Projects in Marginal Drylands – Personal Perspectives

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Introduction

As a scholar who started his ambitious dreams for the comparative study of qanat systems in the world in 1956, I have had many chances to participate in various development projects. These projects were mainly bilateral but also a few multilateral projects. Through those interesting and useful experiences, I have learned many lessons about drylands development. In this paper, my experiences in the Middle East and China are discussed.

The period, when I started arid land studies in Japan, was a difficult time to obtain detailed information about what was going on in other parts of the world. However, fortunately enough, I could get useful information through international academic circles and also got several chances to participate or organize scientific missions abroad in the purpose of study of traditionally technologies or various development programmes (Reifenberg, 1955). Thus I gained first hand experiences and observations on arid land studies and development (Kobori, 1997; __ 1993; __ 1999; __ 2000a; __ 2001).

Case Study - Focus on Egypt

My first experience for desert development projects was the New Valley Project, which started through a strong recommendation of the late Egyptian President Nasser. New Valley is the English translation of the Arabic name, "Wadi Gedida" ("wadi": dry valley; "gedida": new). The project's main target was to create New Valley as a connecting oasis of Western desert such as Kharga, Dakhla, Farafra and Bahariya. Because of the population growth in the Nile Valley, Egypt had to look for new land reclamation areas. Thanks to the development of the new well drilling technologies by the Egyptian Desert Development Organization (EGDDO), it was decided to explore the fossil water from the Nubian sandstone aquifer, expand cultivable land and invite the Nile valley fellahin (farmers) to the new reclaimed oases. In summer 1962 the deepest bore hole was a 1,000m deep.

In 1962, I happened to meet the President of EGDDO at that time, who provided me a special plane to the Kharga oases and showed me a glimpse of the project. From 1963, OTCA (JICA's old name) sent three missions directed by Professor Dr. Kobayashi Masatsugu including geologists, hydrologists, planners and myself. Through a close collaboration with EGDDO and their excellent liaison officer, the mission surveyed all oases including remote Siwa and Northern coastal zone. Besides a general survey, the mission took special attention to the introduction of solar energy system for lighthouses to guide travelers in deserts and installation of auto-monitoring system for water flow of really isolated deep wells in the New Valley. The mission installed an experimental lighthouse operated by Solar battery just in the middle of Cairo-Alexandria Desert Highway. As an experiment it was quite successful. However, at that time the cost of solar battery per 1 watt was about US$300 and it was not practical to introduce the system based on cost considerations.

After one year we found severe damage of mirror surface of the solar battery by sand storms and consequently this lighthouse program was cancelled. The program to transfer all the available data in the New Valley to central monitoring station in Cairo by microwave network was well-designed and the official briefing to EGDDO was a suitable topic for discussion with Egyptian engineers. In 1968, I visited the New Valley again to observe the development of the project. I saw more settled land and watched decline of water production from deep wells. In many cases, artesian wells were gradually converted into pumping wells and this phenomenon meant installation of new pumps to the declined artesian wells. An unlucky failure for the mission was that the mission did not include a socio-economic survey with the fellahin (farmers). Our report was mainly a kind of technical report for overseas development aid process.

Under the above-mentioned process our proposal for the Japanese government was not accepted. Our proposal was not timely from three points of view; namely technical, political and economical. Technical points meant a gap in the technological needs between the two countries. The Japanese side intended to introduce a sophisticated technology such as the very expensive solar-energy monitoring system. I think that Egyptian side had good engineers who might have been able to utilize the new technology but the general circumstances might not admit introduction of so modernized monitoring system. One officer who accompanied us told me that for fellahin's interest one Japanese handy tractor would be more technically appropriate. Oases agriculture is so similar to closed paddy field agriculture where Japanese farmers just started to use handy tractor instead of traditional plough. The Political reason is that the Japanese government had a passive stance towards the Soviet bloc (the late President Nasser refused the Western bloc's aid for the construction of the Aswan High Dam and had already accepted Soviet aid at that time). During the so-called Cold War Japan was much inclined towards the Western Bloc, especially the United States. Under that political atmosphere, it was a bit difficult to go with bilateral aid. The economic reason was very simple. At that time there were financial difficulties brought about by the accumulated debt by recipient country.

Nowadays, I understand that infrastructure especially roads along the New Valley are well developed. I was very surprised that the two-way road between Marsa Matrouh and Siwa is now completely asphalted and travel has become possible within a day. When we passed the same road in 1963, it took almost the whole day for a one way trip.

Among the Egyptian engineers, we found two schools for water management in drylands, the one is so-called Nile School and the other is so-called Desert School. We found two opposite strategies among Egyptian engineers on how to develop marginal drylands. The first group was suggesting the maximum use of Nile water, while the other is in favor of tapping groundwater. The ongoing Toshka project may constitute one of the huge challenges to reclaim western desert using Nile water by long canalization. I may not be able to comment this project without visiting the project site; however, this style of marginal desert development could be a kind of tradition leading back to Egyptian people of the Pharaonic times.

If I add few words, bilateral cooperation between Egypt and Japan is now going very well, even including the peace bridge to connect two continents Asia and Eurasia (Overseas Technical Cooperation Agency of Japan, 1965). I hope that the peaceful cooperation will include the exchange of desert researchers between the two countries and include also the international scientific community (Kobori, 1991; Kobori, 1993; Vivian, 2000).

Case Study – Focus on China

In my observation, the Chinese cases on marginal drylands development are a little different from other countries. First of all, in China "Arid Land Studies" is not only meant to be "science for science" but also "science for development". On-going major operations in combating desertification are well-guided by researchers and also local people. Because of the vast dry zones in China, the needs of the local citizens demand attention as well as their active cooperation. Sometimes, we observe some lack of coordination between the central and local governments and research organizations such as the Chinese Academic of Sciences and national institutes and universities.

For the Chinese government, the Western China development program has a huge target to develop inland areas which include a vast majority of the dry areas. This programme has already completed the Trans-Taklimakan desert highway and work is continuing on an ambitious project to develop a railroad network from Kunming to Llhasa in Tibet. For the sake of these mega-engineering projects, the developers are obliged to study fundamental characteristics of the desert environment such as soil, water, flora, meteorology and mapping. Since the establishment of the People Republic of China, scientists in China have undertaken great efforts to introduce advanced technologies for the sake of research in dry areas. I think that the Chinese cases in combating desertification constitute good examples for other countries; however, this could not be done without the efficient use of local people's participation. Chinese desert scientists have a positive attitude towards bilateral and international cooperation with Japan and the international organizations NGO groups including the United Nations University.

On the other hand, they are also interested in the co-existence and co-habitation of traditional technologies and advanced technologies. We may need to introduce case study on rehabilitation of karez system in Xinjiang. In this area, conservation of the system is not a final target. People are quite keen to revitalize the existing system using modern technology. They are also very interested in the hydrological balance among Karez, pumping wells and open canal systems. Although they are not using modern technologies for monitoring but in the near-future development of new and innovative technologies for tunnel digging or shaft will hopefully be developed.

Lessons for Development of Marginal Drylands

Generally speaking, development of marginal lands is now a most acute problem. In the western China, very rapid development of Hydrocarbon resources and the rapid settlement program along inland rivers such as Tarim has changed water balance of related regions dramatically. Furthermore, unconquerable natural hazards such as dust-storms are now becoming a serious problem not only in drylands but also in neighboring countries including Korea and Japan. The Monitoring of dust-storm is now operated by an international program that involves Japanese scientists that cooperate with their Chinese counterparts.

In Arab countries in the Mashriq or Maghreb, exploitation of underground aquifer is now becoming a serious concern for future development. We know a successful story to develop crop production such as wheat in Central Arabia Peninsula or huge man-made canal to transfer underground water from the Central Sahara to the Mediterranean Coastal Zone in Libya. Those projects are now going on actually, but there are various barriers to be overcome in the future. In case of the Arabian Peninsula, where Central Pivot irrigation system and other technologies cost is high, subsidizing farms production is very necessary. Similarly, the life-cycle of man made huge canal is not yet well studied. The dilemma of developing mega-engineering projects should be seriously discussed not only by the country concerned but also including all neighboring countries.

For multilateral cooperation, I have an unhappy experience on wastewater re-use in dry areas. This was through World Bank initiative related to the Middle-East peace process. I had the chance to visit Tunisia for research on technology transfer from Tunisia to Palestine, especially Gaza District where people are suffering water scarcity problems. In this case, the initial survey was supported by the World Bank (Japan Trust Fund) in collaboration with the Tunisian Government. But the second stage could be bilateral or trilateral between Tunisia, Palestine and Japan. Unfortunately, the logistical process of to start the project was slow, especially due to the Japanese time-consuming evaluation process. Then the political situation in Palestine became so tense that this project had been put on hold indefinitely.

Another failure case on desert development by the Japanese initiative was about the introduction of asphalt moisture barrier technology towards dryland agriculture. This comprised a special bulldozer to install automatically asphalt moisture barrier under the ground to conserve water and prevent the evaporation from the soil. In late 1960's, Japan had an over-stock of asphalt and MITI's division of petroleum had shown much interest to use this technology invented by researchers of Michigan State University. The purpose to support this project was not only for dryland's benefit, but also the consumption of over-stocked asphalt in Japan. For this project, the Desert Development Institute of Japan was established and field surveys in and out of Japan were carried out for foreign countries in Iran, West Pakistan and UAE. However, in the case of Pakistan, the host organization was WAPDA (Water and Power Development Agency) that had a greater interest in dam development and river management. Although we appreciate very much the Pakistani's contribution for a one-month field survey, there was no final agreement on how to move forward this ambitious project.

After this experience, Japanese research group changed the experimental site from Pakistan to Abu Dhabi near Al Ain Oasis. The group supported by JICA and various industrial sponsors, have founded a very modern laboratory for various experiments. Unfortunately, a very strong dust storm completely destroyed this laboratory. Professor Scholz of Berlin University wrote in his mission report to the United Nations University that "the value and importance of the research station of the DDIJ lie in its prestige; as a project it is highly politically motivated and serves to secure the interests of Japanese industry in the Gulf".

This laboratory and the field site are now transferred to the Al Ain University and is getting some support from JICA in collaboration with Shizouka University. In this case, we couldn't get scientific results on asphalt moisture barrier, but those experiences gave Japanese scientists a good lesson on how to adapt new technologies to harsh environments in dry areas (Overseas Technical Cooperation Agency of Japan, 1965; Kobori, 1991; __, 1995; __, 1999; Cordes and Scholz, 1980).

Summary and Conclusions

We need to consider the problem of drylands development from a general point of view of a relationship between human society and nature. I can cite from Al Gore's book "Earth in the Balance" (Gore, 1993):

> "*The Cartesian approach to the human story allows us to believe that we are separate from the earth, entitled to view it as nothing more than an inanimate collection of resources that we can exploit however we like; and this fundamental misperception has led us to our current crisis.*"

The strict separation of Nature, God and Man is not part of the typical Asian mindset. As a Japanese, I have much difficulty in fully understanding the mindset and the way of life of desert people. It is said that monotheism was born in dry areas and Animism was born in humid areas. A British journalist, Ritchie Calder used a very appropriate phrase "Men against the Desert" as the title of his book. I find this title appropriate, which probably stems from his European education and background. If I wrote a similar book, the title would probably be "Men with Desert." In the Chinese poems of T'ang dynasty, we find several phrases about soldiers set to western deserts. Those phrases are often melancholic and we have difficulty in finding men in confrontation with desert. Classical scriptures like al-Quran or the Holy Bible often refer to deserts, which likely also reflect circumstances in which those books were delivered.

We must be careful about the application of new technologies to the marginal drylands. In developed countries, we observed many successful cases using the technology to develop the desert, however in less developed countries we had even observed very tragic failure cases. Sustainable development is easier said than done. The history of development appears to be parallel to the history of the destruction of the environment. The task for us in the 21st century is to reduce the risk of environmental destruction in the process of desert development (Calder, 1953; Thomas and Middleton, 1994; UNEP, 1997; Kobori, 2000b). For this purpose, we have to bear two essential factors:

1. *Technology:* The technology needed should be appropriate to the regional context, it should consume less energy and be environmentally friendly. This technology should not only include advanced techniques but also improvements on the traditional ones.
2. *Peace:* All our efforts and goodwill to develop deserts areas rapidly can be destroyed by war. It is needless to quote other examples, if we remember the battle of El-Alamein during the Second World War and the current Palestine situation.

Deserts are our common global treasures. It is our responsibility to maintain unique and beautiful natural landscapes and also to examine the possibilities of better peaceful use of the areas concerned for the benefit of the people. How to reconcile these apparently conflicting goals is a task which will result in our unending cooperation.

In conclusion, for marginal dryland development, we may need qualified labor to use traditional technologies which have been adapted to the local environment, as well as modern inexpensive high technologies to develop new dryland agriculture, industry and tourism. For those purposes, the UNU in close cooperation with UNESCO and ICARDA is now starting and executing a new project of integrated land management of marginal lands in dry areas that includes at this time research regions in North Africa, West and Central Asia and China.

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3

Traditional Knowledge in the Context of the UN Convention to Combat Desertification

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Introduction

Land degradation has been recognized as a global phenomenon, attributed to combination of improper land use, human pressure, and adverse climatic conditions. Negative impacts are accentuated in the dryland ecosystems where land degradation is defined as desertification. The tragic events of the Dust Bowl of the U.S.A. and the devastating drought of the African Sahel are cited examples of extreme events where desertification caused the disruption of the life-support system of population (Kassas, 1995; Barrow, 1995; UNEP, 1997; Anonymous, 1999). To cope with the situation, the United Nations Convention to Combat Desertification (UNCCD, 1994) was formulated as a binding legal instrument concerned with major threats to sustainability in the dryland ecosystems.

Article 1 of the UNCCD stipulates that combating desertification comprises activities aimed at prevention of land degradation and/or rehabilitation of degraded land. In this context, the convention recognizes a set of knowledge systems that are given interchangeable names by different workers: indigenous knowledge, people's knowledge, farmer's practices, technical knowledge, and traditional knowledge. These terms were either coined or echoed by Norgaard (1984), Gupta (1989), Kerr (1991), Mathias-Mundy (1992), Warren and Rajasekaran (1993), and IFAD (1993). The systems may be collectively referred to as traditional knowledge, and abbreviated TKs.

The bottom line of using TKs in combating desertification is the fact that TKs are manifestations of an inherited code of reference for resource management that enabled people in the dryland to survive their harsh living conditions. This code outlines conservation practices to improve and maintain production based on cognitive experience of interactions between people, the biophysical environment, and the production system. The historical record indicates that production with TKs in many dryland ecosystems was less risky, more equitable, and more efficient in utilizing available human and natural resources (Warren and Rajasekaran, 1993).

It is realized that a differential approach to study the TKs system is needed to cope with the new facts of modern life. The study should take account of the recent fundamental changes in power relations between local, national, and international actors. The objective is to use TKs as complementary to national efforts to combat desertification within the National Action Program (NAP).

TKs in the UNCCD

Relevant Articles in the Convention

The subject of TKs was taken up in many places throughout the UNCCD. The relevant articles include Article 16-paragraph g, Article 17 paragraph c, Article 18 paragraph 1-e and paragraphs 2-a, b, c, d, Article 19 paragraph 1-d, Article 20 paragraph 6, and Article 4 of the African Annex paragraph 1-d. Paragraph 2 of Article 18 of the Convention is most extensive and elaborate in dealing with TKs. It states that: "The parties shall, according to their respective capabilities, and subject to their respective national legislation and/or policies, protect, promote and use in particular relevant traditional and local technology, knowledge, know-how and practices and to that end, they undertake to:

(a) Make inventories of such technology, knowledge, know-how, and practices and their potential uses with the participation of local populations, and disseminate such information, where appropriate, in cooperation with relevant intergovernmental and non-governmental organizations;

(b) Ensure that such technology, knowledge, know-how and practices are adequately protected and that local populations benefit directly, on an equitable basis and as mutually agreed, from any commercial utilization of them or from any technological development derived there from;

(c) Encourage and actively support the improvement and dissemination of such technology, knowledge, know-how and practices or of the development of new technology based on them; and

(d) Facilitate, as appropriate, the adaptation of such technology, knowledge, know-how and practices to wide use and integrate them with modern technology, as appropriate".

The underlying idea of these paragraphs in the back mind of the UNCCD authors was the conviction that combating desertification is time and resource-consuming process, and it requires site-specific prescriptions. This comes in contrast with a previous conviction that technology transfer and implementation of rigorous policies could define a good and effective national program to combat desertification. Lessons learned have shown that this classical top-down approach was not only waste of resources, but also exacerbated the life-support system of the people living in the affected areas as reported by Thompson (1994). She quoted a report in 1990 by the World Bank stating that "lack of understanding of traditional production systems, which were developed over time through adaptation to difficult conditions" is a key reason for the lack of success in most development efforts in the drylands.

Aside from that top-down approach, the most important reasons for failures in the soil and water management programs in the dryland areas include the use of production systems, which are complicated, expensive, and difficult to maintain in terms of both labor and capital. Such systems may be difficult to replicate at a reasonable cost and sustainable output. There is also insufficient training of local users, and a heavy reliance on imported machinery for the construction of conservation works (Barraclough, 1993).

CST Deliberations

The UNCCD structure involves the Committee on Science and Technology (CST), as a subsidiary body to provide advice on relevant matters. Several issues have been dealt with during the last five annual sessions of the CST that were held in parallel with the Conference of Parties (COPs). The usual procedure is to establish an ad hoc panel group to study an issue and submit a report for discussion. Issues discussed as yet include information exchange, benchmarks and indicators, networking, early warning systems, and traditional knowledge. The deliberations are open to all parties to the convention, and the prepared reports are in the public domain.

The first COP, held in Rome in 1997, encouraged parties to provide reports on TKs to be considered by the second session of the CST to be held in conjunction with the second COP in Dakar in 1998. At that time, some delegates highlighted their experience with TKs, and others emphasized the need to develop synergies by integrating TKs with modern technology.

The ensuing discussions and the submitted reports revealed that the quality and quantity of TKs vary among community members, depending on gender, age, social status, intellectual capability, and professional occupation or trade. Languages, religion, socio-cultural aspects, e.g. tenure, and environmental traits are important driving forces in shaping these practices. TKs are dynamic and have built-in mechanisms for innovation and growth of new dimensions according to challenges and circumstances. In practice, communities continue to learn from one another through interactions between neighbors, cross border marriages, and adoption of a given culture to new environments following conquest and subsequent domination. The deliberations of CST-2 may be encapsulated as follows:

- The use of TKs stands out as complementary to the efforts to combat desertification. It is therefore appropriate to make inventories in this domain, and to compile and share relevant information, exchange experience, and establish communication networks to improve information flow so that beneficiaries are ensured of access;
- The need to develop synergies and to integrate traditional knowledge with modern technologies while addressing:
  1. The legal implications of intellectual property rights;
  2. Ways of harnessing the positive attributes of TKs;
  3. The socio-economic benefits to be derived from the development and use of the knowledge; and
  4. Inclusion of TKs in the NAP to combat desertification.

At the end of the session, COP 2 decided to appoint an ad hoc panel with the following terms of reference: identification of successful experiences, strategies for integrating TKs with modern technology, and mechanisms for promoting successful approaches. COP 3 was held in the following year in Recife, Brazil, where the reports of the panel were produced by the Secretariat in documents ICCD/COP (3)/CST/2 and ICCD/COP (3)/CST/2/Add.2. These and other documents of the Convention are available from the Secretariat web site at www.unccd.org.

Document ICCD/COP (3)/CST/2 outlines that TKs for combating desertification could be placed under two categories. The first includes those dealing with biophysical issues such as site amelioration practices, soil and water management practices, agricultural practices, cropping systems, and range management. The second category includes those dealing with socio-economic-cultural issues such as governance, workload/return distribution, herd diversification and flexibility as well as specialist skills such as animal training and medical care. The long list TKs in the dryland ecosystem is indicative that TKs are dynamic and have built-in mechanisms that enable local communities to survive the unfavorable topographic, edaphic, and climatic conditions, which characterize their fragile environment.

It is good to emphasize that local communities can often increase their production output at minimal cost. Bruins *et al.* (1986) illustrated the case with agroforestry and inter-cropping, where production is intensified in space and in time. Casual observation of people in the dryland would show that simple people implement the core principles of sustainability in simple terms without really knowing them. Moreover, Oygard *et al.* (1999) and Van Duivenbooden, *et al.* (1999) observed that current use of yield-enhancing technologies is low in sub-Sahara Africa compared to the international average. Fertilizer use is extremely low, and irrigated areas cover only 20 % of their potential. Therefore, there is large possibility for faster agricultural growth. Appropriate technology could double or triple yields especially in areas with more than 500 mm of annual rainfall. Such remarkable increase would improve both the socio-economic conditions of populations in local communities and provide practical incentive to combat desertification. An upgraded system of TKs stands as a good approach to fulfill this objective. Document ICCD/COP (3)/CST/2/Add. 2 undertook to elaborate this subject at COP 3.

It was established in the document and in the ensuing CST discussion that innovations are needed to establish synergies between TKs and modern technologies. This has been called ecotechnology (Swaminathan, 1999). The objective is to develop new economically feasible and socially acceptable upgraded TKs that are capable of sustaining greater production in the dryland areas (Hausler, 1993; Barraclough, 1993; Seely, 1998). In this context, Hausler (1993) outlined the so-called hybrid approach where natural scientists, anthropologists, and development experts may take certain elements of a knowledge system and incorporate them into the body of other system. Such hybrid knowledge is subsequently disseminated to a wider audience of farmers/local people in a wider geographic extent. Even though it may yield important technical facts, this approach simply reifies existing power relations and the primacy of western expert knowledge within the developmentalist framework. Moreover, it should be remembered that TKs are highly location-specific and based on close observation over long period of time. It is embedded in culturally based value systems, system of production and consumption, and ways of living and relation to natural environment.

The so-called "actor oriented approach" is suggested by Norton *et al.* (1998). It was argued that cross-cultural communication has always been an obstacle to positive interaction between local communities in the dryland areas and the visiting scientists. Anthropologists have developed techniques to elicit components of the knowledge system and make concepts and principles clear and relevant to outsiders. Integrated teams of scientists and active community leaders would work on maps to characterize the main features of the neighborhood such as land use patterns, livestock, watersheds, and soil types. Subsequently, a base line for recommended technologies is defined with concomitant assessment of economic and institutional factors to confer credibility and replicability of the integrated technology. The final product shall be based on compatibility with ecological conditions, need for institutional support, profitability, risk involved, and need for external resources. Pretty (1995) advised that modifying existing practices is usually more acceptable than radical change and that new technology should be presented within a basket of options rather than ready-made solutions.

Warren and Rajasekaran (1993) believe that systematic recording and subsequent validation of TKs is a prerequisite first step towards their upgrading. Collected TKs can provide scientists with important information, a framework for interpreting data, and a way of solving field problems (Seely, 1998). It would be easy to identify how exogenous technologies can be fitted to improve endogenous systems. In this regard, several soils and water techniques within TKs deserve high priority to further enhance the sustainability of local communities. Candidate techniques are rainfall water harvesting, water storage and conveying, utilization of low-quality groundwater, soil mulching, and stabilization of active sand dunes.

Looking Ahead

It is satisfying to note that several national centers have already embarked on systematic recording of TKs systems for use in development (Warren and Rajasekaran, 1993). The functions of the national centers may include:

- Providing a national data base where published and unpublished information on TKs is maintained;
- Designing training methodologies for recording TKs systems in collaboration with research centers; and
- Initiating links between originators of TKs in a country and the development community.

The establishment of more of these centers and strengthening their institutional capacity, both on the national and regional levels are highly recommended. Appropriate cross-linking between centers would facilitate the desired exchange of information. Relevant parties in the dryland and within the scientific community should be aware of the potential role which can be played by these centers in their common effort to combat desertification. Questions to be answered are many including those concerned with sustainability from economical, technological, and socio-cultural perspectives. Most important of all is how to get the local NGOs and CBOs interested in the subject.

A proposal for the establishment of an international center on TKs was submitted by Italy to COP 5 under the title "ITKnet--Innovative Traditional Knowledge Network" as given by document ICCD/COP (5)/CST/2. The project would rely on two phases. A cognitive action would undertake an inventory of TKs, define parameters and indicators, and evaluate a system of incentives to implement and disseminate upgraded TKs. An operative action would set up a pilot network connecting Mediterranean countries as a starting congregation. The network would support partnership building in addition to validating and disseminating upgraded TKs. Several countries supported the Italian initiative and expressed interest in being associated with it. The Global Mechanism of the UNCCD and other relevant international institutions were invited to explore partnership agreement to establish the network.

Some developing countries brought up the issue of property right, and requested that a mechanism should be formulated to define equity of returns from the upgraded TKs. As a matter of interest, this subject is on the present negotiation agenda of the World Trade Organization (WTO). Swaminathan (1999) reported that the Food and Agriculture Organization (FAO) has pioneered the international effort in promoting the concept of "Farmers Rights" in genetic resources conservation. It is possible to expand these rights to accommodate the TKs of the dry land ecosystems.

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4

Drylands Agriculture Management in Iran

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Introduction

Limited water resources and population growth in the world have caused agricultural products to be insufficient for food and feed in some countries. At present time, this limitation is one of the most serious problems in the Middle East countries especially in countries which are located in arid and semi-arid regions. Considering population growth rate and limited water resources in the world, it is anticipated that food security will be the serious challenge in coming decades. In dryland areas agriculture has an important role in food security and sustainability of agriculture.

Agricultural sector in Iran is one of the most important economic sectors in the country; however, water is the most limiting factor for production. More than 90 percent of the renewable water in the country is used in agriculture, but its production is insufficient to meet the demand of the country. This insufficiency is due to low irrigation efficiency. The total dryland area is more than total annual irrigated crop. Cultivated land produces about 64% of wheat, 61% of barely and 92 % of food legumes (peas and Lentil) while about 33% of wheat and 34% of barley and 82% food legumes (peas and Lentil) are produced in dryland agriculture.

Efficient application of water in agriculture (irrigated and dryland) and increasing dryland production in a sustainable manner are the most important issues for producing food requirements at present and future times. Proper research planning management and education in this sector can contribute in preventing the loss of limited natural resources. The use of appropriate technology and efficient application of inputs in the agriculture production (irrigated and drylands) are the most important policies of the ministry agriculture.

General Overview

Iran is located in the Northern Hemisphere, between 25° and 40° N and 44° to 63° E. Agriculture plays an important role in the economy of Iran. It accounts for one-fourth of the Gross Domestic Product (GDP), one-fourth of employment, more than 80% of food requirements, one-third of non-oil exports, and 90% of raw materials for industries. The agriculture of Islamic Republic of Iran enjoyed an average growth rate of 5.1% over the two National Development Plans (1989 to 1999), and expected growth rate for third national Development plan (2000-2004) is 6.2%.

Out of 165 million hectares of the country's areas, about 20 million hectares are irrigated and 17 million hectares dryland. Currently 18.5 million hectares are devoted to horticulture and field crops production, out of which 6 million hectares are under annual irrigated crops, 2 million hectares horticulture crops and about 6.2 million hectares are under annual dryland crops, while the remaining 4.3 million hectares are fallow. The total Natural Resources and Rangeland areas are about 102.4 million hectares including 90 million hectares as pastures (at various level of forage productivity) and 12.4 million hectares are forests.

Climate, Rainfall, and Evaporation

Islamic Republic of Iran is situated in one of the most arid regions in the world. The average annual precipitation is 252 mm (one-third of the world average precipitation), and this is under conditions in which 179 mm of rainfall is directly evaporated. In other words, 71% of precipitation is lost due to evaporation, while annual evaporation potential of the country is between 1500 to 2000 mm. In the past 6 years, particularly in the year 2000, some parts of the country have severely suffered from drought.

The altitudes vary from -40 to 5670 m. b.s.l. and have a pronounced influence on the diversity and variation of the climate. Although most parts of the country can be classified as arid to semi-arid, the country enjoys a wide range of climatic conditions. Both latitude and altitude have a major influence on climate in various regions. This is shown by the spatial variation of annual precipitation (50 mm in the central desert and 1600 mm in Gillan province, situated at the southern coast of the Caspian sea) and a wide range of temperatures up to 100°C (-44°C in Borudjen/Chahar Mahal Bakhtiari province, located in the central Zagrus range mountains and 56°C in the south along the Persian Gulf coast). Distribution of precipitation in Iran is presented in Table 1.

Table 1. Distribution of precipitation in Iran

Annual precipitation (mm)	Area (Km^2)	Percentage
<50	100000	6
50-100	285000	17
100-200	456000	28
200-300	370000	23
300-500	280000	17
500-1000	130000	8
>1000	18000	1
Total	1648000	100

Water Resources and Water Use

The main source of water in Iran is precipitation, in the forms of both rainfall and snow (70% rainfall and 30% snow), which is estimated to be about 413 billion cubic meter (bm^3). About 71.6% of the total rainfall ($295m^3$) directly evaporates. Taking into account $13bm^3$ of water entering the country from the borders (joint borders rivers) the total potential of renewable water resources has been estimated to be 130 bm^3. Currently, the total water consumption is approximately $88.5bm^3$, out of which more than 93% is used in agriculture, while less than 7% is allocated to urban and industrial consumption (Table 2).

Under the present situation $82.5bm^3$ of water is utilized for irrigation of 8 million hectares of irrigated agriculture (horticulture and field crops). About 1.4 million hectares of these areas are managed by regulated flow (irrigation networks), 6.3 million hectares by means of traditional networks and less than 300 thousands hectares are under pressurized system.

Surface water resources provide $37.5bm^3$ water for different consuming purposes (about 42% of the total water consumed) in the country. The existence and importance of groundwater was known and understood by our ancestors thousands of years ago. The traditional method of ground water extraction is Qantas, which brings water to surface by gravity. In recent years more than 50 thousands of various types of wells are dug and used for extraction of groundwater from the aquifers. More than 60 percent of total water consumption in the country ($51bm^3$) is extracted from groundwater resources. Due to inefficiency of traditional irrigation methods and water conveying systems, about 63% of the valuable water is lost, and in practice only 37% of available water is utilized in agricultural production.

Table 2. Estimated consumption of water in Iran (Year 1998)

Consuming Sector	Consumption (m^3)	Percent of total
Agriculture	82.5	93.22
Urban	5.6	6.32
Industry	0.03	0.03
Miscellaneous	0.37	0.43
Total	88.5	100

Socio-Economic Situation

Agriculture in Iran is run privately, since 99% of the agricultural commodities are produced by private sector. Out of the 65 million population in Iran, about 24 million (38%) are living in rural areas (there are roughly 60000 villages). During 1976-98 the rural population increased from 17.9 to 23.6 million. Out of the 14.2 million job opportunities all over the country, 3.3 million (23%) are in agriculture sector. The distribution of the rural population is largely determined by the availability of water, rainfall and arable lands. Thus, with the exception of the well watered and high rainfall Caspian area, the settlements are isolated and scattered through arid and semi-arid regions in both plains and mountains. Nearly more than 90% of the 2.6 million agriculture rural households' posses land and a great majority of these are medium and small farms, which dominate the Iranian agriculture.

Iran has a high proportion of small farm size. About 78% of farmers have less than ten hectares and 11% less than one hectare farm size. Farms with less than ten hectares are about 37 percent of the cultivated land and inhabit about 12 million of rural population. They produce less than 10% of the marketed agriculture production. This is a consequence of the fact that small farmers have low income and many of them are mainly subsistence with no surplus products for sale. Farms over ten hectares provide about three-quarters of the market supplies. Large farms (over 100 hectares), currently, only make small contributions to the agriculture outputs of Iran. The national farm-size distribution for irrigated and dryland agriculture in Iran is presented in Table 3.

Table 3. National farm-size distribution (irrigated and dryland agriculture)

Size (ha)	Total Area (K ha)	Area (%)	Percentage		Average Size (ha.)
			Irrigated	Dryland	
< 1	196	1.6	3.1	0.3	0.4
1-2	423	3.4	5.7	1.4	1.1
2-5	1630	13.0	17.4	9.3	2.4
5-10	2371	18.9	20.4	17.6	4.8
10-25	4467	35.5	29.1	40.7	9.8
25-50	1585	12.6	10.0	14.7	21.2
50-100	961	7.5	6.2	8.8	41.8
Over 100	947	7.5	8.0	7.1	118.5
Total	12580	100	100	100	4.9

Agricultural Production in Iran

The production of horticulture and field crops in the last decade (1988-98) was subjected to positive changes. The primary changes were mainly due to the implementation of the results of research findings and extension activities which contributed to increased yield per unit area. The other factor which caused change was utilization of unused land capacities through development and expansion of area under cultivation. The average annual growth rate of agricultural production was 5.1% during 1988-1998. The total agricultural production for various commodities during 1988-1998 is presented in Table 4. The total annual crops and fruits production had increased from 35.8 million tons in the year 1988 to about 65 million tons in 1998. From among this the production of field crops has risen from a figure of 28.6 million tons in 1998 to 53.1 million tons in the year 1998 and its average annual growth during the course of 10 years was 5.7%. During the same period, wheat production increased from 7.2 million tons to 11.8 million tons and corn grain from 0.143 million tons to 0.941 million tons. Horticulture crops dropped from 57.2 million tons to 11.6 million tons. Unfortunately in the last three years drought has seriously threatened some parts of the country and agricultural production decreased about 8-10%.

Table 4. Agricultural production in various commodities during years 1988-1998 (million tons)

Agricultural Products	1988	1998
Field Crops	28.6	53.30
Irrigated	25.85	44.73
Dryland	2.75	8.57
Horticultural Crops(Fruits)	7.20	11.60
Milk	3.40	5.10
Red meat (lamb and beef)	0.51	0.75
Chicken	0.30	0.70
Egg	0.26	0.50
Fish	0.24	0.40

As mentioned earlier from a total of 18.5 million hectares which are involved in the field and horticultural cycle of production, approximately 10 million hectares are allocated to agriculture under dryland conditions. In such a way 6.2 million hectares are under annual dryland crops and about 4 million hectares are considered as fallow and used in rotation. The production of cereals (wheat and barley) and pulses (lentil and peas) in dryland lands constitutes an important percentage of country's production.

The tables show that the share of dryland crop production in comparison with the total crop production of the country for the concerned cultivated crops during 1988 to 2001 is as shown in Table 6.

Dryland wheat production comprised 33% of the total wheat produced and dryland barley comprised 34% of the total barley produced while dryland pea and lentils comprised 82% of the total production of this crop in the country. From the point of view of area under cultivation, the share of dryland crops was very large in relation to total cultivated areas, in such a way that the area of dryland wheat under cultivation comprised 64% of the total area of cultivated wheat, while barley and pulse comprised 61% and 93% respectively of the total area. But what is important and is apparent regarding the changes in the production of these crops in various years are the diverse changes in the production of these crops and their lower average yield and production being considerably affected by the amount of precipitation. Although this issue is quite obvious but non-sustainability and intense yield variation of crops from one side and erosion and non-sustainability of country's dryland from the other side could be cited as the two most important and essential characteristics of country's dryland farming.

Table 5. Cultivated areas and total production of different crops under irrigated and dryland conditions in 1998, in Iran.

Crop Groups	Cultivated areas (000 ha)			Total Production (000 ton)		
	Irrigated	Dryland	Total	Irrigated	Dryland	Total
	3706	5069	8775	13453	5513	18967
Cereals (1)	173	785	957	250	327	577
Pulses(2)	590	132	751	7629	140	7769
Industrial Crops(3)	423	35	458	9730	428	10158
Vegetables(4)	288	47	335	5316	277	5593
Summer Crops(5)	786	152	938	8899	1179	10078
Forage Crops(6)	5966	6220	12186	45277	7864	53141
Total annual crops	1777	188	1965	11397	263	11660

1. Cereals: wheat, barely, paddy and corn grain.
2. Pulses: pea, bean, lentil, Faba bean and other pulses.
3. Industrial crops: cotton, sugar beet, sugar cane and oilseeds.
4. Vegetable crops: potato, onion, tomato, eggplant, etc.
5. Summer crops: melon, watermelon, cucumber, etc.
6. Forage crops: alfalfa, clover berseem and forage corn.

It is essential to remind that the most important cultivation limitations under dryland conditions are drought, cold, higher temperature in some production regions during growth period, lack of access to appropriate sowing technology intermingled with lack of access to suitable varieties in regions with environmental stresses.

Dryland Environment and Management in Iran

Production data of drylands indicate that more than 5 million hectares of drylands are situated in areas with annual precipitation of less than 400 mm (occasionally 200 mm). In such areas, the average of wheat yield is less than national level and is severely affected by variation in precipitation during growing season. Only 1.2 million hectares of drylands are receiving more than 400 mm precipitation, and produce reasonable yield of 2200 kg/ha. Studying variation in yield and production level in under dryland conditions, particularly in areas with less than 400 mm precipitation, shows that yield in these areas is fluctuating and significantly influenced by the amount of precipitation. Comparison of these data with information of wheat yield and production under dryland conditions in developed countries would demonstrate the unfavorable conditions in dryland of our country, particularly of those areas with less than 400 mm precipitation. Furthermore, drylands of these areas are endangered by severe drought, cold and terminal heat stresses.

Table 6. Yield of irrigated and dryland wheat during the past 13 years (Kg/Ha)

Cultivation year yield	Dryland wheat	Irrigated wheat
1988-88	442	2034
1989-90	766	2265
1990-91	871	2560
1991-92	799	2901
1992-93	947	2777
1993-94	856	3050
1994-95	966	3096
1995-96	722	3067
1996-97	721	3146
1997-98	1094	3423
1998-99	593	3195
1999-00	701	2788
2000-01	709	3070

In general, the drylands in Iran are classified based on annual precipitation, temperature, and wheat growth habit, as follows;

Very Cold Zone

Very Cold Zone with Medium Precipitation

This zone includes Northern and North Western regions of the country, which have an annual precipitation ranging from 300 to 480mm, more than 100 freezing days and average minimum temperature of less than –15 °C. The dryland farming in this zone covers about 2.1 million hectares, which is 30% of the total national dryland cultivation. In these zones, due to long cold periods and freezing days, for more than 3 months in a year, the growth process is halted. The growth pattern of crops in these zones is of winter type with early maturity and tolerant to drought and cold. The main limiting factors to crop yield in such zones includes; drought occurring at the beginning and the end of growing season, cold periods during winter and spring. Biotic stresses in this zone include; common, dwarf and bunt and yellow rust. In this zone, wheat is the main crop in annual rotation with lentil (less than 15%), and occasionally forage crops are also included. Barley is grown on a limited scale.

Very Cold Zone with Low Precipitation

This zone includes some of the Central and North Eastern regions. The average long-term annual precipitation in this zone is less than 300mm and also, the average minimum temperature is less than (-15°C). The number of freezing days in this zone is more than 100 days. The drylands in this zone cover one million hectares. In such areas, the growth process is halted due to cold periods and freezing days of more than three months during winter. The growth pattern of wheat crops in this zone is of winter type with early maturity and tolerant to cold and drought stresses. The main limiting factors of crop yield in this zone are; cold winter periods without snow covering, late cold in spring period, drought periods at the beginning and the end of growing season. Furthermore, biotic stresses in such areas include common bunt and yellow rust. The crop yield in these regions is very low, due to low level of precipitation. Despite these great obstacles, the wheat-grown areas in this zone cover the widest areas allocated to cereal cultivation in drylands. In rotation with wheat, barley and then, lentil are grown on 30% of lands, annually.

Cold-Mild Zone

Moderate Cold Zone with Medium Precipitation

This zone includes Western, South Western, and Central parts of the country where drylands cover 650,000 hectares. The average precipitation in this zone ranges from 300 to 480 mm and the number of freezing days varies from 60 to 100 days. The average minimum temperature during the coldest months varies from 0 to (-15°C). The appropriate cereal growth habit is of winter type, which is tolerant to cold and drought stresses. The main limiting factors in cereal crop yield are cold winter periods without snow covering, late cold in spring, drought stress, yellow and leaf rusts and common bunt. The major wheat pests in this zone are Sunni pest and Sawfly. Degradation of rangelands and pastures, particularly in mountainous areas and hilly lands (with a slope of greater than

10%) and allocating them to cereal crop has led to a significant reduction in their productivity, particularly during the drought, and early generations of Sunni pest would feed on cereal crop. Hence, it is recommended that cultivation on areas with slope more than 10% should be prevented. Another strategy to prevent yield loss due to Sunni pest is to grow early maturing wheat and barley cultivars. In this zone, chick peas is the main crop in rotation with wheat, and except for the lands with high slope, it is a suitable crop for drylands and provides wheat yield stability.

Moderate Cold Zone with Low Precipitation

This zone includes North Eastern and central regions of the country. In this zone, the average annual precipitation is less than 300 mm and the numbers of freezing days vary from 60 to 100 days. Moreover, the average minimum temperature in these regions varies from 0 to -15^{o}C. The drylands farming in these areas cover 550000 hectares. The appropriate growth habit for wheat in this zone is facultative and spring type with tolerance to cold. The main limiting factors of crop yield in this zone are drought stress, late cold in spring, and cold winter periods without snow. The important biotic stresses are yellow and leaf rusts and common bunt. The major wheat pests in this zone are Sunni pest and Sawfly. Sunni pest damages wheat crop severely in this areas due to its longer life cycle on wheat than on barley. Hence, it is recommended to grow barley of facultative growth pattern with tolerance to cold. Spring cultivars tolerant to cold and drought stresses are also recommended. Currently, the barley-cultivated lands are considerably spread throughout this region. Unfortunately, the common rotation in these regions is cereal-fallow-cereal. Low precipitation combined with this rotation has caused less stability in yield and crop production in this zone.

Warm Zone

Warm Zone with Medium to High Precipitation

This zone includes Northern and Southern regions of the country. Within this zone, except for Khozestan province which has an average precipitation of 330mm, most parts have a long-term average precipitation of more than 500mm. In these areas, drylands farming cover 1.35 million hectares. This zone has a tropical warm climate with mild winters, short, hot springs, and long hot summers.

Numbers of freezing days in this zone are less than 1 month. Cereal growth habit in these regions is of spring type with early maturing. The main factors limiting wheat crop yield are warm climate, drought and biotic stresses such as yellow and leaf rust, sepetoria, bunts and fusarium. Sunni pest and Sawfly are the major cereal pests in this zone. This zone can play a vital role in rising drylands wheat crop production, due mainly to its appropriate climatic conditions. In this zone, Durum wheat can be grown. The common rotation in this region is cereal-fallow- and rarely, barley (chickpeas or lentil) are grown in rotation.

Warm Zone with Low Precipitation

This zone covers the North Eastern parts of the country. This section has a warm tropical climate with mild winters, short warm springs, and long hot summers. Number of freezing days in this zone is less than one month. In this zone, the average annual precipitation is less than 300mm. Dryland farming in these areas covers 400000 hectares. The appropriate growth pattern for wheat for this zone is of spring with early maturity and tolerant to drought stress. Considering the precipitation and temperature level, this zone has an appropriate environment for Durum wheat to be grown. The main limiting factors in this climatic zone are environmental stresses such as drought and hot temperatures. Biotic stresses influencing crop yield are, yellow rust, leaf rust and bunts. Common rotation practiced in these areas is fallow and in very limited areas, lentil is grown in rotation.

In principle, one of the most important policies of the government after the culmination of the Islamic Revolution has been given it the development of agriculture sector based on growth, strengthening and development of agricultural research institutions. For the same reason the policy for the establishment of crop oriented research institute and/or important groups of crops were relentlessly followed. At present, there are 22 research institute, 33 Provincial and Regional Research Centers and a total number of 248 research station and research fields with of 4200 researchers and experts conducting more that 4300 research projects.

From the group of research institutes, the Dryland Agricultural Research Institute, centralized in Maragheh of Azabaijan Province and its research station in various provinces, commenced its research activities in 1991 with the onset of official cooperation of ICARDA. The primary researches affiliated to this institute in addition to Maragheh are stationed in divers agroclimatic regions of "Sararud in Kermansh province," "Gachsaran in Kohgullich and Boyerahmad Province," "Shirvan in Khoasan Province" and "Ghaemlu in Kordestan Province." The research activities of this institute are carried out in 10 other stations of dryland regions such as Ormieh, Hamadan, Ardabil, Zanjan, Ilam, Ghazvin, Gorgan, Kuhdasht, Moghan and Kharkeh of Kordestan.

In view of the importance for attending to issues related to dryland agriculture, this Organization has concluded studies and research activities in the field related to breeding and agrotechnique for many years. It has also achieved good results, the variable dryland conditions of the country (diverse climatic conditions, difference in amount of precipitation and its inappropriate distribution, variation in soil fertility etc.) result in complexity of research problems in dryland regions and therefore the results obtained had restricted applications.

In order to develop the necessary changes and basic improvement regarding the output of drylands of our country, the Agriculture Research and Education Organization has decided that investment should be made and widespread research projects and activities must be carried out. With due attention to this important point, the Ministry of Jihad Agriculture decided to develop an Agreement with the International Center for Agricultural Research in dryland Areas (ICARDA). Nevertheless, from the previous years mutual cooperation existed between the Agricultural Research and Education, Organization and ICARDA in the field of exchange of scientific and research information, training of experts and plant genetic materials on a limited scale (the first mutual Agreement was inked in 1984). On the basis of experience gained from these collaborations, AREEO found ICARDA as an appropriate International Research Center for scientific and research cooperation in the field of drylands.

Despite all the challenges in the way of fulfillment of cooperation between AREEO and ICARDA, and in view of the importance of the issue, effort and follow-up action by relevant responsible authorities in solving the issue, in essence the implementation of

Agreement of mutual cooperation commenced from 1992 and was gradually developed during the following years. Today, the results of 8 years of cooperation have revealed its positive effects in such a way that those involved in this affair have been inclined to renew the Agreement. Here I deem it necessary to point out some of the quantitative and qualitative results achieve from this cooperation.

- Field investigations conducted in close collaboration with ICARDA have resulted in recognition of problems and constraints related to preparation of research programs and research programs and research priorities.
- Release of plant varieties; one of the main objectives of this cooperation was increasing of productivity of basic agricultural crops (wheat, barley, pea and lentil) which was constantly exposed to dangers of biotic and biotic factors. Wheat yellow rust is one of the most important diseases affecting this strategic crop in Iran and in the region. As a result of these collaborations 5 varieties of dryland wheat and 3 varieties of dryland barely in cereals and one variety of high yielding chickpea variety and one variety of lentils have been released so far. These varieties are just a few examples of the result of cooperation.
- Acceptable agro-technique methods to overcome problems and difficulties related to cultivation has been included in the past years and at present it has been included in the current program of activities of Iran-ICARDA and its results and the effects of best Iran –ICARDA methods of increasing production is annually discussed in the coordinating and planning meeting held in Iran between AREO and ICARDA.
- From the beginning of the implementation of articles of mutual Agreement till today necessary facilities have been provided by ICARDA for continuation of studies of a number of qualified researches of agricultural research organization for postgraduate studies leading to a Ph.D degree. On termination of their studies, a portion of this Organization's requirement of manpower specialists is supplied. The trained manpower in this section of activity has been 3 persons at the M.Sc level and 54 persons at the Ph.D. levels. Two Ph.D. candidates from local universities have completed their studies at ICARDA. Out of the total number of students registered for postgraduate studies, 16

persons have returned to Iran after completion of their studies. In addition, 140 Iranian researchers have also participated in short-term and medium- term training program in foreign countries. Of this, 50% were from DARI, 30% from Seed and Plant Improvement Research Institute and 20% from other research institutes (Agricultural Engineering; Soil and Water, plant pests and diseases).

Due to the domestic shortage of wheat production over the past 5 years, 5.5 million tons has been imported. Recently, a comprehensive program for wheat crop yield and production enhancement has been prepared and proposed. In this program, 340000 hectares drylands farming (in moderate cold climate with low precipitation) will be reduced. Since the increase in drylands wheat production is provisioned to be achieved through increase in crop yield. The crop yield per hectare is to be increased from the current level of 830 kg/ha to 1160 kg/ha, in this program (a 40% increase in crop yield). The provisioned yield and production of wheat crop in drylands during this program are shown in the Table 7.

Table 7. Annual growth rate of wheat grain yield and production under dryland and irrigated conditions.

Year annual growth rate	2007-2011	2002-2006
Grain yield (dryland)	3.23	4.21
Rain yield (irrigated)	4	5
Grain yield (average)	4.39	6.15
Production (dryland)	3.19	2.47
Production (irrigated)	5.94	7.4
Production (average)	5.17	5.82

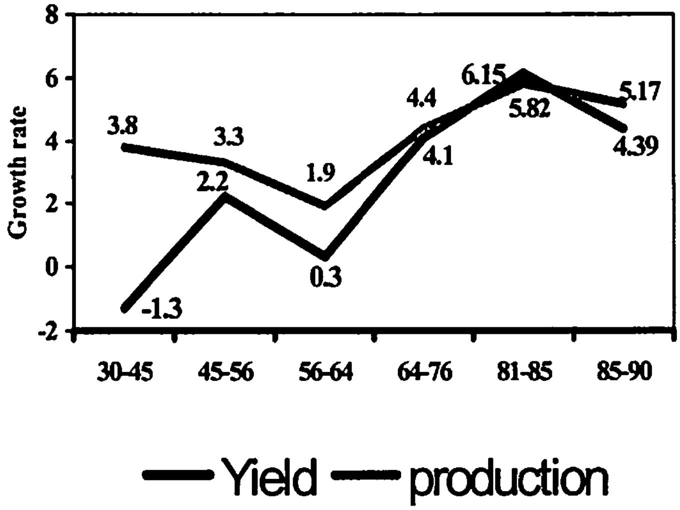

Figure 1: Variation in growth rate of wheat yield and production (irrigated/dry land) for different periods.

5

In Sustain of Sustainable Agriculture

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Introduction

Sustainable Agriculture

The steadily increasing world population and the related needs for agricultural products have put a heavy pressure on natural resources. FAO estimates that the food per capita increased 23 % from 1961 (FAO, 1996), in spite of the growth in population, and according to Pretty and Hine (2001) "*between the early 1960s and mid-1990s average cereal yields grew from 1.2 t/ha to 2.52 t/ha in developing countries whilst total cereal production has grown from 420 to 1176 million tonnes per year.*" These achievements could be obtained thanks to the so-called Green Revolution, based on the high-input agriculture and were unevenly distributed among the various regions of the world. In southern Africa, for instance, per capita production of food decreased remarkably from 1971-72 to 1993-94 (Abalu and Hassan, 1999).

"*Many factors contributed to the recent doubling of world food production. The development of higher-yielding strains of crops and better agricultural practices were important, as were increased use of herbicides for weed control and insecticides and fungicides for pest control. In addition, there were marked increases in the amounts of nitrogen and phosphorus fertilizers applied each year worldwide, in the proportion of arable land that was irrigated, and in the total amount of land that was cultivated worldwide. It was the combined effects of all these factors, and more, that allowed world food production to double in 35 years*" (Tilman, 1999).

But to achieve such a success a toll has been paid in terms of pollution and agro-ecosystems decay – how heavy this toll has been, is a matter of debate. The world agriculture is now facing the challenge of feeding an estimated 10 billions people by the year 2050 while alleviating the pressure on agro-ecosystems, namely reducing chemical and physical pollution, avoiding any enlargement of cropped areas and protecting biodiversity, avoiding the overexploitation of natural resources, including water and forests, and protecting the landscape and the environmental amenities. Further challenges are put by those who highlight the need for a new "food systems paradigm" (i.e. it is not sufficient to produce enough food, but *the quality* of nutrition must also be taken into account: Welch and Graham, 1999); those who want to ban the use of synthetic fertilizers and pesticides; those against the radiation of foods; those against the reuse of treated urban wastewaters for irrigation; those against Genetically Modified Organisms.

A second Green Revolution is expected able to reconcile intensification and sustainability through reconciling intensification and sustainability (Sherwood and Uphoff, 2000). The concern over the decaying agro-ecosystems as a consequence of the ever increasing pressure put on land, water and atmosphere by an ever higher use of synthetic pesticides was remarkably expressed by Rachel Carson as early as 1962, in her famous book *Silent Spring* and gained impetus later with the mounting awareness of ecological problems. This contributed to the evolution of an acute awareness of the need for a *sustainable development*; while consensus on this principle is practically universal, the exact meaning and extent of sustainable development has been and still is a matter of debate. Rigby and Càceres report that at least 386 definitions of sustainable development exist (Rigby and Càceres, 2001). With specific reference to agriculture, the term "sustainable land management" surfaced later, probably in 1989 (American Society of Agronomy, 1989). A "classical" and famous definition is that given by the UN-backed World Commission on Environment and Development (WCED) commonly referred to as Brundtland Commission, according to which sustainable development is that meeting the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). The vagueness of the above definition has given room for a variety of conflicting interpretations.

Nevertheless, "*although sustainability has become one of the forefront issues faced by agriculture, sustainable agriculture continues to remain an ill-defined concept*" (Sands and Podmore, 2000) and O'Riordan (1985) described sustainability definition as "*an exploration into a tangled conceptual jungle where watchful eyes lurk at every bend*". Ikert (1996) stated that "*a sustainable agriculture must be ecologically sound, economically viable and socially responsible*" adding that "*sustainable systems must be individualistic, site-specific, and dynamic*". Atkinson and McKinlay (1997) note that "*as public perceptions of priorities change, what is considered sustainable today may not be considered so in the next decade*"; we can add that what is considered *unsustainable* today may not be considered so in the next decade. Hansen and Jones (1996) commented that "*although sustainability is an important concern at several levels in the hierarchy of agricultural systems (Lowrance et al., 1986; Lynam & Herdt, 1989), it is particularly relevant at the farm level. If agriculture is to meet the needs of society....it must first meet the needs of the farmers.*"

Hansen, in a comprehensive critical review of agricultural sustainability issues, highlights two interesting concepts:

1) that alternative agriculture movements were basically originated in North America and Europe, where conventional agriculture is typically a high-input one and food is abundant, as opposed to conventional agriculture of most developing tropical regions, therefore "*attempts to link strategies to sustainability by definition fail to consider to match technologies to specific environments*"; and
2) that the primary need in most developing countries is to increase productivity, since ecological disasters can be brought about by the failure to adequately feed populations (Hansen, 1996). Wood (1999) noted that linking or equating the agro-ecosystem "sustainability" to its "resilience", "stability" or "resistance", as repeatedly suggested, is misleading because "*agroecosystems that do not change for the worse in the face of stress are likely also not to change for the better ...that is they are unresponsive...Stable agroecosystems that do not become more productive with greater inputs...condemn farms to a low productivity ceiling*". Such a kind of "non-dynamic sustainability" collides with the need to enhance crop productivity in order to meet future needs of mankind without putting to culture more natural land.

In spite of some optimistic or not-so-pessimistic views (e.g. Penning de Vries et al.,1995; Avery,1999; Lomborg, 2001) little doubt actually exists that the present conventional agriculture is on the whole unsustainable and that steps must be taken to check the environmental decay. Although food quality is sufficiently protected, at least in theory, through the existing laws (and indeed no evidence is found in the scientific literature supporting or rejecting a worse quality of conventional food as compared to the so called "organic" food: Reganold, et al., 2001; Bulluck III et al., 2002; Williams, 2002), yet the damage to the "natural capital", not to mention the social aspects very much stressed by Ikerd (1996, 2001a, b), is much higher than commonly perceived. It has been reported that in the UK the "external costs" of agriculture in 1996 amounted to a staggering 89% of the average net farm income (Pretty et al., 2000), that "annual damage by pesticides and fertilizers to water quality is suspected to range in the billions of dollars" (Doran et al., 1995) and that annual off-site damages from soil erosion by water in the USA are over US$ 7 billion (Pimentel et al., 1995).

Many alternative, more or less fanciful approaches have been suggested to conventional, high-input agriculture, all aiming to reduce the input of non-renewable resources and all claiming to permit the achievement of a sustainable agriculture, such as the USDA backed Low Input Sustainable Agriculture (now converted to Sustainable Agriculture Research and Education, SARE), Integrated Farming System, Conservation Tillage, Ecological Farming, Permaculture, Organic Farming, Alternative Agriculture, Biodinamic Farming and many others.

Of all the above solutions only organic farming has an established set of officially coded rules, with minor differences among different countries. Nevertheless many sound principles deserving full consideration, sometimes more rational than those of organic farming, are suggested by the other systems, which can be usefully adopted in the quest for enhanced, more sustainable agro-ecosystems. Conversely some principles of organic farming are clearly hindering the progress towards sustainability hence the need to objectively evaluate all the possible combinations and then select the optimised strategies.

The focus here in fact is not to debate whether conventional, high-input farming systems perform better or worse than alternative systems – it is out of discussion that they must be actually improved. The point is rather to try to find out the best combination of seriously based principles and strategies to "sustain sustainable agriculture," thus gaining a widespread and durable farmers acceptance and therefore securing a long-term application, since farmers can become "the sentinels of sustainability".

Agriculture, allegedly a major environmental polluter, can radically reverse its present position of defendant if it succeeds in enhancing its productivity level while changing into positive its negative environmental impact and fully developing its potentially crucial role in the protection of the environment and the society through one or more of these processes; by; (i) sequestering CO_2 in the soil and the plants, (ii) supplying clean energy, thus becoming an energy supplier rather than a consumer (iii) caring landscaping and biodiversity development (iv) recycling urban wastes (both solid and liquid) and (v) safeguarding consumers and operators.

The Required Holistic Approach

We are presently going through a critical phase of conversion in agriculture requiring solutions for reconciling widely differing dimensions, namely agricultural productivity, farm economic sustainability, environmental protection and the social aspects (food safety, quality of life). The need to consider simultaneously in a holistic approach many dimensions was acknowledged at least as early as 1984 (Douglass, 1984) and later universally accepted (e.g. FAO, 1993; Sands & Podmore, 2000; Cornelissen et al., 2001; Sulser et al. 2001

The four criteria or "pillars" listed by FAO in the Framework for the Evaluation of Sustainable Land Management, FESLM (Smyth and Dumansky, 1993), to assess sustainability in land management are:

a. production should be maintained;
b. risks should not increase;
c. quality of soil and water should be maintained: and
d. systems should be economically feasible and socially acceptable.

They are reasonable and are generally accepted as undisputed guidelines addressing economical, ecological and social dimensions at the same time, with the only caveat that in view of the forecast increase in world population from 6 to 10 billions, by 2050 production should not only be *maintained* (pillar 1) but increased accordingly, while of course eliminating to the possible extent any areas of under-nourishment.

Reliable and validated simulation tools exist for bio-economical simulation and to optimize the input of resources in agronomic production at field scale, such as the well known, well tested Decision Support System for Agro-technology Transfer, DSSAT (IBSNAT, 1993), now adopted together with a Dutch model and the Australian "Agricultural Production System Simulator", APSIM, by the International Consortium for Agricultural Systems Application, ICASA, in order to achieve the possible synergies (http://www.icasanet.org).

In the Netherlands, for instance, CLM (CLM, 1996; Hanegraaf et al., 1998) developed a useful and comprehensive methodology to assess the sustainability of energy crops in Europe. It notably encompasses environmental aspects, including erosion, groundwater depletion, biodiversity, landscape, greenhouse gas emissions, CO_2 sequestering, energy ratios, plus economic and social aspects.

Zander and Kächele (1999) elaborated a modelling system including various modules which permit an economic and ecological analysis of production activities, geared on a multiple goal linear programming module and apt to be used both at farm and regional scale. Both biophysical and bioeconomic simulation tools in fact are required to adopt such a holistic approach and the adoption of new and advanced mathematical techniques (e.g. fuzzy sets: Cornelissen et al., 2001; rough sets: Brusaporci and Vindigni, 2002; fractional programming: Lara and Stancu-Minasian, 1999) is a powerful support in the progress in this complex field.

In conclusion presently agricultural systems models, although promising and attracting a sizable research activity, are more useful for formulating policies and general strategies than to influence the farmers decisions; however single "modules" are already used in the practice for single segments of the agricultural activity, such as irrigation management, fertilization, pest control, which gives promise for a further development in the near future.

Indicators

As Doran (2001) pointed out "*indicators of soil health and strategies for strategic management must be linked*"; Doran, from his standpoint, focuses attention primarily on soil health (a synonym for soil quality and sustainability), but the principle is absolutely correct for all the indicators needed to work out any appropriate strategy, since they are an essential tool for an *a priori* appraisal of local conditions, a monitoring of the impact in the course of actions, and an *a posteriori* evaluation of the selected strategy outcomes.

Since the problem of objectively and effectively assessing agro-ecosystems quality has been impending on scientists for decades, quite a number of indicators have been suggested: indicators are "*tools for aggregating and simplifying information of a diverse nature into a useful and more advantageous form*" (Sands and Podmore, 2000).

In order to approach such complex problems the adoption of appropriate qualitative and quantitative indicators has been often advocated to obtain objectively based guidelines (e.g. Sands and Podmore, 2000). Doran et al. (1996) elaborated a clever, simple set of strategies and indicators for sustainable agricultural management based on "*generic indicators of soil quality and health which are measurable by and accessible to producers within the time constraints imposed by normally hectic and unpredictable schedules*".

Janet Riley, in the preface to the special issue of Agriculture, Ecosystems and Environment on indicator quality points out the lack of consistency in definitions and the non-comparability of scale, concluding that "*the international challenge then is to identify common indicators having consistent definitions across sectors, themes and countries...More social and political indicators need to be created and tested so that the transfer across different domains or cultures can be validated*" (Riley, 2001a) and elsewhere judiciously adds: "*There is little problem with finding an indicator; the problem is to find an appropriate one*" (Riley, 2001b). Tisdell, for instance, outlines the difficulty in finding out a satisfactory method for evaluating the economic aspects, since the discount method normally used, which estimates the net present value for all the future profits, requires the selection of a correct discount rate. This is not at all easy- and "*assumes a perfect capital market and a degree of certainty that is unlikely to exist in practice*". He concludes that "*a conservation farming practice is likely to be adopted and sustained in areas where (1) it is more profitable than the alternatives, (2) it does not involve large initial outlays and* *liquidity or finance problems, and (3) the returns from it are not very uncertain compared with the alternatives"* (Tisdell, 1996).

Doran quite fittingly comments that "the use of simple indicators of soil quality and health which have meaning to farmers and other land managers will likely be the most fruitful means of linking science with practice in assessing the sustainability of management practices" (Doran, 2002). To him, agricultural sustainability results from a balance among social responsiveness, economic viability and environmental stability (Doran, ibid.).

Energy and CO_2 Sequestering Aspects

One important aspect in evaluating agricultural systems, which has been regrettably overlooked with only a few exceptions (e.g. Gomez et al., 1996; CLM, 1996; Uhlin, 1997; Hülsbergen et al., 2001; Hülsbergen et al.,2002) refers to the energy input, since "energy intensity is a measure of the environmental effects associated with the production of crops (consumption of fossil fuel and other resources, emission of carbon dioxide and other combustion gases)" (Hülsbergen et al., 2001). Spedding et al. (1981) stated that the single most important aspect of agricultural efficiency in the future is likely to be that of energy use.

An indicator based on energy ratio or energy productivity (namely the output/input ratio) is not always meaningful, first because the energy in output, namely in agricultural products, may have a negligible interest (Pimentel, 1973), like in the case of ornamentals, and second because an extremely high energy ratio can easily be achieved at the expenses of production whenever a very low input is adopted. In this sort of balancing the input of solar energy is generally not considered, nor is that of human labour. The same consideration applies to energy intensity, defined by Biermann et al. (1999) as the ratio of energy input to that contained in the product and by-product, expressed in units of Grain Equivalent (GE), which practically approximates dry matter production. Energy gain, namely the difference between output and input, is a more significant indicator (Biermann et al., 1999).

Analysis of energy indicators for Swedish agriculture (Uhlin, 1997) evidenced that, contrary to what many maintain, intensive systems are more energy productive than low-input and self sufficient systems: compared to 1956, outputs in 1993 had a 40% increase as opposed to an input increase of only 14%, with a parallel enhancement in energy gain. Considering the solar energy productivity of plant production, namely gross biomass in plant production divided by total solar energy, a 75% increase can be appreciated passing from 1956 partly traditional agricultural systems to 1993 specialised, mechanised and fully fertiliser-based systems.

One further important aspect deserving more attention is linked to CO_2 capturing and long-term sequestering in the soil: an appropriate soil management can in fact concur to significantly reduce CO_2 pollution in the atmosphere, thus reducing the greenhouse effect (e.g. Schomberg, 1999; Follett, 2001; Pretty and Ball, 2001; Halvorson et al., 2002). Accordingly, when looking for a trade-off among the various contrasting options in selecting "the best" farming system in a specific environment, full consideration must be given also to this factor and its potential "positive externalities", and a suitable indicator is needed.

Striving for Sustainable Agriculture

The considerations discussed above have shown that:

1) today's agriculture has achieved the scientific and technical ability to provide food for a steadily increasing world population but the price paid to achieve this success, in terms of environmental decay and quality of life, cannot be accepted and there is some reason to fear a collapse of agro-ecosystems in the future;
2) strategies for a sustainable agriculture are urgently needed and an arsenal of sometimes contrasting ways to achieve sustainability is available; and
3) sustainability can be achieved provided that prejudice-free system approaches are adopted, supported by appropriate indicators: although thoroughly validated and accepted system approaches are not immediately available, ongoing intense research and progress give reason to believe that they will be operative in the near future.

In the following, a necessarily incomplete review will be exposed of the possible interactions of the principal practices that must be simultaneously evaluated in order to avoid neglecting some important aspects while giving too much emphasis to others. Only for the sake of clarity the management practices to be examined will be grouped under four headings, although we are fully aware of the close interrelationships linking them all; cultivation, fertilization, irrigation, and pest control. Practices in every single group will be analyzed for their impact on; economy, environment and society.

Again, since the social, economic and environmental impact are closely interlocked, a separate analysis is in principle incorrect, however it is deemed necessary for sorting out the outcomes of the various possible actions. Furthermore it must be considered that conflicting indications may result inside every single group, such as, for instance, the need to associate no-tillage (positive effects for protecting soil fertility, sequestering CO_2 and minimizing off-site damages) with the spraying of herbicides (negative effects due to the risk of local and downstream pollution). Similarly, social aspects to be privileged can include employment enhancing, which conflicts with farm net profit and environmental pollution, human energy being notoriously by far the most polluting of all.

Our aim is to demonstrate that reasonable tradeoffs (or "best compromise" solutions) can be achieved when rationally combining the possible actions empirically tested in the field with the available data and information on their impact and that the best results can be in fact obtained from this integrated approach. Of course, the best strategy is that able to optimize to the possible extent the outcome under the three aspects economy (including productivity), environment and society, which unfortunately is seldom achievable. A win-win solution in fact can be found rather easily when only a couple of aspects are considered, but finding the "best compromise" solution can become a difficult task when three or more aspects are simultaneously considered, and a weight must be assigned more or less arbitrarily to each of them. The scope of the present paper is to present a conceptual framework to assist decision makers while evidencing some rather diffuse misconceptions.

Cultivation

Various forms of soil cultivation exist, ranging from mouldboard ploughing to no-tillage, as listed below (from CTIC, 1998):

- *Conventional tillage*: mouldboard ploughing followed by disking or harrowing, implying soil inversion.
- *Mulch tillage or mulch ripping*: the soil is tilled prior to planting with chisels, disks, sweeps or blades; weed control is obtained with herbicides and/or cultivation.
- *Ridge tillage*: the soil is left undisturbed from harvest to planting except for nutrient injection. Planting is completed in seedbeds prepared on ridges with sweeps, disk openers, coulters or row cleaners. Residue is left on the surface between ridges. Weed control is accomplished with herbicides and/or cultivation. Ridges are rebuilt during cultivation.
- *No tillage*: the soil is left undisturbed from harvest to planting except for nutrient injection. Planting or drilling is accomplished in a narrow seedbed or slot created by coulters, row cleaners, disk openers, in-row chisels, or roto-tillers. Weed control is accomplished primarily with herbicides. Cultivation may be used for emergency weed control.

In those cases that conservation tillage (particularly no tillage) can be adopted, including most fruit and citrus plantations and vineyards, advantages can be appreciable under diverse aspects:

Economic: reduced tillage operations automatically reduce costs; particularly with no-tillage, when feasible, plant root system is not disturbed and yield is increased; grain yield is enhanced through the encouraged rainwater infiltration; costs for irrigation are reduced; in-site and off-site damages (external costs) depending on erosion and downstream pollution are mitigated;

Environmental: reduced cultivation implies reduced energy inputs (e.g. Swanton et al., 1996), therefore determining less pollution; soil is less disturbed and its structure is protected; accumulation of organic matter, a fundamental component of fertility, is encouraged; microbial biomass and soil fauna are increased; CO_2 releases to atmosphere are much reduced

Social: workers conditions are improved due to the reduced/eliminated tractor trips; a wide ranging alleviation of pollution is achieved, from local fertility decay consequent to erosion to off-site damages such as reservoirs siltation, recreational areas impairments, rivers eutrophication, gas emission, water body quality, etc. It is worth to mention here that there is a general consensus that off-site damages consequent to erosion far exceed in-site damages. Consequently the advantages to the society of adopting a large scale conservation program exceed those to single farmers.

Fertilization

Stinner and House (1989) suggested an inverse relationship between the levels of chemical input and the system sustainability, and their principle is generally assumed correct; Zandstra (1994, as reported by Hansen, 1996) however proposed a different scheme, with insufficient chemical inputs leading to exhaustion of natural resources and excessive inputs leading to accumulation and eventually pollution. The two principles are not as opposed as it can appear at first sight and can be reconciled observing that Stinner and House suggest to substitute chemical inputs with information and biological control, which implies avoidance of exhaustion.

Nitrogen

Nitrogen is the most widely used fertilizing element and is also the most highly polluting. The principles of organic farming ban the use of synthetic fertilizers (which gave origin to a flourishing industry of "organic" fertilizers of uncertain composition and extravagant cost), on the assumption that green or animal manure enriches soil in organic matter and reduces nitrogen leaching. While enrichment in organic matter by animal or green manure is unquestionable (but with other so-called organic fertilizers it is highly doubtful), avoiding nitrogen leaching has been demonstrated a wishful thinking, since the lack of synchronisation between N release by organic matter and N uptake by crops can lead not only to an insufficient supply to crops in the critical phenophases (e.g. Myers et al., 1997; Pang and Letey, 2000)

Impacts

Economic: of course reducing nitrogen doses to the possible extent appears as a typically win-win solution, however it is only partly true because the reduced physical input is at least in part economically balanced by the costs for monitoring, analyzing soil and leaves, accurately managing the fertilization. Compared to organic manure, mineral fertilization is somewhat cheaper and permits a more targeted and time-efficient action, thus reducing risk of crop malnutrition.

Environmental: The main environmental risk of nitrogen fertilisation is certainly depending on the pollution of water bodies, which applies both to organic and inorganic forms. Nitrogen is notoriously one of the most energy- demanding factors in farming activity, however recent technological progresses in fertilizer manufacturing have substantially reduced the energy required, passed from about 80 MJ/kg in 1972 to about 40 MJ/kg in 1999 (Uhlin, 1999).

Social: A mixed organic/mineral fertilization as described above, with moderate doses of mineral N applied after controlling the nutrient level in the plant tissues and the soil, permits to achieve the safest results in terms of pollution avoidance. This in turn brings about a better fruition of recreational areas, fishing ponds and water courses, and a reduction in emissions. Exchanging large N applications for more analyses, monitoring and accuracy in management entails a more qualified and rewarding job for operators.

Solid phosphoric fertilisers are available as mono-ammonium phosphate, di-ammonium phosphate, triple superphosphate and single superphosphate; additionally, high-grade liquid phosphoric acid is available. Furthermore, phosphorus is available as phosphate rocks (PRs); Rajan et al. (1996) give a review of PRs use for direct application to soils. Phosphorus content of PRs is relatively unimportant, since what really matters is their reactivity in the soil, which in turn depends on the soil itself, the PRs mineralogy and the level of rock grinding. PRs are acknowledged as non-active in basic soil and in those soils on a calcareous matrix which are so common in the Mediterranean region; to alleviate this problem it is suggested to apply them in combination with green manures or in the composting process.

Impacts

Economic: Assessing *a priori* the most economic form of P fertilizer is a difficult undertaking; excluding the use of PRs, which can indeed be considered as inert rocks in most Mediterranean areas, the selection is limited to the high-grade or low-grade, more or less soluble solid forms. Of course liquid phosphoric acid, which is the more costly, is only used in those cases that a permanent irrigation system, particularly a microirrigation system, permits to distribute it to the crops uniformly and inexpensively; it has in this case the additional advantage of cleaning pipelines and emitters and discouraging the entry of insects into the emitters,

Environmental: Cadmium accumulation through the application of mineral P has been a matter of concern; however, through novel manufacturing and refinement processes, the Cd concentration has been reduced to <5 ppm P (HydroAgri, 1998) whereas untreated PRs keep intact their Cd content. Energy considerations are one further factor against the adoption of PRs.

Social: Once again, environmental considerations are closely interlocked with social aspects. All those practices and technologies permitting to mitigate fertilizer environmental impact are simultaneously of benefit under social aspects.

Irrigation

Irrigation can be the most costly operation both in monetary terms and in terms of energy input. The cost of a cubic meter of water in the Mediterranean area, for instance, can exceed euro 0.50 (desalinised sea water costs in Cyprus euro 0.70/m^3, Papadopoulos, 2002, pers. comm.) while the direct energy input to lift and pressurize water from deep wells can exceed 4 MJ/m^3, with a corresponding cost, just for electric energy, of over euro 0.15/m^3. Furthermore, water availability is ever decreasing and competition is mounting among the various uses (domestic, agricultural and industrial) with agriculture taking the lion share, namely up to 90%, and using it rather inefficiently on the average. As a consequence careful assessments of real crop water requirements, an enhancement of conveyance and application efficiencies. A better management and whenever possible the adoption of a deficit irrigation schedule are needed. But again, human inputs (for plant water status monitoring, correct irrigation management, irrigation system maintenance, participatory irrigation management and capacity building) are called in substitution of physical inputs.

More research and demonstration activity should be devoted to water harvesting, which can be considerably useful not only in reducing irrigation requirements but also in the reduction of runoff and consequently in the protection of soils from water erosion. Irrigation, an indispensable productivity factor in arid and sub-arid climates, can be very useful also in humid areas in order to reduce the risk depending on short, erratic drought periods. The total volume of irrigation water to be applied in this case is of course less than in arid areas, but the probability of precipitations following water applications, and consequently of water logging if excessive amounts are applied, requires a more careful management.

The selection and sizing of the most appropriate irrigation system, as a function of local human, climatic, economic and agronomic conditions is critical in the process of optimizing the resources. Energy requirement, resulting from the sum of <u>direct</u> energy to lift and pressurize water plus <u>indirect</u> energy for manufacturing and installing the irrigation system, is a generally overlooked, yet important factor in the selection of irrigation methods (Sardo, 1982).

Also irrigation with brackish and saline waters is actively explored, with teams studying plant response to irrigation at various salinity levels and implications on the soil and the environment (e.g. INCO-DC, 2001; DRC, 2002); results so far achieved show that unsuspected possibilities are open for the use of large, till now neglected unconventional water resources.

Impacts

Economic: In order to achieve the highest net income, when designing an irrigation system a trade-off is required between application uniformity and system cost. A higher uniformity, in fact is linked to higher initial costs but permits substantial savings in terms of water quantity because it is closely linked to application efficiency. One further aspect to be considered is the pressure required by the irrigation system, which may not be relevant in those regions where only supplemental irrigation is practiced, but influences heavily costs whenever volumes of about 5.000 cubic meters/ha/year or more are applied. Third, evaporation losses depending on the selected system can be of importance, particularly in those arid or semiarid regions where they can account for 30% or even more. When carefully managed, irrigation can be very useful even in humid areas since it determines a reduction in production risk.

Environmental: All those considerations applying to economic impact apply to energy input as well, since savings in water quantities or in required pressure automatically translate into energy savings. Furthermore, savings in water volumes alleviate the burden on the often negative balance of water resources and reduce the risk of water logging and salination. When associated with fertilizers application ("fertigation"), irrigation permits to increase fertilizers efficiency, provided that application uniformity is sufficient, thus reducing the applied quantities and closely controlling leaching amounts.

Social: Irrigation is a powerful tool in the improvement of farmers social conditions, not only enhancing their income but also reducing the risk depending on climate vagaries. It also adds to social stability by increasing the employment and food security. Further aspects refer to the quality of aquifers and watercourses, which can be impaired or protected by an appropriate/inappropriate irrigation management.

Pest Control

Agriculture today uses worldwide about 2.5 million tons of pesticides annually (Wijnands, 1997). Out of such quantity only about 0.4 % reaches the targeted pests (Pimentel, 1995), while losses through volatilisation are of the order of 80 – 90% (Taylor and Spencer, 1990). Pest control is probably the sector where a really integrated view of farm management is most required, since it can be the result of a number of concurring activities, encompassing plant selection, sowing date, crop rotation, cultivation and even irrigation and fertilisation, plus of course pesticide application, if and when necessary.

The trouble with the "therapeutic" principles, is how to determine the threshold beyond which an intervention is warranted, since the threshold depends on a multitude of factors such as pest population, the intensity of predators and their likely increase, damage functions for individual pests, crop susceptibility according to the particular crop phenophases, weather conditions and forecasts. The lower the threshold fixed for starting the intervention, the lower the risk of pest damage to the crop but the higher the cost in terms of economy. Impact on the the environment and the society and as a consequence the threshold cannot be decided with *a priori* rules of thumb. The principle of a "dynamic economic threshold", based on the modelling of the crop and pest evolution as impacted by pesticide sprayings and aimed to profit maximization, was developed by Bor (1997). He suggested that future studies should enlarge the scope to include health and environment- related aspects. Doubtless, an intense scouting and management can greatly assist in safely raising the threshold level and reducing the external input.

Some objection is raised against the advocated solution of crop rotating to control pest development (Way and van Emden, 2000; Jeger, 2000). Leaving weeds grow on field margins to encourage predators can be a sound practice but can also encourage pests, which nest there (Gurr et al., 1998; Way and van Emden , 2000 and Peet, 1995).

Recent progress has focused on the reduction of broad spectrum insecticides, toxic also to useful insects and on the development of selective alternatives. The cost of the intensive scouting and monitoring may or may not exceed the savings from pesticide reduction (Fenemore and Norton, 1985; Peet, 1995; Walker, 1999).

Successes of pest management in the USA are illustrated by the leaflets released by SARE (http://www.sare.org/10yrsofsan/pest/pestmgt.htm); on the other side, the intensive monitoring, the relatively costly and sophisticated equipment required by IPM and the inherent higher risk for crops make it unsuitable for many developing countries, particularly in those areas where subsistence crops are grown to sustain the farmer families. It can also be argued that IPM has few probabilities of success at the other extreme, with very high-value crops, where no producer is willing to take a chance.

At any rate, to avoid possible confusions, it must be clearly appreciated that "*IPM is not organic farming. This is a critical point. IPM may provide a bottleneck to the adoption of organic farming and viceversa*" (Jeger, 2000). IPM as advocated by the principles of organic farming in fact is a restricted form of the generally accepted form, where the use of synthetic pesticides is totally banned, whereas IPM as commonly intended aims at reducing their use to the possible extent.

Impacts

Economic: Pimentel et al. (1993) compared economic results for conventional and alternative pest management practices in tomato, concluding that potential reductions in herbicides were of the order of 80%, in conventional insecticides again of 80% and in fungicides of 50%, with corresponding cost increases (for mechanical cultivation, scouting and management) of 30%, 0% and 10%, respectively. Apparently, they did not consider additional shortcomings depending on mechanical cultivation.

Environmental: Clark et al. (1998) and Edwards-Jones and Howells (2001), applied the environmental impact quotient (EIQ) developed by Kovach et al. (1992) to evaluate the environmental hazard of pesticides suggested for organic farming. The EIQ analyses three distinct categories of hazard, to farm workers, consumers and the environment. The conclusion of Clark et al. (1998) was that EIQ with organic farming is about half that with conventional farming in corn while it is zero in tomato. Further objections can be moved to the rationale of permitting the use of broad-spectrum organic insecticides, such as neem or rotenone while prohibiting the more environmental-friendly selective synthetic insecticides. Furthermore, although it may come as a surprise, it must be acknowledged that "botanicals" can be more toxic than conventional.

Social: Including evaluation of hazards to the workers and the consumers, EIQ is a good indicator of social impact, unlike EEP (Environment Exposure to Pesticides) which only relates to pesticides impact on air, soil and groundwater (Weijnands, 1997). However EIQ, focusing only on the pesticide action, fails to consider the side impact of alternative solutions. For instance, the EIQ value of an alternative, organic, "ecological" pesticide may well be less than that of the equivalent conventional, synthetic pesticide. But it is also important to evaluate the impact of the practices required to support the action of the environmentally benign pesticides, such as more cultivation or more targeted fertilization (for instance silica addition). In conclusion an integrated approach to the integrated management is needed, which is still missing.

Policy Issues

Presently a significant reduction in organic farm number is registered in some states of the European Union, due to decreased subsidies. This is regrettable because when reverting to conventional management farmers are likely to re-adopt relatively polluting and unsustainable practices (it must be kept in mind, however, that European agriculture is far less polluting than its American counterpart. One third of the world market of pesticides is purchased in the USA. An effort should be made to transform this volatile consensus into a solidly based and convinced consensus. To obtain this, rather than unreasonably proposing maintenance subsidies to farmers beyond those in the transition period the solution is straightforward; the dogmatic principles of organic farming must be abandoned in favour of flexible, farm-tailored solutions, based on a really integrated approach, with an exhaustive and comprehensive consideration of productive, economic, environmental and social aspects. It will then be possible to really convince the farmers, through a participatory process, of the advantages of sustainable methods, with the support of demonstration farms and capacity building courses, to be conducted by trained, skilled, prejudice-free extensionists and advisers. In any case, before putting any constraint on farms, undisputed evidence must be achieved of the need of putting them. Too many principles have gained dogmatic acceptance just because they have been endlessly repeated.

Certainly a good solution is to invest in research and demonstration, and in parallel activities of capacity building with the active

participation of the stakeholders: intensive inputs can eventually be replaced by intensive appraisal, monitoring, management and assessment. When producers become the watchers of soil health, namely of environmental quality, obvious and solid advantages on the ground of social and environmental impacts will be achieved.
Considerations on the economic impact are clear-cut. Unprofitable agricultural systems quite simply will never be accepted, and securing at least the same profit and the same risk of conventional systems is a prerequisite for the large-scale success of any sustainable system. The fact that farmers accepted for a while the subsidised organic farming rules does not imply that they really supported the organic farming principles. They just supported the subsidy.

Relying on the premium prices paid by consumers for organic products can be elusive. This is because premium prices in many cases go to wholesalers and retailers rather than to producers. This can fluctuate according to public perceptions and fashions of the moment, or more simply it can be forecast that consumers' willingness to pay more for a safe food will vanish when the traceability systems now being planned will be enforced; permitting to control that conventional food complies with existing norms and is practically as safe as the "organic" one from the standpoint of pesticide pollution (it is widely demonstrated that their nutritional value is identical). In the event that for environmental/social reasons (for example in order to reduce off-site effects of erosion) limitations are imposed to the free fruition of lands by landowners, it is equitable that society pays for any additional burden.

The Dutch school of economics of Wageningen (e.g. Kruseman and Bade, 1998; Hengsdijk et al., 1998; Ruben et al., 1998) has made a considerable progress towards the elaboration of operative bio-economic models, combining agro-ecological and socio-economic aspects into an integrated analysis permitting an objectively based policy formulation.

In general terms the variability in vulnerability and resilience of different agro-ecosystems dictates a parallel flexibility in strategies. It is striking that, unlike in the USA where much attention is dedicated to soil, water and energy protection, neither in the EU Regulation 1257/99 nor in the rigid rules issued by the European

Commission for organic agriculture (Regulation 2092/91 and amendments) any specific, explicit provision is made for soil, water and energy conservation, nor to combat physical pollution, whereas counter-productive constraints are put on other items: this in spite of the EU concern for environment. It is time that such norms be revised and room be given to formation, training, monitoring and serious advising. It appears desirable to substitute the present flat rate payments, unrelated to actual management costs, with more intense activities in research & demonstration, monitoring, management, technical assistance, in organizing demonstration farms and courses for capacity building, in stimulating participatory processes. In any case it can no longer be tolerated that such an important issue as sustainable agriculture falls prey to unskilled amateurs and dreamers while taxpayers' money goes to funding counter-productive activities. It is reasonable to expect that the objective of the norms and subsidies be not to privilege niche producer and niche consumers who can afford to pay premium prices for a supposedly better food, but rather 1) to protect everybody's health and 2) to conserve the environment. The first goal can be achieved through the application of existing -or maybe amended- quality norms, food labelling and an accurate monitoring of its quality; the second through an appropriate holistic approach to the agroecosystems management.

Different approaches are required of course with the problems in developing countries, but there again solutions must be sought in total freedom from dogmatic constraints, caring people welfare and environmental protection and avoiding parochial attitudes.

Discussion and Conclusive Remarks

In the light of what has been discussed, pursuing sustainability in agricultural systems appears as a still ill-defined but inescapable task, to be based as far as possible on a global approach to farming systems, harmoniously combining all the resources offered by science and technology. Although results obtained by researches are sometimes contradictory, due also to the enormous variety of experimental conditions and the uncertainty in some data, and their indications are sometimes biased, there is some solid ground on which is possible to work confidently.

In this paper there is no attempt to elaborate a new system for reaching sustainable agriculture. It is just an endeavor to work out a conceptual framework for focusing and organizing some basic principles which should not be neglected.

A rational, sustainable farming system must be flexibly designed, since farming systems are multi-purpose and multi-method and therefore highly dynamic. As a consequence the process of elaborating an "optimized" farming system must integrate in a synergic mode all the relevant aspects, must be free from prejudice and dogmatism, and open to promptly include any useful new principle or technological innovation. This can only be obtained through the adoption of an integrated approach and opportune indicators.

It is necessary that in a really "organic", "synergic" approach some important, so far neglected aspects be given due consideration and unessential or indeed harmful constraints be abandoned. Only the adoption of flexible, advanced, rational strategies, to be selected with the participatory process of all the stakeholders, principally farmers, can secure a serious and widespread acceptance of sustainable agriculture.

The task is evidently too challenging and the stake too important to indulge to philosophical, emotional, non-rational approaches. All the resources of science and technology should concur in a coordinated, synergic effort towards the Holy Grail of sustainable agriculture.

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6

The Activities and Achievements of the Matruh Project

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Overview of the Project

The Matruh Resource Management Project was established in 1994 to break the cycle of resource degradation and poverty in the western parts of the North West Coast of Egypt. The project was designed at a total cost of US$ 29.5 millions (IDA credit is 22.0 million, and the contribution of the Government of Egypt (GOE) and the beneficiaries is 5.1 and 2.44 millions respectively) and will be closed by the end of 2002.

The project area extends 320 km from Ras El-Hekma in the east to El-Salloum in the west with an average depth of 70 km inland. The agricultural production relies exclusively on an average rainfall of 140 mm/yr (Taimeh and Mansour, 2000). Arable land is almost 16% of the total project area, of this, 7% is actually cultivated with orchards (mainly figs and olives) and barley. Rangelands accounts for 48%, while a 36% of the area is rocky and sparse rangelands for supporting runoff generation.

The Bedouin population in the project area is 190000 and is composed of Awlad Ali and is organized in 40 sub-tribes. Each sub-tribe is further divided into clans and bayts. The extended household is the base level unit in the project area (MRMP/ICARDA, 2000). The tribal leadership is hierarchical supported by their customary law "Darbet Awlad Ali" and customary council "Majlis Orfi". The majority of the people (80%) are under poverty line, while the remaining (20%) are safe only during the years of good rainfall (three years out of ten are considered good rainfall years).

Because of the importance of the indigenous knowledge and accumulative experience, the existing tribal structure and the traditions of the society have been utilized to develop an effective mechanism to encourage active participation by the Bedouin communities' members for managing their natural resources. The area was divided into 38 local communities based on tribal affiliation and geographic location. The local community has represented the basic social coherent unit for planning and development. The members of the local community selected 7 – 9 representatives constituting the Community Groups, CG for developing their Community Action Plan (CAP). The CAP matches project interventions of resource management with socio-economic development activities according to the needs of the local community.

The implementation mechanism was supported by strong institutional arrangements. T he National Coordinator supported by the National Coordination Committee has facilitated the decision making process and support at the national level. At the Governorate level, the Project Coordination Unit, PCU has been established, fully staffed and equipped to ensure effective coordination, control of funds, project planning and monitoring. The Project Coordination Committee, PCC composed of representatives of all development agencies operating in the region and chaired by the project Director General (DG) has coordinated the implementation of project activities.

During the last periods, the project has realized distinguished achievements. Fund disbursement from IDA reached 99.9% and 92.5% of it was spent on investment. Needed staff members were recruited and vehicles and equipment procured. Infrastructure required for project implementation was established including the Adaptive Research Center, a training center, 6 sub-regional support centers, 15 social development centers in addition to re-innovation of 35 one-class schools and the development of Monitoring and Evaluation, M&E system. An ambitious TA and training programs were implemented in addition to regional and international conferences and workshops.

In the area of water management and soil conservation achievements are impressive. A total of 8423 cisterns and reservoirs with a total physical capacity of 1.33 million m^3 were excavated with a potential water storage capacity of 2.3 million m^3. In order to support agriculture production on a total of 5620 feddans, 435 thousands m^3 of dykes were erected. A total of 36 wadis were developed and a total of 177455 m^3 of dykes and structural works were constructed and 1600 feddans of deteriorated rangelands were reseeded to conserve soil and water from erosion (MRMP/ICARDA, 2001).

In the area of range management and improvement, a total of 12 tons of indigenous seeds were collected and propagated. Sixteen nurseries were established for the production of fodder shrub seedlings and a total of 6.32 million seedlings of fodder shrubs and trees were planted in a total of 21212 feddans of deteriorated rangelands. New fodder shrubs such as spineless cactus were introduced to the region.

For improving biodiversity in the project area, a total of 80180 fruit trees including driable figs, olives, grapes, apple, carob, etc. were planted in the suitable sites, in addition to the introduction of jujuba, palm trees and honeybees keeping to the project area.

An ambitious adaptive research and extension programs were implemented under the umbrella of farming systems approach. Trials and demonstrations were carried out on 33 permanent sites and on 119 demonstration fields distributed in all agro-ecological zones. Test-proven recommendations on over 40 major topics/problems were developed and disseminated. A total of 993 field days and 406 field demonstrations were conducted to train 8250 farmers in the project area.

Extensive services were provided to the Bedouin women with emphasis on literacy education, improving nutritional and health conditions, environmental awareness, enhancing the contribution of women to family income, and encouraging and supporting the establishment of women NGOs in the region.

Activities and Achievements in Matruh Resource Management Project (MRMP)

Introduction

Rainfed agriculture in Egypt occupies 2–3% of agricultural land; mainly in the NWC, Sinai and in the south east corner. Although this may not appear significant in relation to the total agricultural land, it is important to local communities and economics and to the national security. The poorest of the poor are living in these areas.

Constraints to Development in the NWC

The government of Egypt initiated its development plans 1960's for facilitating the sedentarization of the Bedouin population. The passage from traditional pasturalism to a more sedentary farming without adequate technical support has led to the over-utilization of the area's natural resources. The over-utilization, lack of viable production alternatives, uncoordinated development plans and rural poverty are all linked in the cycle of degradation. The Weak participation of the Bedouin families in the planning, design and implementation and the failure in addressing the farmers problems have led to accumulation of these problems. The absence of effective natural resource management strategy sensitive to the local culture and the Bedouins traditions, the absence of effective research strategy based on farming systems approach, and the weak extension services have contributed significantly to the continuation of the degradation process. The failure in establishing a pragmatic approach for Monitoring and Evaluation has led to failure in evaluating and monitoring the deterioration.

Project Area (Features and Characteristics)

Population and Social Structure

The Bedouin population in the project area (190,000) is composed of the six main tribes of Awlad Ali. These tribes are divided into 40 sub-tribes, which is a blood related group, is the functional of most important in dealing with natural resources and Government. Each sub-tribe is further divided into clans (5 – 7 generations depth) and further into extended households bayt (3 – 4 generations depth), each household is an extended family. The tribal leadership is hierarchical and leaders are designated at each level. There is a customary law called "Darbat Awlad Ali" and a customary council "Majlis Orfi" at each level. There is still pronounced group solidarity with recognized communal responsibilities at each level.

Although, women play an important role in agricultural production, harvesting, the care of livestock inside the house and the domestic activities, the involvement of women at the community level is low. All decisions are made by men. However, women are involved in implementing some activities such as the gathering of stones for building schools, etc.

Income in the Project Area

Agricultural production is the main source of income contributing about 75% of family income, followed by income from trading (16%), then off-farm employment (8%), whilst 1% of family income comes from handicrafts.

Establishing a Poverty Line
The lower and upper limits of poverty line were estimated in the project area to assess the incidence of poverty in the project area. The lower limit (Egyptian pound, LE 7890) is defined as the maximum income level with which a household (7 persons) can barely survive at the most rudimentary level. The upper limit (LE 11830) is defined as the income level that is necessary to attract and keep small-holders in the area.

Income Levels and Distribution
The estimation of household income was done using farm resources data (barley area, fruit trees and livestock) available for the beneficiary database for each household assuming a weighed 10-year average of resource productions. Table 1 shows income groups, gross income as well as agricultural income.

The data shows that households in the first category are below the lower poverty line, whilst households in the second category are below the upper poverty line. Keeping in mind the fluctuation in rainfall, the third category would be under poverty line 6 years out of ten.

Table 1. Household incomes

	Households			
Income	Number	%age	Gross	Income
Ultra poor	10410	56	< 10000	< 6000
Poor	4523	24	10000-20000	6000 – 12000
Non-poor	3881	20	> 20000	> 12000
Total	18714	100		

Project Objectives

a. To implement a program of sustainable natural resource management in order to conserve the water, land and vegetative cover.
b. To alleviate and improve the quality of life of the local population.

The project includes following components:

a. Water Harvesting and Watershed Management.
b. Rangeland Management and Improvement.

c. Adaptive Research.
d. Extension.
e. Rural Credit.
f. Project Management.

Implementation Approach

Institutional Arrangements

The MALR have the overall responsibility of project implementation which is fully entrusted to the PCU.

The PCU is fully staffed and equipped to ensure effective coordination, control funds, project planning and monitoring. The PCU have full administration and financial autonomy, including for the disbursement of project funds.

The PCC established in Matrouh chaired by the DG and including DDG, representatives of the development agencies, the Head of Matrouh Governorate executive council and elected representatives of the local communities. The role is to coordinate implementation process, review and approve annual work programs with budgetary allocations. It meets once a month.

Participation Approach

Because indigenous knowledge is very important in the implementation of development programs, especially in the tribal areas, the project has utilized the existing tribal structure and traditions of the society in the area to develop an effective mechanism to encourage active participation by the local Bedouin community in the sustainable management of their natural resources base and in alleviating rural poverty. The local community (LC's) represented the basic social coherent planning unit for planning and development, and for the implementation mechanism and means for optimum use of resources is the Community Action Plan (CAP). This has ensured that all the planning, selection of activities and the delivery of services are all in harmony with traditions and values of the Bedouin community. The CAP matches project interventions of resource management with socio-economic development activities according to the needs of the LC's. It guaranteed the effective beneficiary participation and equity in distributing the benefits.

Preparation of the CAP

A preliminary household survey was conducted at project initiation to determine tribal structure, identify the targeted local communities, Bedouin population and their resources. Based on the geographic location, tribal affiliation and numbers of households, the project area was divided into 38 local communities.

Each local community (LC) members selected 7 – 9 active members/representatives, constituting the community groups (CG), and its members were trained on the participatory concepts and planning methodologies. The local community groups (CG's) developed drafts of the CAP's, with the technical support of the project staff. The draft CAP's were discussed and finalized for technical viability as related to available resources, and for socio-economic feasibility. Finally, CAP's are contracted for implementation in three years with the local community representatives in public ceremonies.

Project Components & Achievements

The following is the summary of project achievements during the period from 1994 to the end of March 2002.

Project Management

i. Project Management has realized distinguished achievements, reflected by enhanced implementation of all project components, and by satisfaction of local communities. The project management has efficiently utilized project funds. Fund disbursement from IDA contribution reached 99.9% by the end of August 2002 (92.8% is spent on investment). The project is fully staffed (248 seconded and contracted members, 5 PhD, 6 M.Sc., and 81 B.Sc. holders, 40 technicians and 116 auxiliary staff) and vehicles and needed equipment were procured.

ii. Infrastructure required for efficient project implementation was established including the Adaptive Research Center, the Training Center for Rainfed Agriculture, 6 Sub-Regional Support Centers, and 15 Social Development Centers in addition to re-innovation of 35 one-class schools. An effective monitoring and evaluation system was developed, including data basis and GIS for mapping project activities and monitoring and evaluating the implementation process. Five automated meteorological stations and 10 rain-guages were established.

iii. More than 16300 man-days (m/d) of local and 1500 m/d of overseas training for staff and beneficiaries were implemented, in addition to extensive on the job training. Over 3000 m/d of TA were efficiently managed for effective implementation.

iv. Thirty eight Community Action Plans were prepared by the community groups supported by project management staff, reviewed and approved by PCU and PCC and implemented in the 38 local communities.

v. The innovative managerial and operational model was developed and adopted based on bottom up planning and community based participatory approach; farming system approach to research and technology transfer; and the integrated watershed management approach to sustainable resource management. The model is still developing and needs augmentation.

vi. International Conference on biodiversity was held in March 1999 in addition to the Regional conference on Rainfed Agriculture in Arab Countries in March 1998. Regional workshops on range management and improvement, integrated watershed management, participatory planning, development of drylands and CDD were conducted in the project during the last three years.

Development Activities

The following activities were implemented mainly through the implementation of the Community Action Plans (CAP's):

A. Water Management and Soil Conservation

i. Improvement of structures design was implemented for cost saving, structure stability and more water storage and use efficiency. New techniques of water harvesting were introduced and an extensive program of workshops and field days on water purification techniques and maintenance of structures were carried out for improving awareness and skills of the local communities.

ii. The approach of integrated watershed management has been introduced and implemented as a planning tool for sustainable resource management and for avoiding potential social conflicts on runoff water rights as development in upstream areas can adversely affect downstream areas. Contour surveying and mapping, soil characterization, delineation of catchment areas and hydrological assessments were carried out for 64 wadis and works have been completed in 36 wadis with a total of 217000m^3 of structural works. Soil conservation activities were carried out to protect the wadi tips for reducing sediment transport on rangelands, reseeding of 2161 feddans by perennial species and the planting of 64 km of shelterbelts for protecting soil surfaces.

Table 2. Activities implemented through Community Action Plans

Activity	Numbers	Total	Total Area	Beneficiaries
Cisterns	8000	1.25	--	8000
Reservoirs	423	81000	--	423
Dykes	5109	435000	5620fds	5109
Drip Irrigation			--	
Watersheds:				
Dykes	36 wadis	177455m^3	19717 fds	
Reseeding			1600 fds	
Tree Belts		10km	100 fds	150

Table 3. Approaches used in planting fodder trees and shrubs

Activity/Approach	Shrubs Planted (million)	Area (feddan)	Beneficiaries
Small non-fenced areas	2.9	8212	2997
Large fenced areas	3.12	6250	250
Interplanting on barley fields	0.3	6750	965
Total	6.32	21212	4212

B. Range Management and Improvement

i. A total of 12000 kgs of indigenous seeds were collected, multipulated and distributed to the local communities' members.

ii. Providing support for the establishment of 16 small nurseries (48 privately owned plastic houses) for the production of fodder shrubs and tree seedlings in the local communities.

iii. The planting of 6.32 millions of fodder trees and shrubs for increasing the supply of cheap forages, availing green forage materials in the summer time and reducing dependence on costly concentrates.

iv. Introducing new forage species; 47 feddans of spineless cactus in 82 locations (80 beneficiaries).

v. Reseeding of 2485 feddans of deteriorated communal rangelands by perennials.

C. Adaptive Research

i. Major farming systems were characterized for problem identification. Adaptive Research programs in different areas were implemented on 33 permanent sites and on 119 fields distributed in the three agro-ecological zones of the project area. Test proven recommendation on over 40 major topics/problems were developed and disseminated in collaboration with extension and other units of the project and with participation of the local communities.

ii. Research results and achievements were documented and publicized by means of 27 research papers and reports, contribution to 15 technical extension bulletins, 8 news messages to local newspapers and participation in 28 local and overseas scientific conferences and workshops.

D. Extension

i. The project has established its extension system that is well staffed, equipped and integrated in its activities with all project components. A variety of extension methodologies, technologies and approaches were used, focusing on field demonstrations (406) and field days (993), training farmers (8250 beneficiaries) and utilization of Multi-media audiovisuals techniques and outputs in addition to the daily and weekly radio programs (560 hours). A total of 110 extension technical bulletins were produced on range/livestock, horticulture, and crop improvement and a total of 49000 copies distributed and four video films were produced. The project mobile communication unit has strongly contributed to the dissemination of information and extension messages.

ii. Improved barley varieties (Giza 126) were introduced in 10000 feddans for demonstrating the disadvantages of barley mono-cropping and the benefits from introducing food and feed legumes in rotation with barley. Participatory barley selection by farmers was introduced as a new methodology for barley breeding on 8 sites in all agroecological zones.

iii. In the area of animal husbandry, the project introduced the early weaned lamb fattening at 2 months age using recommended feeding and health care, urea treated straw, fodder shrubs and new feed resources (olive pulp). Rotating ram technology was demonstrated on 15 sites to maintain proper genetic characteristics.

iv. In the area of horticulture, improved management practices (pruning, fertilization, supplemented irrigation and IPM) were introduced in 15 fig farms, 12 olive farms, and 4 grape farms in the project area. In addition, the planting of 80180 fruit trees (driable figs, olives, grapes, apple, and carob) for demonstrating and enhancing the establishment of orchard farms. Improved management practices were demonstrated to improve vegetable production (melon, mint and others).

v. New activities were implemented for the first time in the area such as the planting of jojoba (44 feds, 24 beneficiaries), date palm plantations (1300 trees, 65 beneficiaries), and bee keeping (135 beehives, 27 beneficiaries).

E. Women in Development

Bedouin women have an important economic role in the project area. They not only participate in all aspects of resource development and conservation, farming and livestock production, but are also involved in non-agricultural income generating activities in addition to household management and social responsibilities. The following are the achievements:

i. Literacy education is a very important activity of good social impact; education of 159 classes of 6500 girls; rehabilitation of 35 old schools in rural areas, construction of 15 social centers (each with two classrooms for boys and girls and other facilities) and the establishment of 5 libraries (one on each SRSC).

ii. Improving nutritional conditions by the establishment of 1520 home gardens to produce vegetables on small areas (250 m^3) for home consumption and improving diet balance.

iii. Sanitary conditions by supporting the establishment of 2502 latrines in the project area.

iv. Health improvement and environmental awareness (2920 women); by conducting 78 training courses on fig jam processing (1112 women); 49 courses on olive pickling (669 women); 165 courses on home gardening (1500 women); 66 workshops on health awareness (1630 women); 24 sessions to enhance environmental awareness (443 women); and 18 courses on handicrafts skill development (498 women).

v. Supplying 11000 seedlings of trees for 2967 women to provide shade and fruit for household consumption.

vi. Small in kind credit to support establishment of income generating activities:

- 1000 gas ovens were provided to women to reduce firewood cutting and use and for relieving women from walking long distances in search for firewood and subsequently saving many hours a day.
- 870 hand water pumps (40% grant and 60% loan).
- 585 credits for poultry production with an average of LE 150.0.
- 26 loans for raising goats.
- 169 widowed women were supported to establish water storage facilities close to their houses to save time and efforts.

vii. Establishment of women NGO, bank account opened, management board formed and the mission, mandate and operational regulations defined. The major role is to facilitate marketing.

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7

Integrated Watershed Management Approach - The case of the Marginal Drylands of North West Egypt

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Overview of the Project

Bedouins' settlement, rural development, and urbanization have increased the pressure on the fragile resource base of the coastal marginal drylands in the Northwest Coast of Egypt, creating a cycle of natural resource degradation and poverty. The Matruh Resource Management Project (MRMP), with technical assistance from ICARDA and participation of local communities, has employed holistic approaches to break the degradation cycle and alleviate poverty. This paper presents MRMP/ICARDA experience in employing the "integrated watershed management" approach to sustainable resource development. Basic concepts and methodologies were highlighted, and its application on Abou Grouf watershed was exemplified. Based on land use planning, rainfall/runoff analysis and crop water requirements, the water balance of the watershed was assessed, and options of resource use were identified and evaluated. Due considerations were given to water rights, equity, and environmental needs.

The water balance analysis indicated that available water resources of Abou Grouf have already approached full development. It however, showed a water surplus of 265,400 m^3 and 151,200 m^3 in wet (probability=20%) and normal years (p=50%), respectively; but, in a dry year (p=70%), when appropriate interventions t are planned, the annual runoff matches the irrigation water requirements of the developed downstream areas of the watershed. Further, new developments in the upper watershed would adversely affect the orchard areas downstream, probably provoking social disputes. Therefore, only limited water-related developments should be considered in the parts of the watershed contributing runoff water to the developed downstream areas. Significant improvements of agricultural production in Abou Grouf watershed could be achieved by adopting improved farming technologies, and by improving the efficiency of the use of already utilized resources. Natural resource assessment, development and conservation interventions in marginal drylands, should be planned and monitored at the watershed level. This is essential for the resource productivity and agricultural production to be sustained, and to ensure equity, social peace and environmental protection.

Background

The Bedouin communities in the Northwest Coast (NWC) of Egypt have developed indigenous knowledge, skills, and resource management practices, which maintained, for ages, the ecologically balanced systems in a harsh semi-desert environment. They have also developed drought-coping strategies, traditions, and a lifestyle that had sustained their livelihoods, and maintained equity and social peace between and within the Bedouin tribes. However, the settlement of Bedouins and the rural development implemented in the last few decades on the marginal drylands have transformed the traditional pastoral systems to sedentary agriculture. This transition, together with urbanization and aggressive intrusion of the tourism industry, and the drive for modernizing the Bedouin lifestyle have exacerbated the pressure on a resource base, intrinsically known for its fragility and low productivity. Vast areas of rich vegetation were damaged, overgrazed, and/or cultivated. Biodiversity was eroded, and natural habitats and ecological systems degraded and poverty increased. Recently, new developments in upstream areas of some watersheds have badly affected rainwater runoff to old well-developed downstream areas, resulting in conflict that threatens social peace between and within the tribes.

The International Center for Agricultural Research in the Dry Areas (ICARDA) was contracted (1996-2001) to provide technical assistance to Matruh Resource Management Project (MRMP), that was established to break the degradation cycle and alleviate poverty in vast area (about 20,000 km^2) in the North West Coast (Figure 1). The project (1995-2002), co-financed with US$ 29.6 million by the World Bank, the Government of Egypt (GOE), and beneficiaries, was a resource management and rural development project with a strong base of adaptive research and technology transfer program. The technical assistance was provided for project components: soil and water management, the adaptive research for crop, range and livestock improvement, extension, human resources and social development, and the project management. The GOE and funding agencies (WB, IFAD, and GEF) have supported this successful project by extending the project to a second 5-year phase, with tentative funding of US$ 50 million.

Constraints to Resource Development

The project was challenged by a number of biophysical, socioeconomic, policy and institutional constraints. Rainfall, the principal source of water, is low and highly erratic, with annual long-term average of 145 mm at the coast that declines rapidly as one moves in-land. As rain occurs mostly in a few heavy storms and as a consequence of the existing topography and physiography, suitable conditions arise for active runoff and for the implementation of water-harvesting technologies. Arable land is scarce (less than 10 % of the total area) with low cropping intensity and diversity (mainly barley, with some fig and olive trees). Soils are poor and eroded, and rangelands are highly degraded. Crop yields are very low, averaging 700 kg/ha for barley and 50 kg/tree for fig (two major crops in the NWC). Crop and livestock yields are highly variable, with little potential for improvement. Infrastructure and public services (credit, marketing, transportation, health, education, etc.) are inadequate, and employment and economic opportunities are scant, so that the population is among the poorest and less advantaged in the country.

Research and Development Approaches

MRMP, in collaboration with ICARDA and with the participation of the Bedouin community, has employed holistic, multi-disciplinary, and multi-institiutional integrated approaches to achieve its objectives. These are (i) the integrated watershed management approach, dealing with the whole watershed as the physical unit for resource development; (ii) the farming systems approach to research and technology transfer, considering the whole farm as the unit for agricultural development; and, (iii) the community action planning approach to rural development.

In this paper, we present MRMP/ICARDA experience in using the integrated watershed management approach for promoting technologies that effectively contribute to sustaining the natural resource base and to the alleviation of poverty.

Integrated Watershed Management Approach: Concepts and Methods

The objective of implementing the integrated watershed management (IWM) approach to resource management, in marginal drylands, is to achieve optimal utilization of scarce resources (water, soil, and vegetative cover) for sustainable improvement of productivity and livelihoods, and for environmental protection. These goals might be achieved through the establishment of appropriate land use systems that considers the peculiarities of each watershed, the interests of farmers and communities, and development options that optimize resource use while minimizing detrimental effects. The approach is relatively new, and its theory and application is still evolving. Therefore, it would be useful, before presenting its application in MRMP, to briefly introduce some basic concepts and methodological procedures of the approach.

Concepts and Definitions

The watershed concept: A watershed is defined as the entire land area, determined by topography and natural boundaries that drains water to a certain drainage outlet point of this area. Hydrological boundaries/water divides constitute the outer borders of the watershed, within which all the elements of development should be considered as part of the integration process (this includes people, natural resources, institutions, and policies, etc.). A watershed is conceptually and practically made up of two parts, the catchment's area where rainwater runoff is generated, and, the target areas where runoff is utilized. A watershed might also be consisted of sub-watersheds, or sub-sub-watersheds, each draining to a specific outlet, but all draining to the main outlet point.

The integration concept: A watershed is a naturally balanced complex of biophysical and socioeconomic components integrated by mutual relationships and interactions. The development or alteration of any part of the watershed may have consequences on other parts of that watershed. Development interventions of interest to upstream communities might affect the interest of downstream communities, and improvement in the production of one farm/ farming system might be made at the expense of other farms/ systems. The balance becomes even more critical at advanced stages of development, and in many cases imbalanced actions have resulted in conflicts between beneficiaries. Thus, to ensure sustainability and social equity, development actions should consider existing and probable interactions between and within the different biophysical and socioeconomic elements of the watershed as a consolidated resource management unit.

The basic concepts of the approach: Contrary to traditional, random and piecemeal development activities, the IWM approach considers planning the activities for the watershed as a consolidated biophysical and socioeconomic unit for development. The approach is holistic, multi-disciplinary, community-based and participatory. It combines natural resource development and conservation, with agricultural production, and social development in a balanced framework according to resource availability in the watershed, actual and potential resource use, and peoples' attitudes and aspirations to improve their livelihoods. The approach combines qualitative and quantitative analyses of resources (land, climate, plants, animals, humans) to assess development potential. It necessitates effective collaboration between research institutes, extension, development agencies, and other stakeholders. Participation of targeted communities in all stages of the approach is imperative to ensure sustainability and acceptance of interventions.

Methodology

Water, in the drier environments, is the most critical element in watershed management, and is emphasized in this paper. Water in the watershed is allocated between various uses, based on people priority allocation; human use first, followed by livestock, then agricultural use. Many criteria are considered in water allocation. Such factors are land topography and hydrology, soil characteristics and crop-water requirements, existing water rights and equity considerations over the watershed, environmental protection needs, and economic return per unit of water.

Application Modules and Procedure

The IWM approach is based on modules for watershed appraisal, planning, and implementation of development and conservation measures, and for monitoring and evaluation of outputs and outcomes. It is implemented through logical steps, as follows:

1. Determine watershed boundaries and area using topographic maps, satellite images, and field verification techniques;
2. Characterize the biophysical and socioeconomic features of the watershed;

3. Set a land use plan, based on the biophysical and socio-economic characteristics of the watershed;
4. Assess the hydrological situation and calculate the water balance of the watershed, based on land use planning and rainfall/runoff analysis;
5. Identify and evaluate alternative resource development and conservation options, in consultation with communities concerned for decision-making and implementation of best options. Due considerations should be given to existing developed areas, water rights, equity, and environmental protection needs;
6. Contract the beneficiaries for implementing the development works, preferred to be done by local contractors, and most preferably by the beneficiaries concerned;
7. Supervise and follow up implementation of the contracted works; and
8. Monitoring and evaluation of outputs and outcomes

Methodological Constraints

The application of the IWM approach faced difficulties; some are severe indeed such as:

a) Lack of local expertise, especially on how biophysical and socioeconomic elements can be integrated in watershed planning, and how the multi-disciplinary/ multi-institutional teamwork can be done efficiently;
b) Lack of basic data essentially needed for applying the approach, and especially those related to rainfall/ runoff assessment and water balance analysis; and
c) Community issues related to facilitating effective participation, and ensure respect and adherence to the IWM plan when conflicts of interests arise between individual beneficiaries, and/ or communities, or tribes.

Application of IWM Approach on the Abou Grouf Watershed

The project area includes 218 watersheds and sub-watersheds of variable conditions. An NRMP/ICARDA multi-disciplinary team has used, with participation of local Bedouin communities, the IWM approach on a number of these watersheds. The team consisted of international experts in hydrology, water harvesting and water engineering, land use planning and soil conservation, and socioeconomics, supported by project experts (soil and water, crop and horticulture production, range, and GIS). Abou Grouf watershed, representing many watersheds at a critical stage of development, was deliberately chosen to elaborate the crucial necessity of using the IWM approach for attaining sustainability, and avoiding probable social disputes.

Abu Grouf provided a unique and challenging opportunity for IWM planning. The population comprises several local communities of different tribes. Water resources were at near-full development stage, and already developed orchards in wadi downstream and coastal plain utilize most of the runoff water. However, households that do not have trees, mostly located at catchments upstream, have initiated development works that affected the water supply to the orchard area, threatening its sustainability and creating a water right and social disputes. The situation has been worsened by barley cultivation of a huge area, traditionally used for runoff generation. It is a project strategy to respect the already developed areas, and not to impose different land uses even if recommended by resource assessment, unless otherwise were accepted by the concerned beneficiaries.

Characteristics of the Abou Grouf Watershed

Location, and resources: Abou-Grouf watershed is located about 50-km eastern to Marsa Matrouh city, capital of the NWC region. It is bounded by the Mediterranean Sea to the north, and the Saharan desert to the south. The total area of the watershed is 21.5 km^2. The cultivated area is around 200 ha, of which 155 ha planted to fig, 13 ha to olive, and 32 ha to barley. Average yield is 26–39 t/ha for fig, 2–3 t/ha for olive, and 0.6–0.9 kg/ha for barley. The population is 3150 (484 household/ family) belonging to 46 extended families 'aila', 8 sub-tribes 'bait', and 4 main tribes "qabiela". The total livestock is 615 sheep and 250 goats. There are 99 dug-cisterns, 5 cemented-reservoirs, and 248 small dikes (196 earth, 44 dry stone, 8 cemented stone).

Geo-morphological characteristics: The watershed can be divided into three zones. The plateau zone is the upper catchment area (about 13.5 km^2), the escarpment zone (4 km^2) is the middle part, and the (4 km^2) coastal plain is the lower terminal downstream of the watershed. The runoff from the watershed discharges into the sea after crossing the Matrouh-Alexandria highway. Many small channels exist in the upper catchment, which converge to one deep wadi in the middle reach, and open out into a wide shallow channel and ultimately to the coastal plain. The altitude difference between upper and lower catchment area is about 150 m, with rapid drop in the middle part from 130 to 75 m. Geo-morphologically, the watershed can be divided into two main zones:

1. The coastal and escarpment: extends to 4.5 km from the sea. Its elevation varies from zero at seacoast to around 125 m above sea level. The coastal area, extends around 3 km from the sea, consists mainly of active white sand and coastal dunes on the sea, followed by alluvial plains sloping gently towards the sea. The escarpment zone, 3 km from the sea to around 4.5 km, is mainly comprised of bare soil and stratified stony bedrock. It is steep, hilly with rolling topography, and sparse range. It consists of a narrow (1.5 km width) sloping area characterized by variable slopes (1% at the coastal plains up to 22%). The drainage network is densely developed in the upper parts of the escarpment zone that drain into the main Abou-Grouf wadi and a number of short secondary wadis. The outlet of these wadis ends in the coastal plain. Runoff irrigation is mainly developed at the northern end of Abu-Groof wadi floor and in the coastal plain where around 70 ha of irrigated land is planted with fig and olive trees.
2. The plateau: extends 4.5 km from the sea to approximately 9 km. It is mainly formed of a large hill (4 × 1.5 km) surrounded by a shallow depression. Hillside slopes average 5%, and hill elevation reaches 160 m. A small drainage system comprised of small wadis is developed on the northern side of the hill, which forms part of wadi Abou-Grouf drainage system. Gravels are generally dominant with bare rocks at a few locations only, and alluvial soils in depressions. Barley is cultivated in the depressions, in addition to a few isolated orchards, and rangelands of a variable density occupy about 50 % of this zone. Sheet erosion is common. The drainage capability is fair to moderate due to a number of depressions. At the far southern part, contouring tracks, roads, and depressions caused runoffs

generated on about 6 km2 to drain to another adjacent watershed. But, during exceptionally heavy events, this area may partly drain into the mainstream of Abou Grouf watershed. Therefore, this area was included in the watershed for flood estimation purposes and for planning of areas in depressions, but not for water availability for downstream areas. Barley is cultivated in the depressions, a few isolated orchards, and rangelands of a variable density occupying about 50 % of this zone.

Agro-climate

The climate in Abu Grouf is arid Mediterranean, characterized by dry warm summer, and mild cool winter. Rainfall is low and extremely erratic with most precipitations occurring on October-March. Rainfall distribution is very irregular and occurs as isolated storms. Rainfall amounts and analysis are presented below. The variable rainfall distribution governs agricultural activities, and restricts the development of profitable farming system. Wadi Abou Grouf is located within the first and second climatic zones. The precipitation and air humidity increase towards the coastal plain in the north. The climate pattern is reflected by plant distribution, where fruit trees are found towards the north, and rangeland towards the south. Barley is cultivated in the first and second zones where water and soil conditions are not suitable for fruit trees.

Topography

Different landforms occur along a South-North transect in the watershed. The first is the plateau flat area, which serves as a runoff-generating area. This area is large enough and included flat areas where water accumulates and better soil conditions exist. The second landform is rocky steep slopes, with practically no soil, and is a good source for runoff. The third landform is the back slope positions where sediments, carried by water erosion, accumulate from upper slopes. Soil depth is a function of slope steepness, and generally increases as one moves away from the steep surface. The fourth landform is the toe slope, which occupies a middle position between the back slope and the flat bottomland. At this position, the soil becomes deeper and has finer soil texture. The fifth landform is the flat land where the slope is minimum, soil depth is at maximum, and soil texture is the finest. The soil depth-slope variations along the described transect, coupled with climate characteristics, control soil properties and plant-land suitability.

Land Use Analysis of Abu Groof Catchment

The project covers a large area, and conventional land use assessment, based on detailed soil surveys, is time consuming and costly. In practice, resource assessment had to meet the project's immediate developmental objectives that necessitated immediate decision-making on land use. Hence, a rapid characterization and assessment of current and potential land use was carried out in the field. Land map units were specified according to topographic position, slope, soil texture and depth, stoniness, vegetation cover, erosion characteristics, and laboratory data, when available.

Soil analysis of different rangeland, barley, and fruit tree areas indicated that soils, regardless of the location, are calcareous with low clay and variable, but high sand contents. Soils are generally very low in organic matter, available P and K. Fertilization with NPK for orchards is necessary to maintain productivity. Manure, and/ or any form of organic residues is also needed for improving the physical properties of soils. Farmers in the project area, as is common in dryland farming, refrain from fertilizer use due to the cost and risk involved. The project has however promoted technologies to improve soil fertility, such as alley cropping of legumes in orchards during wet years, introducing legume crops in rotation/or in mixture with barley, inter-planting fodder shrubs and shrub planting on range.

Current land use differs largely between the different parts and hydrological sub-systems of the watershed. In the coastal plain, orchard (fig and olive) covers nearly 35 % of the area, indicating availability of adequate water supplies, and fertile and deep soil. The orchard area decreases in the escarpment, as it is confined mainly to the southern part of wadi Abu-Grouf. Some orchards are also observed on the 'isolated' part of the plateau. Sparse range occupies 50 % of the lower part of the escarpment and the plateau. Barley is grown on land depressions (hataya), which also include some isolated orchards. More barley has been grown on marginal flat lands at the expense of range area and runoff generation and flow. Vast areas in the plateau and the escarpment's upper part, mainly comprised of bare soils and rocks, generate runoffs used elsewhere in the watershed. Erosion and overgrazing had substantially reduced plant cover and palatability, and good vegetation is only observed alongside the waterways.

The potential land use is primarily determined by soil properties and productivity, while within the project context, the recommended use of a land unit might additionally be based, on runoff-related factors. Such factors are given priority in determining land use due to the interdependent effects of runoff generation, flow, and use between watershed units. Based on determinant factors above, land units were identified and specified for recommended uses (see Table 1).

Table 1. Summary of potential, and recommended land use for the map units

Map Unit	Potential Land Use	Recommended Land Use
1	None	Catchment
2	Poor	Catchment
3,3A	Poor-moderate range	Catchment/ improved range
4	Shrubs	Catchment/ improved range
5	Fruit trees	Fruit trees
6	Shrubs	Range and housing
7	Fruit trees	Fruit trees
8	Fruit trees	Fruit trees
9	Poor range	Catchment
10	Range	Catchment
11	Very poor range	Catchment
12	Poor range	Catchment
13	Very Poor Range	Catchment
14	Range	Improved Range
15	Very Poor Range	Catchment/ improved range
16	Poor range	Catchment
17	Fruit trees	Fruit trees, Acacia
18	Fruit trees	Fruit trees, Acacia
19	Poor range	Catchment
20	Fruit trees	Fruit trees
21	Very Good Range	Catchment / improved range
22	Very Poor Range	Catchment / improved range
23	Fruit trees (figs)	Catchment
24	Very Poor Range	Catchment
25	Range	Catchment
26	Barley, Range	Barley improvement

Hydrological Assessment

The hydrological study aimed at assessing the hydrological situation (water balance) for identifying water development potential of the watershed. The assessment required detailed information on rainfall (volume, distribution, and storm intensity, etc.), runoff coefficients, the area, and the topographical and geo-morphological characteristics of the watershed, and current and potential land use. Soil characteristics and suitability for different uses, crop-water requirements, and conserving already developed areas in the coastal plain and wadi floor should also be considered. Location specific information on some of these factors, especially as related to rainfall, runoff coefficients, and crop-water requirements were lacking. Data developed in other areas, of similar environments were used after some modifications, based on experience, intuition, and common sense of senior experts of the study team.

Hydrological systems: Abou Grouf includes a waterway system connecting the different gullies in the watershed. Four hydrological sub-watersheds/ sub-systems that affect the water budget balance over the catchment were identified:

1) An isolated system (sub-watershed I) in the southern side of the watershed comprised of the southern part of the plateau hill, and large depression of 4 km by 2 km. This system has very limited contribution to runoff flow to the wadi;
2) A main system (sub-watershed II) includes the northern side of the plateau hill and main wadi drainage system. It is the largest hydrological sub-system, and runoffs generated in this sub-system are the main water source for orchards in the coastal plain;
3) A set of 6 small wadis (large gullies) of different size (sub-system III) developed on the escarpment surface. Runoff water generated in these wadis flows also downward, supplying water to the coastal plain; and
4) An isolated and small hydrological system (sub-watershed IV) constituted of small wadis at the west-northern part of Abu-Groof watershed. Runoff water generated in this system ends also in the coastal plain.

The hydrological situation (water balance) at the watershed was estimated (presented below) for the four hydrological sub-systems using the « cell » principles. The area of each sub-system was divided into a number of cells which have common characteristics in terms of surface slope, land cover, and rainfall amount.

Rainfall Analysis: the closest meteorological station is located in Marsa Matrouh airport, some 50 km western to Abou-Grouf. The long-term (1944-1992) annual average is around 145 mm with minimum and maximum values of 50 mm and 275 mm, respectively

(SD 65 mm, and CV 46 %). A frequency analysis of the long-term annual rainfall records was performed using the log-probability law and the empirical equation. Rainfall distribution over the watershed area was done by applying a reduction coefficient on the annual rainfall amount as a function of inland distance from the seacoast (Rigner, 1998). Based on the above assumptions, annual rainfall amounts for different probabilities, in the center of the main zones of Abu-Groof watershed were estimated (Table 2). The annual rainfall for a given value of probability (p) for a given cell was obtained from the related isohyetal map developed, using Rigner's assumptions.

Table 2. Annual rainfall amount (mm) for various probability of non-exceedence

Zone	P = 20 % (Wet year)	P = 50 % (Normal year)	P = 70% (Dry year)
Coastal zone	175	145	97
Escarpment (upper)	163	133	93
Plateau	150	120	85

Annual Runoff: the rational method was used to estimate the annual runoff volume. The rational method is expressed by the equation:

$$R = 10^3\, C.P.A \qquad \text{.......................................(1)}$$

where: R is estimated annual runoff volume (m^3), C is annual runoff coefficient, P is annual rainfall (mm) and A is watershed area (km^2)

Runoff volume (R_i) generated in each cell for probability 'p' is estimated by equation (2):

$$R_{i,p} = 10^3\, C_{i,p}.P_{i,p}.A_i \qquad \text{.......................................(2)}$$

where $C_{i,p}$ is average runoff coefficient of the cell 'i' for probability 'p', $P_{i,p}$ is average annual rainfall (mm) over cell 'i' for probability 'p'; and A_i is area (km^2) of the cell 'i'.

Annual runoff volume for the whole sub-system is estimated using the equation:

$$R_p = \Sigma\, R_{i,p} \qquad \text{.......................................(3)}$$

Runoff coefficient ($C_{i,p}$): Data on runoff coefficients were lacking, and the project, supported by ICARDA, has initiated experiments for this purpose. However, relationship between rainfall and runoff coefficient as observed in some West African watersheds, of biophysical conditions similar to Abou Grouf, was used. These areas receive annual rainfall of 100 – 200 mm, the land cover is similar to that of Abou Grouf's, and mean slope of approximately 0.5 %. The effect of slope of the various cells on runoff coefficient AC≅ was considered using the correction factor ($C_i/C_{0.5\%}$) as a function of the land slope (Rodier and Robstein, 1988 cited by Wakil et.al, 2000).

The runoff coefficient C_i for a given cell is obtained from the equation:

$$C_{ip} = C.C_i/C_{0.5\%} \qquad \text{...(4)}$$

where C is determined from the West African relationship curve according to the annual rainfall value over the cell area for a probability 'p', and to the type of the cell land cover.

Annual runoff estimation: Annual runoff generated in the cells of the four sub-systems was calculated for three values of "p" 7o%, 50% and 20% by applying equation (2).

Irrigation Water Requirement of the Coastal Plain: irrigated area in the coastal plain was estimated at 70 ha. Irrigation water requirement of this area is given by the equation:

$$I_r = A\ (C_w - P_e) \qquad \text{...(5)}$$

where I_r is the irrigation requirement (m^3), C_w is crop water requirement (mm) estimated at 500 mm, P_e is average effective rainfall (for C=0,70; C is the reduction coefficient) and A is irrigated area estimated at 70 ha.

And, the estimated irrigation requirements for the irrigated area in the coastal plain for different value of probability 'p' are given in Table 3.

Table 3. Estimated irrigation water requirement in the coastal plain

Probability (p)	Rainfall (P) (mm)	Effective Rain (P_e) (mm)	($C_w - P_e$) (mm)	Irrig. Requirement (m^3)
20% (wet year)	175	122.5	378.5	264 950
50% (normal)	145	101.5	398.5	278 950
70% (dry year)	97	68	432	302 400

Water balance analysis: The water requirements of the already developed area in the coastal plain and wadi floor should be satisfied prior to any further development at Abou-Grouf. Table 4 presents the water balance situation, assessed for three values of " p" 70%, 50% and 20%, by subtracting irrigation water requirement of the 70-ha orchard area from the estimated annual runoff generated in sub-systems II and III (sub-system I was not included as it contributes to the main wadi and coastal plain only partly, on occurrence of very heavy storms). Although there is a runoff surplus in wet and normal years, but in dry year (p= 70%) the annual runoff is in a critical equilibrium with the water requirement of already developed area.

Table 4. Estimated annual runoff and irrigation requirement in the coastal plain

Probability (p) (%)	Runoff Water (m^3)	Irrigation requirements (m^3)	Water balance (m^3)
20% (wet year)	521 390	264 950	+ 256 440
50% (normal)	430 120	278 950	+ 151 170
70% (dry year)	294 302	302 400	- 8090

Community Participation

Community participation in IWM was facilitated through an operational model based on decentralized management, multi-disciplinary teamwork, and community-based action planning. The project area was administratively divided into 5 sub-regions, with a Sub-Regional Support Center (SRSC) was established on each. The population was grouped by tribal affiliation and geographical considerations into 38 local communities (LC). Each LC has a Community Committee (CC) selected by its members to manage their affairs, facilitating a link between the community with SRSC and project management. Due to Bedouin traditions, restricting direct contact of men and women, the CC was accordingly comprised of two sub-committees. As facilitating units, the SRSCs were staffed and equipped to assist the CCs to formulate community action plans (CAP), based on R&D needs as identified by LC members. CAPs are then contracted for implementation. Membership in LC is optional, but requests from non-members were not considered.

Implementation of community participation for IWM was generally not easy as it represents new mode of thinking and operation. It took the first two years of project time to identify and apply proper methods and criteria for organizing the population into the 38 LCs, and to gain acceptance of the beneficiaries to make collective decisions and actions. Another 2-3 years were needed to complete the CAPs for the 38 LC. Intensive training (formal, and on-job) of project personnel and LC members was conducted on participatory approaches for setting the CAPs. The exercise was even more difficult under the complicated situation of Abou Grouf. Biophysically, water resources were near full utilization, and very limited choices were left for development at upstream areas. Socially, the households in the watershed were from different tribes, and they were affiliated to 3 LCs, with two of these LCs have their land resources overlapped with neighboring watersheds.

Development Options

Following the completion of the land use and water balance analyses above, several meetings were held with the LCs inhabiting Abou Grouf watershed to explain the current situation, and developmental options.

The natural resources of Abou Grouf, especially water, have already approached near-full utilization. Except for the far isolated upstream area (sub-system I, not draining to the main wadi), further substantial water developments on other parts (sub-systems II, III, and IV) would badly affect the already developed areas and the livelihood of communities at the watershed downstream. But, households at the upstream areas of these sub-systems wanted to dike parts of the land and plant trees to support property rights and ownership claims. However, the options discussed were as follows:

Option 1: to continue random development on sub-watersheds II, III, and IV. This would lead to overuse and degradation of the natural resources, and to social conflicts between upstream and downstream inhabitants. (unsustainable option).

Option 2: to abide to the integrated watershed plan (sustainable option), which per-se does not include many alternatives due to the critical hydrological situation (no water surplus).

The plan suggested the following:

1. Substantial water development potential is feasible only on sub-system I, where new tree plantations, barley and rangeland can be developed. However, the water balance for this sub-watershed should be more precisely reassessed to quantify this potential.
2. Agricultural development on sub-systems II, III, and IV should be based on improved cultural practices and water management to enhance runoffs generation and flow and to improve water use efficiency on existing orchards, barley, and rangeland. Some new range development on specific sites (Table 1) could also be considered.
3. Cisterns are mainly used for human and livestock needs, and for horticulture if extra water was available. However, establishing new cisterns for producing small-scale, high-value cash crops were considered, provided that runoffs will not be affected significantly. A Few farmers have initiated this investment, but its technical and economic feasibility should be investigated. Research is also needed to identify the optimum mini-catchment area for the cistern under variable conditions, optimum supplemental irrigation strategies and practices, best cropping options, and farmers' acceptance and attitudes.
4. Soil conservation measures, proposed to protect land, were incorporated with range development, and were restricted to land units targeted for range improvement (Table 1). They were limited to protecting gullies' tips from backward erosion by filling the tips with stones to reduce water speed, but not to impede water flow.

Agricultural Production Improvement

As an integral component of IWM approach, new germplasm and cultural technologies for crop/range/livestock improvement were tested and adopted on the watershed. Crop improvement has focused on a new simple package of barley production (variety, small dose of phosphate, and a slight modification of tillage and seed rate), introduce vetch in rotation or mixture with barley, interplant fodder shrubs on barley, and incorporate new crops in the cropping system. New species of fruit crops were introduced, and cultural practices as well (pruning, fertilization, supplemental irrigation, harvest, and post-harvest handling). Range improvement was based on fodder shrubs (with and without fence), and direct re-seeding of annuals and perennials; and livestock R&D has focused on improved fattening regime, health, and nutritional aspects using local feed materials.

Assessment of Adoption and Impact

Rapid rural appraisal, farm surveys, and case studies (MRMP/ICARDA, 2000; MRMP/ ICARDA 2001, a and b) were used to assess adoption and impact of new technologies on productivity and income. Data were analyzed by SRSC, not by watershed, and data of El-Hekma SRSC was considered as representative to Abou Grouf. It was found that 85 % of farmers were benefited from crop improvement technologies. Adoption rates were 44 % for barley package, 35 % for crop rotations, 60 % for barley-vetch mixture, and 48 % for shrub interplanting. Most adopters increased yield by over 25 %, and some 10 % of producers gained 50 % or more of yield increases. Over 65 % of rangeland holders were benefited from shrub planting and reseeding technologies, reducing the feed gap by 25 %; and, some 50 % of herders increased their income by 30 %. Renowned for its orchards, the adoption of horticulture technologies in Abou Grouf was more impressive; improved pruning (85 % of farmers), pest control and harvesting (65 %), and only 30 % for supplemental irrigation (due to lack of water). About 65 % of fig and olive producers increased yield by 60 %, and farm income by 50 %. These figures might be higher than other watersheds, as Abou Grouf was privileged being a pioneer test and demonstration site, with extensive contact between project personnel and experts with its LCs.

Conclusions

The following experiences may be concluded from the work at MRMP:

1. Implementing community-based approaches for resource development is difficult and time consuming. This should be well recognized in the project design and implementation.
2. In organizing the population of a watershed, the social complexity, especially the overlap of resources on neighboring watersheds should be avoided, in order to avoid overlap between the community plan and the watershed planning.
3. It is emphasized that development and conservation of natural resources should be planned, implemented, monitored and evaluated at a watershed- level base. This principle becomes even more critical for marginal drylands at a relatively advanced stage of resource development.
4. When there are several authorities involved in developing the same area, difficulties arise in implementing the plans. It is thus preferable to have only one authority in charge of present and future development endeavors, particularly in the absence of strong linkages among various agencies operating on the watershed. Proper mechanism and legislations need to be identified to ensure abidance to the plan.

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8

Water Management in Egyptian Coastal Drylands

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Systematic Approach to Water Management in Drylands

General characteristics of Drylands

Drylands prevail in regions characterized by semi- to hyper-arid climate. They have special features that can be summarized as follows:

1. Large rainfall deficits and high spatial and temporal variability of rain.
2. Evaporation is very prominent in the hydrological cycle.
3. Only a minor fraction of the rainfall becomes runoff.
4. Base-flow rates are several orders of magnitude lower than the peak flow.
5. The hydraulic contact between surface water and groundwater is often via the unsaturated zone thus affecting groundwater recharge.
6. Groundwater and surface water fluxes are relatively small.

In the Arab region, drylands generally prevail in areas covered by *wadi systems*. The word system is used to indicate the interaction between the surface and the subsurface environments, including water and human.

Systematic Approach to Research & Development in Drylands

In the framework of UNESCO-IHP (V) activities, two themes have been identified for networking in the Arab region, namely, Groundwater Protection and Wadi Hydrology. Research priorities have been identified by the members of the two networks, among which "Systematic Approach to Research and Development in Wadi Systems" is one (UNESCO, 2002). Several main technical points specific to the conditions of the Arab Region have been stressed in the approach, including:

1. Definition and delineation of wadi flow systems and their relation to regional flow or deep groundwater systems (Attia, 1997).

2. Evaluation of wadi-bed transmission losses by undertaking infiltration experiments and measurement of vertical distribution of moisture content (using neutron probes or TDR technique).

3. Survey of lithofacies variations to define spatial heterogeneity, and upscaling point profile measurements.
4. Estimation of aquifer recharge by quantifying the relation between transmission losses and recharge, which needs data collection for the residual moisture in the unsaturated zone, evaporation losses and subsurface geology.
5. Measurement of stage and wadi flow in the upper, middle and lower reaches.
6. Periodic measurement of groundwater levels (deep and shallow).
7. Water sampling, and chemical and isotopic analyses for runoff, wadi aquifer and deep groundwater.
8. Design and installation of a permanent observation network to provide; long-term trends, estimation of water budget, estimation of recharge rates and determination of quality changes.

Recommended tools include, among others:

1. Research on wadi aquifer systems often requires data and information to help a proper assessment of recharge, flow, and quality. The use of remote sensing and nuclear tracer techniques are good tools in such studies.
2. Data on the groundwater use can be collected either by the responsible institutions, or by the water users (stakeholder), or both. LandSat imagery may provide appropriate information on land use and land cover.
3. Hydrogeologic mapping and vulnerability maps are good guides in such studies if properly developed from field measurements. The development of such maps should thus be considered part of the systematic approach for investigating and protecting wadi aquifer systems.
4. The process of scaling-up from point data to areal estimates of hydrogeologic variable is a complicated issue that needs considerable efforts by hydrogeologists. However, with the developments in hardware and software (e.g. GIS and numerical techniques), estimates of areal hydrogeologic variables can be improved, provided there are well-trained staff.

Importance of Drylands (Wadi Systems) to the Arab Regions: A general background

General Characteristics of the Arab Region

The Arab Region is a nearly continuous surface of land extending from northwest Africa in the west to the Arabian Gulf in the east. It is occupied by twenty two countries of which all of them are members of the Arab League and share the same language.

A large part of the region is situated in a transitional area between the equatorial and mid-latitude climates. As such, the warmest period of the year usually occurs between June and August. With the exception of the sea coastal strips and the tops of the few mountains, the climate in the Arab region is generally of the arid type. For most of the year many parts of the region are warm, relatively dry, and receive considerable radiation and bright sunshine. This results in high rates of evaporation and evapo-transpiration.

Water Resources in the Arab Region

Water resources which are common in the Arab Region can be grouped under four different categories: rainfall, stream flow, groundwater and desalinated water.

Rainfall -The annual precipitation on the Arab region is estimated at 2,220 billion m^3/year, or about 160 mm/year on average. Some parts are practically rainless, while others (very few) receive as much as 1,000 mm/year. A large portion of the precipitation is lost by direct evaporation.

Stream flow - Some of the streams traversing the Arab Region are perennial in nature, while others are intermittent or ephemeral. The perennial streams are those streams which never dry up. The water flowing in these streams is commonly produced by surface runoff. However, stream flow in the dry seasons can be sustained by groundwater. The ephemeral streams are usually called wadis. Wadis are essentially filled with water during, and shortly after, heavy rain storms. Appreciable base flow may occur in some cases. Most of the perennial rivers in the Arab Region are international rivers. Although carrying large discharges (e.g. The Nile, Euphrates), most of the perennial streams originate outside the Arab region. Wadi flows, on the other hand, may constitute potential fresh water resources, if properly managed (ACSAD, 1997).

Groundwater - Groundwater constitutes an important source of water for almost all Arab countries. It is reported that the replenishment of groundwater in the Arab Region is about 25% of the total surface flow in rivers, replenished from local rainfall within the frontiers of the region (ACSAD, 1997).

Desalinated water - The Gulf States Co-operative Council (GCC) has always been world leaders in using desalination for municipal water supply. Two-thirds of world installed capacity of desalination plants exist in these countries.

Main Issues of Water Management

The major issues facing water resources management in the region can be summarized as follows:

1. Aridity and continuous decline in per capita water share.
2. Uneven geographic distribution of water resources.
3. Rapid population growth, rapid urbanization, internal immigration and uneven settlement patterns.
4. Environmental degradation, including depletion of natural resources.

Environments of Wadi Systems in the Arab Region

Wadi systems commonly develop in three zones across the Arab Region, namely, *desert valleys, coastal plain, and intermontane plateau* areas.

Desert Valley - In typical Desert Valley environments, wadis are usually not vigorous enough to maintain their courses over topographic obstructions of volcanic or tectonic origin. Channel of a large number of wadis flowing in the interior parts disappear into sand dunes or in the vicinity of isolated outcrops. This normally results in the formation of close basins. These, in addition of having limited storage capacities, become a focal point for the accumulation of salts and their concentration in shallow sub-surface water through evaporation.

Coastal Plains - On the basis of the physiographic and hydro(geo)logic setting, Coastal Plains can be divided, into three types, namely, *Afro-Arabian Shelf, Afro-Arabian Shield and Areas of recent techtonism and volcanism.* In the first types (Afro-Arabian Shelf), aquifers may not be formed due to the hard surface of wadis, or, if formed, groundwater is subjected to sea water intrusion due to overexploitation. In the second types (Afro-Arabian Shield), potential aquifers are found with good potential of shallow groundwater. In the last type (areas of recent techtonism and volcanism), which are predominated by low lands located between the highlands and sea coastline, thick deposits (over 400 m) may contribute to the formation of extensive wadi aquifers with good reserve of groundwater.

Aquifers in Intermontane Plateau Areas - These areas are generally a result of inland accumulation of Tertiary basalt and associated materials from the prolonged eruption events related to the dislocation of Arabia and Africa.

Issues pertaining to Water Management in Egypt: General Background

Physical Setting

Egypt covers an area of about one million square kilometers. It is divided geographically into four regions:

(1) the Nile Valley and Delta, including El Fayum depression and Lake Nasser;
(2) the Western Desert, including the Mediterranean littoral zone and the New Valley;
(3) the Eastern Desert, including the Red Sea littoral zone, the islands and the high mountains; and
(4) Sinai Peninsula, including the littoral zones of the Mediterranean, the Gulf of Suez and the Gulf of Aqaba.

The most part of the country lies within the temperate zone, and the climate varies from arid to extremely arid. The air temperature frequently rises to over 40^0 C in daytime during summer, and seldom falls to zero in winter. The average rainfall over Egypt as a whole is only 10 mm/year. Along the Mediterranean, where most of the winter rain occurs, the annual average rainfall is less than 150 mm/year, decreasing rapidly in the inland. The evaporation rates are high, being in excess of 3,000 mm/year. The hydrography of Egypt comprises two systems; a system related to the Nile, and a system related to the rainfall in the past geological times, particularly in the Late Tertiary and Quaternary.

The Nile system comprises the Valley and Delta regions, which are morphologic depressions filled with Pliocene and Quaternary sediments. The other hydrographic system in Egypt is the complex network of dry streams (wadis), the formation of which dates back to past wet periods in the Tertiary and Quaternary. This system covers more than 90% of the surface area of Egypt, including the Western Desert, the Eastern Desert, and Sinai. The main catchment areas drain towards the Nile Valley and Delta, to the coastal zones, and to inland depressions.

The landscape in Egypt can be broadly divided into the elevated structural plateaux and the low plains, which include the fluviatile and coastal plains. These geomorphologic units play a significant role in determining the hydrogeological framework of Egypt. The structural plateaux constitute the active and semi-active watershed areas. The low plains contain productive aquifers and are also, in some places, areas of groundwater discharge.

Hydrogeological Framework

The hydrogeological framework of Egypt comprises seven main aquifer systems (Attia, 1994).

1. The Nile aquifer system, assigned to the Quaternary and Late Tertiary, occupies the Nile flood plain and desert fringes. The storage capacity of the system is about 500 million cubic meters. Groundwater is essentially replenished from activities based on Nile water.

2. The Nubian Sandstone aquifer system, assigned to the Paleozoic-Mesozoic, occupies a large area in the Western Desert, and parts of the Eastern Desert and Sinai. Its storage capacity is estimated at 20,000 mm^3, but groundwater is almost non-renewable.

3. The Moghra aquifer system, assigned to the Lower Miocene, occupies mainly the western edge of the Delta. Groundwater is

almost non-renewable, except for the portion located on the border with the flood plain which receives underflow from the Nile system.

4. The Coastal aquifer systems, assigned to the Quaternary and Late Tertiary, occupy the north and east coasts. Groundwater is found in thin lenses floating over saline water. The main recharge source is rainwater.
5. The wadi deposits, assigned to the Quaternary, occupy mainly the lower parts of wadis (both internal and coastal). They vary in thickness from few decimeters to tens of meters. The aquifer is recharged from rainfall and surface runoff during flash flood events.
6. The karstified Carbonate aquifer system, assigned to the Eocene and Upper Cretaceous, predominates essentially in the north-middle part of the Western Desert. It is essentially recharged through upward leakage from the Nubian sandstone.
7. The fissured and weathered hard rock aquifer system, assigned to the Precambrian, predominates in the Eastern Desert and Sinai. It is essentially recharged either from local rainfall (Sinai) or along its extension in Sudan.

Population Distribution

Egypt's population is estimated at 66 million (2000). About 63% of the population is concentrated in the Nile Delta area (including the city of Cairo and the coastal Governorates of the Delta), 36% in the Nile Valley (between Aswan and Giza), and the rest distributed among the remaining area of the country. This indicates that about 99% of the population is concentrated in over 11% of the physical area of Egypt. This situation results in: (i) a continuous pressure on the agricultural land and Nile water resources; (ii) a continuous degradation of land and water resources; and (iii) an unhealthy life style.

Alleviation of the pressure, especially in Cairo and the delta Governorates is a major concern of the Government. This dictates population redistribution, and initiation of new settlements and economic activities, in which non-Nile water will play an important role, if properly managed.

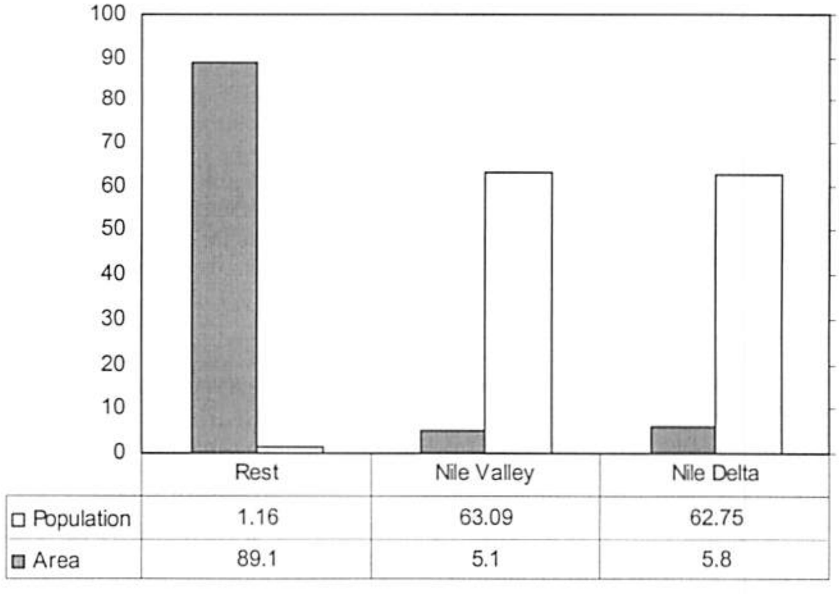

Figure 1: Population Distribution

Main Issues of Sustainable Development

The major issues facing Egypt sustainable development are summarized in Table 1. One of the means to rehabilitate the situation is by redistributing the population over the country physical area.

History of Water Management in Egypt's Coastal Drylands

Prevailing Water Resources in Coastal Drylands

The main sources of water in the regions occupied by coastal drylands include: (i) rainfall; (ii) flash floods; and (iii) groundwater (fresh and brackish). The characteristics of each source depend to a large extent on the land use style(s), the frequency and intensity of rain (season), harvesting and conservation practices and hydrogeological characteristics. In general, water management technologies are the main governing factors in the availability of water supplies in such regions.

Table 1. Summary of Issues Affecting Egypt Sustainable Development

Issue	Causes
Partial utilization of Egypt's territories	• Nile valley morphology and type of boundaries • Aridity and uneven distribution of water resources over the country
Unbalanced population distribution and continuous immigration from rural to urban areas	• Lack of regional plans and facilities/services to the rural community • Continuous decrease in job opportunities in the rural areas, especially in the farming sector
Lack of suitable potable water and sanitation in some regions, especially the rural ones.	• The economic condition of the country • Concentration of activities on the urban regions/governorates
Decrease of per capita agricultural land area and share in main food.	• Heritage and distribution of land among the family. • Poor return from agriculture ad transfer to cash crops • Encroachment of urban areas
Continuous decrease in per capita water resources.	• Deterioration of water quality. • Poor enforcement of protection legislation. • Growing high water consumption crops. • Inefficient use of water on the farm level • Inefficient use of water distribution. • Low efficiency of urban drinking water supply.

Water Management Practices

Rainfall Harvesting - The average rainfall over Egypt is only 10 mm/year. The highest rainfall intensity is recorded along the Mediterranean coast (about 150 mm/year), in the Central Sinai and in the most south-eastern region of the country. Most of the rainfall occurs in the winter season (October through March). The country has a long history of rainfall harvesting practices. Bedouins along the North-West coast and in the Sinai Peninsula have sustained on such resources for hundreds of years. They developed earth retention dikes and other rainwater harvesting structures to collect and store the occasional rain showers. Exploitation of the stored water in aquifers has been based on what is known as Roman wells, galleries, interconnected man holes and cisterns. Many of these structures are still in use. Rainwater and runoff are also harvested in wadis along the coastal belts in the North West coast and Sinai. A well known water harvesting system in wadis is "El Harrabat" or "Escapes". These are small artificially constructed micro catchments (few hundred square meters in area). The surface area is lined with smooth plain concrete with an appropriate slope towards a covered underground reservoir (50-1,000 m^3 in capacity). Water stored in these reservoirs is used during the dry season for all types of uses.

The present application of such systems is generally confined to the downstream portion of the catchments and does not consider all elements of environment. Moreover, large areas within the catchment are either used to dispose solid wastes or are poorly used by the locals. This calls for a proper survey of catchments, proper protection and an integrated approach to harvest and conserve rainwater.

Flash Flood Harvesting - Several regions in Egypt are covered by wadis. The main regions of interest are located in Sinai, the Eastern desert and the North-Western coast along the Mediterranean Sea. Some are active while others experience occasional floods. Experiences with flash flood harvesting in Egypt are still limited; being mainly confined to the lower portion of the catchments. Many of the existing dams are partly successful, mainly due to: (i) poor citing in areas with fractured rocks; (ii) sedimentation in the upstream portion of the dams; (iii) lack of defined projects for the use of water; and (iv) low economic feasibility.

The construction costs of downstream reservoirs are high, particularly in arid areas like Sinai where the high but infrequent peak flows necessitate a large spillway. The economic feasibility may also be affected by the high evaporation rates and by the effect of sedimentation. The construction of protection dams, however, may very well be justified irrespective of their economic feasibility.

Groundwater - Fresh groundwater is found in coastal regions in various forms, the most dominant are lenses (few decimeters to more than 10 meters thickness) floating over saline water. Formation of such lenses is mainly due to rainfall infiltration. The general practice in attracting groundwater is with the help of connected shafts, skimming (radial wells) and galleries. However, in the absence of proper capture structures and recharge facilities, the sustainability is questionable.

Towards a Water Resources Management Plan for the North-West Coastal Zone of Egypt

Introduction

Water resources management in coastal zones dictates the conservation of natural resource base and its proper utilization. Coastal zones in Egypt are generally characterized by their remote locations with respect to crowded settlements in the Nile valley and delta (Ministry of Water Resources and Irrigation, 2001). Water resources are scarce and their developments require high investments that may not be compensated by the economic return. Wherever the topography and soils are suitable, available surface runoff made agricultural and other activities possible, allowing the settlement of Bedouins.

In the past, several structures have been built (dams, reservoirs, etc.) in the wadis but little attention paid to the hydrogeological conditions and the environment resulted in poor water management and soil erosion. This called for considerations of the characteristics of these regions which differ greatly from the Nile valley. Water conservation structures should be properly cited and designed to ensure sustainability, taking into consideration the traditions of the locals, characteristics of rainfall (intensity and time) and the comparative characteristics of the regions in the selection of development styles.

Physical Setting

The North-West Coastal Zone (NWCZ) of Egypt is a narrow strip running from Alexandria to the Libyan border. Topographic water divide defines the width of the zone and extends between 5 and 40 km from the coastline. The elevation increases from sea level (along the coast) to a maximum of 200 m above sea level along the water divide. The total surface area is about 16,000 km^2 and the present population is about 117,000, mostly concentrated in the towns and holiday resorts (in summer) along the Mediterranean coastline. Matruh is the largest town and the capital of the governorate with a population of 52,000 people.

The landscape and morphology is characterized by east-west running ridges. Recent sand dunes extend along a large portion of the coastline. Parallel to these dunes, are ridges of old consolidated dunes. Narrow plains occupy the narrow strips between the two types of dunes, some of which are marshy (sabkhas). The southern side of the plain is bordered by a succession of transitional slopes with an irregular relief forming a series of closed depressions surrounded by hills. The area from Fuka westward is intersected by a considerable number of wadis generally running south to north. Based on the catchment area of the main wadis, the NWCZ zone can be subdivided into six distinct sub-basins: (i) Salum-Sidi Barrani; (ii) Sidi Barrani-Alamel Rum; (ii) Alamel Rum-El Kanayes; (iv) El Kanayes-Ras Abu Gerab; (v) El Dabaa-El Hammam; and (vi) El Hammam-El Max.

Water Resources

Rainfall and Runoff - Rainfall data are available from stations located along the coast and thus are not representative for the rainfall distribution over the zone. The rainfall along the coastline is about 150 mm/year (in winter), but decreases rapidly towards the south to 75 mm/year. However, the interannual variation is very remarkable. The total annual rainfall on the sub-basins is estimated, based on average figures over the basin, at about one billion m^3/year for the whole region.

Most of the runoff is harvested for agricultural purposes but there is also a tradition to store surface runoff in cisterns and Roman wells for potable purposes . More than 3,000 cisterns exist, of which about 500 are in good condition (a total storage capacity of 200,000 m^3). The storage capacity of reservoirs ranges from 100 to 3,000 m^3.

Fresh Groundwater-Groundwater is found in most of the exposed geological formations in the region, including: (i) coastal dunes (beach sediments); (ii) alluvial deposits in the lower portion of some streams (drainage lines); (iii) the consolidated dune ridges of the Alexandria formation; and (iv) the limestone and sandstone formations. The coastal dunes are a prominent feature all over the zone. The dunes receive direct infiltration from rainfall and from seepage of surface runoff behind the dunes. The water is generally of good quality (salinity <1000 mg/l TDS). However, the quantities that can be abstracted are limited due to the presence of saline water underneath the fresh water lenses.

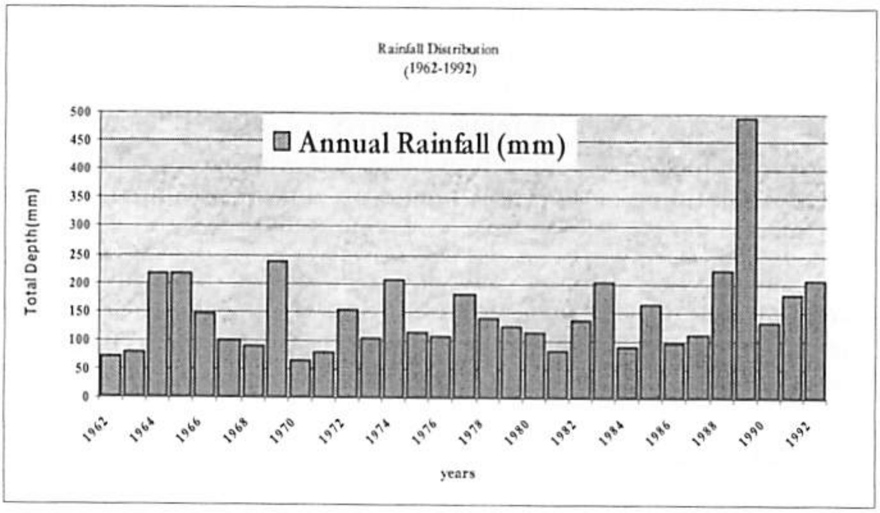

Figure 2: Rainfall variations in the NWCZ

Brackish Groundwater - Under most of the area, brackish groundwater is found. About 50 billion m^3 of brackish groundwater are believed to be stored in the formations along the coastal zone. Desalination of brackish groundwater is already practiced in the region. Few are summarized in Table 2.

Nile Water - Nile water is diverted to the region by various means. Surface water is pumped through the Bahig and Hammam canals mainly for agricultural uses. Potable water is pumped from Burg El Arab treatment plant to Matruh through a 300 Km pipeline. A capacity of 300-650 m^3/day is pumped through 7 booster stations.

Table 2. Brackish Groundwater Desalination Plants at Some Locations of the North-West Coastal Zone.

Location	System	Owner	Date	Capacity	Investment
	RO	EPV	1988	4,000	5
Alexandria	ED		1995	2,400	2.8
Abu Kir	ED		1987	4,000	5
El Alamein	RO		1996	2,000	2.3
Burgel Arab	RO		1995	4,000	4.5

Reuse - A large portion of the NWCZ is presently occupied by cities and resorts with wastewater treatment facilities. The effluent is either disposed into the sea or used to irrigate the green areas and belts. The continuous increase in settlements will result in increasing volume of wastewater causing a nuisance in its direct use or disposal. Such water can be reused for agricultural development either directly or after additional treatment by infiltration and storage (SAT).

The summary appearing in Table 3 which provides possible types of water resources in the North-West Coastal Zone (NWCZ) and the potential for development indicates that *rainfall runoff and fresh groundwater have a limited potential for large-scale development.* The region has sustained on these resources for centuries through a balanced system of small-scale surface runoff collection, harvesting systems and appropriate means of groundwater abstraction. These resources are still important and could even be enhanced if appropriate technologies are applied.

Planning Approach

The MWRI has finalized the National Plan for Non-Nile water resources (groundwater, rainfall and runoff). Areas for potential development along with wadis subjected to high flood risks have been identified from the plan, for detailed investigations. Among those areas, the NWCZ is considered of first priority for which detailed investigations are taking place along with the assessment of brackish groundwater and impacts of development.

The first step in the planning exercise was the formation of an interdisciplinary team. Several reconnaissance visits have been made by the team focusing mainly on discussing issues and perceptions of people and inventorize on-going water resources systems. This step was followed by data acquisition and collection of available information.

Table 3. Summary of Water Resources in the NWCZ

Resource	Present	Additional	Technology	Remarks
Rainfall runoff	small portion	limited but important for small scale rural areas and winter crops	spreaders, dikes and cisterns	limited feasibility unless combined with retention function (flood protection)
Rainfall/ runoff infiltration	in dunes and wadi deposits	Limited due to limited recharge and salinity	galleries and dug wells	Important but needs recharge facilities, monitoring and control
Fresh groundwater	1 million m^3/year	Limited due to salinity and poor applied technologies	dug wells with low capacities	important for local water supplies but needs control and appropriate technologies
Brackish groundwater	Minor	Large quantities suitable for agriculture and fish farming	high capacity abstraction wells	Further studies needed to determine locations, yields and quality (desal cost L.E. 1.5-2/m^3)
desalinated groundwater	About 10 million m^3/year	believed to be high	wells and desalination plants	
Desalinated sea water	5-10 plants operational	unlimited resource	desalination plants	Cost L.E. 3-4/m^3 if large units are used

The following steps have been identified as prerequisites for the plan;

1. The plan cannot ensure sustainability unless all aspects are considered, including perceptions of people, present and styles, types of activities, existing works, etc.
2. The main data needed for the plan are the records of rainfall, topography, land classification, geomorphology, geological structures, lithology, infiltration tests, etc.
3. Main information include satellite images, hydrogeological maps, vulnerability maps, land use maps, settlement, styles,

land use and disposal, soil classification maps, delineation of catchments, etc. Ground checks will be carried out as they are always important to calibrate data information.

4. Integration of maps is an important step that needs final editing by the team to ensure proper representation of features prior to integrated modelling.
5. Finally, the preliminary plan can be developed and discussed with officials, locals and other possible stakeholder to seek their approval and commitment. Implementation should include also the monitoring system to allow periodic evaluation and adjustment, if needed.

The plan should also consider development and enforcement of legislation, including: (i) control on construction or settlement in areas subjected to high flood risk in wadis; (ii) proper and safe disposal of effluent (domestic, industrial, etc.); and (iii) prevention of any interference or adverse impacts of new developments on existing settlements (natives). The plan should also identify the suitable developmental activities, making use of the comparative characteristics of the region and ensure that water management styles are not copied from other regions (see Table 4).

Table 4. Examples of development Types in the NWCZ

Type of Development	Source of Water	Extent	Requirements
Summer Resorts	Desalinated sea water	an area of 50,000 acres	Land use plan, protection from flash flood if any and appropriate disposal of effluent
Unconventional Agriculture	Winter rain, brackish and desalinated groundwater	an area of 100,000 acres	Proper assessment of brackish groundwater potential and long-term impacts on the resource
Fish farms	Brackish groundwater and sea water	an area of 40,000 acres	
Native settlements and activities	Winter rain, harvested runoff and shallow groundwater	an area of 10,000 acres	Participation of natives from the beginning and selection of their areas and activities

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9

A History of Traditional Water Management

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Introduction

Before the industrial revolution, the modification of environment was carried out through knowledge and techniques which were the result of long-term collective experience. This knowledge, and specifically water management technologies, was produced by people and passed on to people by recognizable and competent actors. They were systematic (inter-sectorial and holistic), experimental (empirical and practical), passed on from generation to generation and had a cultural value. This kind of knowledge promoted diversity, valorized and reproduced local resources.

Each technique is not an expedient to solve a single problem, but it is an elaborated and often a multipurpose system that is part of an integral approach; society, culture and economy. It is strictly linked to an idea of the world based on the careful management of local resources. Therefore, the traditional technique is an integral part of a set of links and relationships that is strongly integrated and supported by symbols and meanings. Cultural structure that is socially shared which is the system of the local historical science and knowledge makes it possible for the traditional technique to be performed.

To consider traditional knowledge as more than a simple set of techniques means to evaluate them in the framework of environmental, productive and cultural conditions of societies. Therefore the history of traditional water management technologies and local knowledge is the study of social groupings. They keep a relationship with nature by means of a series of practices to use resources which represent their technological dimension and are integral part of the cultural system. Thanks to this knowledge, the populations are able to obtain an increasing number of resources from the environment in comparison with the resources that nature offers. The communities who live in harmony with the resources can endure for very long periods of time. Deep changes can also occur either in longer periods of time or they can be concentrated in more rapid status revolutions that cause the passage from one social grouping to another.

The traditional knowledge system of water management technologies is rebuilt according to the common classification of social groupings used in archaeology and anthropology; *hunters-gatherers, farmers-breeder* and *agropastoralists that use metals.* Besides these three categories there are two other synthesis represented by more complex traditional social systems of intensification and integration of knowledge; *oasis* and *urban eco-system.* Within these systems the technologies of previous social groupings seem to be stratified and combined in a diversified way according to different social and environmental situations.

The *oasis* is an artificial creation based on perfect environment knowledge. In the desert the environmental context of aridity is interrupted by a specific water management which create niches and microenvironments that can counter to the negative overall cycle. The *urban ecosystem* is the oasis model changed into town. This system consists of large caravan-route towns in the desert or urban clusters that are not as small as the oasis model. Irrigated areas are created by using favourable geomorphological situations in given geographic systems. A big capital dominates each unit of landscape; isolated basins in the middle of the desert; large plains among the mountains; oasis along hydrographic networks; crossroads of remote, international and intercontinental routes. However, these ecosystems are also traditional habitats that exploit the resources available, thus becoming important regional historic centres with urban characteristics.

From the First Water Harvesting Surfaces to Paleolithic Hydraulic Labyrinths

Water is so important for the life of all organisms that even animals have developed useful behaviours to manage it. In the desert many species of mammals dig holes to facilitate natural water harvesting and some animals, like the beavers, build dams to control water. Therefore, it is not surprising that the first hominids built surfaces and dikes for water harvesting. The most archaic structure of this kind that has been identified so far could be that found in the site of Isernia, exactly in La Pineta area, where a paleosurface dating back to 700,000 - 500,000 years ago was made up of several travertine stones, bone remains and calcareous handmades that formed a primordial layer (Peretto, 1991). However, the techniques used during the Paleolithic by nomadic Hunters-Harvesters belonging to our Sapiens species are more certain. They could move from place to place thanks to the good knowledge of the territory and in particular of the methods of water findings and supply.

The Paleolithic population used to harvest drinkable water in caves thanks to water dripping and percolation; moreover, they realized stone paving to harvest rainfalls and divert them to pits. They used dams, ditches and stone arrangement to facilitate plant growing and fishing (Drower, 1954). In steppes, in savannahs and in deserts along karst plateaux or along interfluvial plains human groups exploited those favourable areas near the territory subject to swampiness and drought alike thanks to flow adjustment techniques. These techniques became imposing trapping systems for fishing as those found in Mount William in Australia (Lourandos, 1980) and in New Guinea where a complex system of draining canals developed from 9,000 to 6,000 years ago (Diamond, 1997). The labyrinthic shapes reproduced in symbolic rupestral graffiti are the same as those used in the fences where the first domestication experiences were carried out. Water harvesting is associated to the origin of spirituality and of art as it is testified by drawings in caves and by the finding of an artificial stone barrow dating back to 150,000 years ago in El Guettar in Tunisia, holding flints and paleolithic handmades, clearly showing functions linked to hydraulic practices (Gruet, 1955).

Such knowledge, which results from experiences gained in the long run, is consolidated through the success of holders; it is recorded through the symbolic thought and art and is handed over to generations through tales. Starting from the most archaic African sites, the knowledge is spread worldwide at the same time as the development of human groups. The system of Hunters - Gatherers knowledge was a sublayer shared by all populations that changed, developed or lost its importance according to socio-environment conditions. It sometimes re-emerged, thus highlighting the analogies that are often found in myths, in techniques and in forms among people and far places.

Water Control and Irrigation Techniques used by Farmers-Breeders

Phenomena of sedentariness without agriculture occurred in Jericho from 12,000-10,000 years ago. In this phase structures supporting soils were realized by building holding walls and clay platforms with coated environments for drinkable water (Cauvin, 1994). Since the eighth millennium in Africa, in the Middle East, in Anatolia and in the Pakistan-Indian area original ways of cultivation in arid areas developed in places where the broiling sun gave yields that justified the necessary engagement (Childe, 1954). Nonetheless, due to the lack of rainfall, it was necessary to develop methods of water management in these areas.

Before introducing irrigation techniques, populations used water directly and naturally available that in arid conditions can be found as atmospheric moisture and soil deposits. The first kind of water supply, that is to say the moisture that deposits in the soil, played a key role in the introduction of cultivations organized in small steady orchards in the sites where the phenomenon was more determinant: areas situated near the basins, water courses or geological situations and stone mounds that favoured water steam supply and dew condensation. By observing the best vegetative cycle of naturally-grown plants the most suited areas could be identified. Likewise, it was possible to establish the places where to exploit the second water supply, that is to say the water held in soil deposits. Alluvial soils, the loess, wadi dry courses were the most suitable means to preserve water resources in upper layers, thus allowing the development of the first neolithic societies that from "nomadic cultivation", relying on spreading seeds in favourable areas where the populations came back only for harvesting, switched to practices of space arrangement. Caves, characterized by natural water dripping, were excavated to follow the flows and better intercept them; otherwise they were widened and deepened by creating openings on slope walls as well as draining and harvesting cisterns.

These practices would then become underground techniques of drainage tunnels and passive architecture that in suitable geomorphological situations, would allow the troglodytic settlements and the development of stone towns (Laureano, 1993). The extraction activity in flint mines allowed the building of the first pit courtyards provided with radial tunnels. The pattern that can be found in Grimes Caves in England and in the mines of Gargano in the South of Italy (Di Lernia, 1990) is reproduced in water harvesting devices and in underground dwellings with a central courtyard. These techniques developed in dry karst areas and on calcareous plateaux like the Murge in Puglia, but also in semi-arid clay plains of Northern Africa and loess stretches in China. Steady elliptic or semi-circular settlements, characterized by several perimeters of ditches, established in rainy areas, in poorly drained plains or in karst areas as well as at the edges of high plateaux without water courses. Under climate alternation conditions, they meet many functions linked to water balance, they drain water during rainfalls and preserve it for dry seasons, they are used as drinking troughs and ditches to collect useful sewage and waste to fertilize soils, they symbolically mark the places and strengthen the social cohesion, the group identity and the propensity to sedentariness. Ditches are multi-purpose structures, resulting from the evolution of simple pits used to collect water and waste.

This practice was useful to select domestic cultivated species and to identify seeding periods suited to any kind of plant. As a matter of fact, seeds and sewage went into the ditches where they sprouted spontaneously in the most suited season. By sprinkling the fields with the water harvested in pits it was possible to understand the fertilizing capacities of manure. Many traditional techniques, which are still used, show this capacity of using symbiosis with other organisms in the ecosystem management. In Burkina Faso thanks to a method called "zai", it is possible to regenerate highly degraded soils using water pools, waste and also the combined action of termites. The soil is dug with holes that are filled with water in the humid season whereas during the dry season they are used as dump-sites for rubbish and manure. Such practice attracts termites that digest rubbish which can be easily assimilated by plant roots whereas the tunnels dug in the soil by termites increase soil porosity. The holes are then sown, thus obtaining very high crop yields. Multi-purposeness and polivalency are therefore the successful conditions of typical neolithic structures handed over by traditional techniques.

On Murge plateaux in Italy the practice of ditches dug to favour soil collection and plant growing has been preserved up to more recent years. In Daunia in Puglia and on Murge plateaux there are thousands of dug perimeters of neolithic villages (Tinè, 1967) which are also found in Germany in the site of Kol Lindenthal along the Rhine Valley and in China in the site of Banpo along the Yellow River that are similar to settlement and water management patterns which are still widespread in Ethiopia. The dwellings are made up of hut-like structures which are scattered outside the perimeters and are equipped with cisterns and ditches to preserve the wheat. The development is realized by repeating the pattern. The construction of the settlement entails the arrangement of the territory at the same time. From both a material and a symbolic standpoint, the organization of the village is the same as the organization of the production area, the image and the functioning and order of the world.

In the 6th millennium the first techniques of canalization and the banks of flow diversion that implemented irrigation by flooding developed in the plains and interfluvial basins of Iraq and Anatolia. The settlement structures with an orthogonal texture developed on the matrix of the canals. The first non-circular constructions were realized with water and adobe, the same slime of cultivations, like in the settlements of Çatal Hüyük and of Jarmo, in the plain of Konia in Anatolia and at the foot of Zagros Mountain in Iraq, which preceded urban organizations. The squared shape allowed diversified and complex solutions with greater evolution potentials. The dwellings could stretch and cluster gradually without leaving any free areas.

In inter-fluvial plains large clusters grew at the same time as the development of techniques supporting the soil with continuous wall curtains, construction of platforms, banks and canals. Consequently, dwelled and rural areas were organized in a different way. The clustered forms of settlements met building, climatic and defensive needs and were different from the agricultural organization albeit materials, like the adobe, did perfectly integrate in the landscape. These practices allowed to carry out large-scale water management techniques in alluvial valleys such as the Indo, the Nile, the Mesopotamia, the Yellow River which had been developed by important state-owned organizations rightly called hydraulic societies (Wittfogel, 1957). These were ancient empires built on alluvial deposits of slime, loess and sand along afroasiatic fluvial basins and also in karst areas of Mesoamerican rainforests. The geographic size and the big hydraulic structures led to political despotism, bureaucratic hypertrophy as well as to state militarization. Indeed, in more fragmented landscapes lacking water coming from big rivers, the traditional techniques of water catchment and management developed owe to the activities of small-scale communities.

Water Catchment and Soil Consolidation Techniques of Agro-Pastoralists Who Used Metals

During the Metal Age the populations organized in familiar clans could easily move by the use of carts and horses, thus widespreading techniques that allowed the exploitation of new tillable areas. The agro-pastoral and transhumant economy exploited those areas that had not been previously colonized, by structuring paths from mountain ridges towards the sea. Terracing was realized in inaccessible slopes whereas hanging gardens were introduced in big capitals characterized by interfluvial basins. However, the use of the metal spread slowly, although it had been anticipated by the significant results achieved by some communities in the neolithic age.

Since the fourth millennium the technique of excavating cisterns and water intakes had developed in order to irrigate the fields from the settlements situated on high hills, thus exploiting the force of gravity. In the same period, in Belucistan (Iran and Pakistan) the civilization preceding Harappa used earthened dams called *gabarband*. These were used to keep water flows in the soil as well as dams accumulating sand that favoured the sedimentation of slime and the control of alluvial sediments and floods. In the third millennium, the civilization of the Indus valley developed in this area. In the centres of Harappa and Mohenjodaro this civilization used water supply systems in dwellings, techniques of sewage disposal and irrigation practices which were similar to those that would be used in Rome after 2,000 years. Moreover, wells equipped with a stone structure that enabled to reach the water tables were introduced.

In the same period, the hydraulic Egyptian and Sumerian civilizations developed the big monumental architecture starting from the experience derived from the construction of banks and canals necessary for irrigating and fertilizing their lands. The first pyramids were made up of adobe, which was the direct evolution of the Neolithic building techniques of banks as well as of mud platforms in Africa, in Mesopotamia as well as in Mesoamerica.

The soil left during excavation formed the first holy mounds. Their change into monuments favoured sedentariness, social identity and the transfer of working activities during the standstill of hydraulic works. The powerful state control of hydraulic societies needs these big works that glorified and justified the despotism and the powerful administrative bureaucracy. Settlements placed on fortified hills developed in rough areas of the Middle East, of Mediterranean Isles and Peninsulae and on coast promontories of arid areas. Towns, citadels and acropolises had to withstand the sieges and to ensure having drinkable water.

In the Bronze Age, in the sites of Arad (Amiran, 1970), Jawa and Megiddo, in the north of the Arab desert (Barrois, 1937), and of Qana, in the South of Yemen on the coast of the Indian Ocean (Laureano, 1995), the area within the walls was used to harvest water and feed either open-air or excavated cisterns that could be reached through tunnels and staircases. Tilled fields or the eventual urban development at the foot of the hill, were fed by pipes that, in case of coast clusters, also supplied the port structures that would thus provide ships with water. During sieges, canals were cut down and defenders, who barricaded themselves on the summit, continued to produce the water that had been denied to attackers. Each rock or wall mass could produce water and protect the soils. The different thermal inertia combined with the atmosphere creates colder surfaces bringing about condensation. The walls intercepted winds and moisture. The interstices between blocks and the stone porosity withhold the water. The shadow protects it from evaporation. The rocks prevent the soils from dismantling, thus facilitating humus formation.

As a matter of fact, the majority of dry stone structures widespread in the arid lands of Puglia contribute to water production. In this area the mounds of porous rocks absorb the night frost, thus supplying the soil with moisture (Nebbia, 1961; Cantelli, 1994). Therefore, the stones of the most imposing walls are arranged with the slabs bended inside to allow the frost to pass through the filling stony ground. The dry walls preserve the hydromorphic qualities of the soil, thus acting as thermoregulators and moisture balancers both in arid areas and under very cold conditions hindering the formation of ice. This is the reason why there are dry walls, stone circles and stone arrangement which are generally used as catchers of moisture also in those areas subject to heavy rains such as Ireland and the Orkney Islands. Here, thermoregulation counterbalances soil glaciation and permafrost formation. During this period the circular megalithic structures and conic structures with false vaults developed as the fusion between the African hut and the techniques of wall construction of wells and cisterns. These forms have created the Micenean tholos, the trulli of Puglia, the talayotes of the Baleari Islands and the several rural structures made up of wall masses, harvesting areas and underground cisterns that have increasingly imposing forms like the nuraghis, that is the most outstanding evolution of the possibility of clustering of round forms on the territory and of the use of megalithic structures for moisture condensation.

In arid areas a series of techniques developed ranging from simple stone arrangement, half-moon mounds to dry stones, thus evolving in complex double wall curtain devices equipped with harvesting cisterns. Several archaeologic clues can still be found in the Negev desert, along the Arab wadi and in the Jordan valley. All these areas are completely desert, but thanks to these methods of moisture catchment and soil protection they used to be fertile and rich. Some archaeologic research (Evenari, 1971) has shown that century-old olive tree and vineyard wastes were irrigated using a system of small dry walls collecting dew that in Arabic are called *teleylat al 'anab*, meaning mounds for the vineyard. The plants grew inside small fences whose stones, arranged with large interstices, caught the wind full of moisture. The vineyard and the olive tree could thus grow even without any source or water table. The walls, the stone mounds, the tombs, the trulli and the calcareous rock called specchie, the talayotes, the nuraghi, the telayet el anab are used as water condensation and preservation structures. The stone mounds carry out their function during the day and at night. In the broiling sun the wind carries traces of moisture which seeps into the interstices of the stone mounds that have a lower temperature inside because it is not exposed to sun rays or it is cooled by the underground chamber if it is present. The decrease in temperature causes the condensation of drops that are absorbed by the soil in case of walls or fall into the cavity. Efficiency of condensation chamber is amplified by the collected water which supplies further moisture and coolness. Overnight, the process is reversed and the condensation takes place externally, thus producing similar results.

The cold surface of stones condenses the moisture and dew slides in the interstices, thus wetting the soil, or it is harvested in the chamber of the cistern. Most of these structures are usually considered as funerary monuments but they can be exploited for hydraulic uses, both for functional or worshipping purposes. In Matera, on Murgia Timone plateau, along the ditch of the archaic neolithic fences, structures formed by a double circle of stones which was crossed by a corridor leading to a central underground area were introduced during the Bronze Age.

Similar techniques are used in the neolithic Saharian area, in the Arab desert and in Yemen, the latter being considered as an area where the civilization of hidden waters developed and relied on air hydrogenase (Pirenne, 1977). Moreover, they are widespread all over the Mediterranean area. Their most imposing urban application is found in Petra that used to be the centre of the two ancient Edomite and Nabatean populations (Zaydine, 1991) after which this agricultural technique was named. The contacts with Southern Arabia through the Incense Route explain the similarities with the Sabean hydraulic techniques that, in the so-called Marib dam, which is actually a system of dividers and water intakes (Dentzer, 1989), boast the most imposing example of soil formation practices by flooding in complex structures. In the highest sites characterized by rare rainfalls, these devices are associated with surfaces harvesting rainfalls which develop in a terraced or courtyard architecture organized for this purpose. Temples and worshipping monuments, like successively the mosques, used to catch water.

As a matter of fact, in the long run it would be increasingly difficult to identify the functions of the works. Likewise the tombs, the kurgan, the tholos, the holy constructions used the forms of the hydraulic structures for many reasons. Firstly, water was actually used in religious and funerary ceremonies; secondly hydraulic knowledge was often handed over by holy or heroic personalities; finally because the funerary mausoleum reproduced the architecture of the structures producing water, that is the source of life. In small scale societies, the familiar clans celebrated their ancestors through mausoleums and related rites, thus strengthening the identity of the group and highlighting the strategic points to be crossed. In such a way, during this period the territory was meant as an integrated network of centres that exploited different ecosystems. The practice was already advanced in the middle of the II millennium in central Italy where highland villages got in touch with each other during seasonal transhumance, since they shared paths characterized by water devices, worshipping complexes, stopping areas and pasturelands (Barker, 1981).

In hydraulic civilizations the sovereigns gave a monumental interpretation of the techniques of local cultures getting hold of them. Therefore, it is important to remark that in the middle of the 1st millennium, Pharaon Tutmosi I dug "underground rooms in the wadi" on the left shore of Thebes. These were the first monuments of the area that would successively be known as the Valley of Kings all over the world. The localization of underground structures that followed the extensions of the course of the fossil river of the desert, let us think about the reutilization of pre-existing works that were used to intercept the hydrographic network or the monumental use of the experience gained in these activities. The general condition of these areas did not hinder the existence of small-scale family-run agriculture in communities capable of preserving their independence and of handing over the local knowledge within these areas, or in marginal and geographically protected situations. Therefore, adapted knowledge developed within those societies, that compared to hydraulic ones, are called hydroagricultural, hydrogenetic or autopoietic societies. These social forms survive owing to the isolation and to the geographic harshness in places that had been voluntarily chosen for these characteristics and transformed by clever communities in centres of a particular economic importance by means of commerce or by cultivating rare species, or because of strong cultural reasons relative to the religious faith and to social cohesion.

The separation between small-scale communities and the hydraulic society is highlighted, both from a material and symbolic standpoint, by the construction of the Big Chinese Canal started in the middle of the first millennium B.C. The work is situated at the end of the silk route that had widespread and exchanged traditional knowledge for hundreds of years, to link the course of the Yellow River of the desert to that of the Blue River of the Chinese Empire. Developed along a northern-southern direction for about 1,700 km, it is the most extended canal in the world and due to its geographic imponence and to the impact on society it can be considered as a real artificial Nile. Its realization structures the Chinese area, thus experiencing its territorial, social and administrative changes. During the first millennium large-scale irrigation took place in interfluvial basins and water production in deserts through drainage tunnels, qanat, foggara and falaj. The latter widespread the oasis that synthesizes the traditional knowledge capacity of creating autopoiesis and enhances resources in balanced ecosystems (Laureano, 1995).

From Oases to Urban Ecosystems towards a Sustainable Future

The oasis is an autocatalytic system whose initial supply of condensation and moisture is extended by planting palm trees that produce shadows and attract organisms, thus forming the humus. The palm grove creates a wet microclimate which is fed by hydraulic catchment techniques such as the drainage tunnels of foggaras, hidden rainfalls, the condensation and the control of underground flows and floods. Adobe dwellings do not lead to the waste of wood to fire bricks; they are cooled by the underground path of water and provide waste for field fertilization. The system manages the water resource according to a cycle of use that is compatible with the renewability of the quantities available and increases them at the same time.

In the desert the domestication of the date palm, the foenix dactilifera, is the requirement to plant the oasis. The palm groves extend from the main neolithic poles through the Sahara desert and the other deserts, thus developing the knowledge necessary to create the oasis effect: autopoietic cycles, the hydraulic production and the resource management (Laureano, 1987). The techniques also spread wide in the Northern Mediterranean area and in southern banks of the desert in places where the date palm cannot ripen. In these situations other plants are used with horticulture in order to guarantee the soil maintenance and the shadow besides the specific fruit like the olive tree in the Mediterranean Basin and the Papaya in Sahel and in South Arabia. An enlarged pattern of oasis is thus created as capacity of creating living situations in difficult and harsh environments by using the hydroagricultural knowledge.

In case of rare resources, urban ecosystems realized in close man-nature relationships trigger vital cycles, autopoietic dynamics which are able to self-reproduce and be sustainable. The urban ecosystem is the stratification of the local knowledge accumulated which therefore takes the characteristics of a town rather than of a village. Irrigating areas are created under favourable geomorphological and precise geographic conditions. A capital dominates each landscape unit, isolated basins in the middle of the desert, large plains between mountain peaks, stripes of oases along hydrographic networks, crossroads of faraway international and or intercontinental roads.

However, also the small habitat systems, whose urban texture can be explained by analysing the hydroagricultural matrix and the needs of water catchment, become historic centres of regional importance with urban characteristics. They feature different realities that can be found in several situations, adobe oasis-like towns, such as the Saharian or the Yemeni towns that use the organic wastes of dwellers to fertilize the sterile sands and make them suitable to the realization of imposing architectures. Stone oases that were excavated since Prehistory in Southern Italy and in the Middle East are able to condensate the water needed in caves and in dry constructions, religious oases, sculptured in the erosion valleys of Cappadocia, of Palestine, of Thebaid and of Ethiopia or installed along the silk route up to China. They are arranged as hermitages and walled gardens, irrigated by drainage tunnels, cisterns and canalizations.

Sea oases widespread in the arid islands of the Mediterranean Sea and of the Red Sea that are fed by air sources and rainforest oases since Maya architectures that developed in a humid climate can be interpreted by understanding the functions of water collection which is important within a Karst environment without surface courses. Urban ecosystems are the continuity of traditional knowledge that from the first caves, the stone arrangement and the artificial rivers develop and diversify under different environmental conditions up to the realization of increasingly complex hydraulic systems. Likewise the traditional historic centres of Southern Italy and Maghreb, they were dense and concentrated settlement patterns which were used as barns, trade markets and centres for service organization in close relationship with the agriculture landscape. The crisis of traditional agriculture followed the exodus from these centres. Since they were generally situated in harsh and mountainous areas with their traditional architectures, water harvesting systems and soil protection techniques used to be territorial garrisons able to contrast soil degradation. It is an alternative socio-economic pattern to that of hydraulic civilizations relying on an increasing development supported by the significant demographic growth triggered by the agricultural potential and continued by an imperial policy, by incomes coming from the exploitation of huge quantities of workers and from the waste of resources in monuments or in wars. The consequences of the hydraulic pattern corresponded to those of the unlimited development logic belonging to contemporary affluent societies; hypertrophia and the destruction of the territory, the bureaucratic centralization and the increasing destruction of the environment up to the ecological catastrophe.

The local knowledge continues to be handed over in apparently backward areas or in the advanced society and in places of cultural importance. It is therefore wrong to consider traditional knowledge as marginal compared to current significant economic and technological processes. F rom a quantitative standpoint their use still supports the greatest part of humanity that is distributed in less industrialized countries. Paradoxically, in these places where traditional techniques are still widely used they are considered from the modernist thought as backwardness phenomena, whereas in developed countries they enhance their image and their value. As a matter of fact, more modern countries still use traditional techniques, thus consolidating and stabilizing their role within the society and the economy.

The values of tradition, the practices of working and the craftsmanship capacities are the key basis of the very high added value of significantly economic productions for many highly developed countries. In the regions of Valais, in Switzerland, of the Loira Valley, in France, of Tuscany in Italy, traditional techniques are still employed in agriculture, thus allowing the highest quality landscapes to stabilize, a vehicule of highly profitable sales of produces. Historic settlements, traditional landscapes and local knowledge offer solutions that have to be safeguarded and that can be recommended and renewed thanks to modern technology. It is not a question of readopting every technique without distinction but to grasp the logic of the traditional pattern that has allowed the society to improve its status and to carry out technical, architectural and artistic realizations which are important in the history of cultures (Laureano, 2001).

The traditional knowledge has always been a dynamic system capable of integrating the innovation studied for a long time with the local environmental sustainability. It is proposed that the proper and advanced knowledge for working out a new technological paradigm should be based on the progressive values of tradition, the capacity of enhancing internal resources and managing them at a local scale, multi-purposeness and integration between technical, ethic end aesthetic values. The production which is not considered as a value in itself but it is targeted to the well-being of communities and relies on the principle that each activity shall feed another one without any waste and make use of the energy which is based on cycles that are continuously renewed.

Table 1. Comparison between modern and traditional knowledge

Modern Knowledge	Traditional Knowledge
Specific Solution	Multipurpose System
Immediate Efficacy	Functionless in the Long Run
Specialization	Holism
Dominant Powers	Autonomy
Separation	Integration
External Resources	Internal Inputs
Conflicts	Symbiosis
Monoculture	Relatioship and Complexity
Uniformity	Diversity
Severity	Flexibility
Expensive Maintenance	Self-Regulation and Work Intensity
Internationalization	Contextualizing
Waste	Saving
Technicism and Rationalism	Symbolism and Wealth of Meanings
Dependence	Autopoiesis

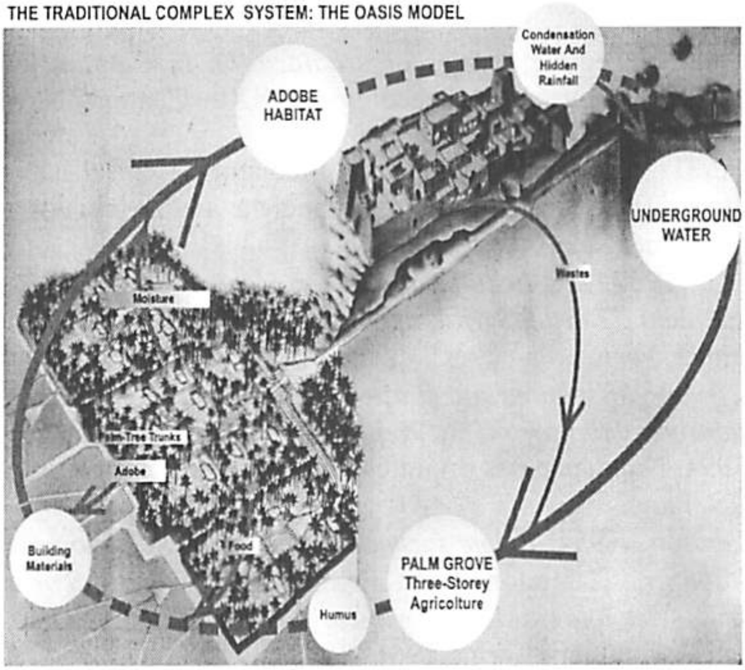

Figure 1: The traditional complex system; the oasis model

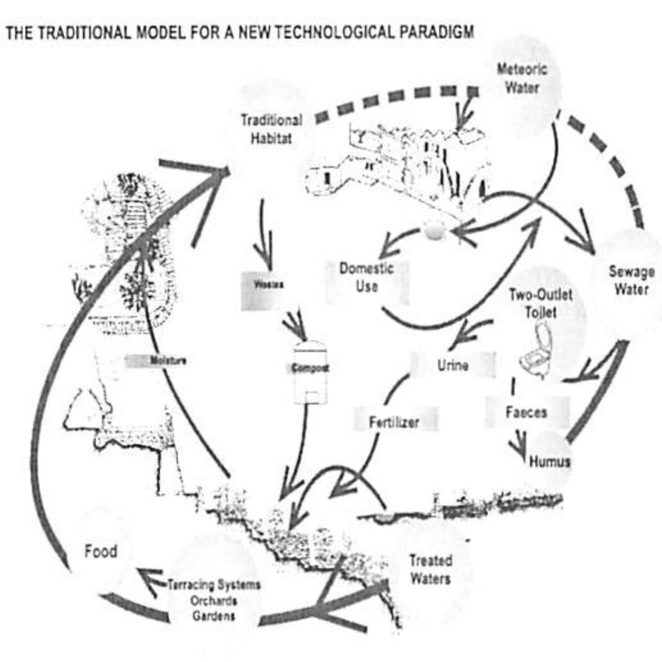

Figure 2: The traditional model for a new technological paradigm

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10

Irrigation Scheduling of *Aflaj* of Oman:
Methods and its Modernization

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Introduction

In Oman, agriculture is almost fully dependent on irrigation owing to the fact that most crop production areas receive only between 100 to 200 mm of rainfall annually (Norman, et al, 1998 a,b). Oman has 4,112 *falaj* of which 3,017 are live *aflaj* (افلاج), producing about 680 x 10^6 m^3 of water per year and 410 x 10^6 m^3 $year^{-1}$ is used (Al-Hatmi and Al-Amri, 2000). *Falaj* (فلج) (singular of *aflaj*) can be defined as, a canal system, which provides water for a community of farmers for domestic and agricultural use. The term *falaj* is derived from an ancient Semitic root, which has the meaning "*to divide*", hence the water shares in *aflaj* is divided among the owners (Wilkinson, 1977). The local nomenclature of the *falaj* implies the system as a whole (Wushiki, 1997). Normally a farming community owns all *falaj* water. *Aflaj* vary in size and the smaller ones owned by a single family while the larger ones belong to hundreds of owners. In every *falaj*, there are some water shares not owned by individuals but allocated to the community. The value of these shares are allocated for *falaj* service, mosques, emergencies, etc (Al-Abri, undated). Many villages and towns in Oman have more than one *falaj* system; for example, the town of *Samail* has 16 different *aflaj* systems.

Typical Omani *falaj* administration consists of a director, *wakil* (وكيل), two assistants, *arifs*(عرفاء) , one for underground services and the other for above ground services, banker, *qabidh*(قابض) , or *amin aldaftar* (امين الدفتر) , and labor, *bayadir* (بيادير) (Sutton, 1984, and Wilkinson, 1977). The *aflaj* systems are arranged in such a way that domestic use is primary and agricultural use is secondary. In most *aflaj*, water is first allocated for drinking purposes, then for uses in mosques, forts, men's public baths, women's public baths, and lastly to the area for washing dishes and clothes. After domestic uses, *falaj* is used to irrigate the permanent cultivated lands, mostly for date palms followed by the seasonally cultivated lands. This arrangement helps farmers to control drought.

The *Wakil* is in charge of the overall administration of the *falaj*. For example, he is in charge of water distribution, water rent, expenditure of *falaj* budget, solving water conflicts between farmers, emergencies and other decision-making activities. *Arif* (عريف) can be in charge of timing irrigation in the field. The *qabidh*'s job is to control the *falaj* income, which comes from special water shares, land or crops located for the *falaj*. He is also in charge of updating the *falaj* transaction book, giving an annual report to the *falaj* owners and does other tasks as directed by the *Wakil*. The administration of the *falaj* system depends on its size. Some *falaj* can have administration system as described above where as others may not have full administration but normally should at least have a *wakil*.

In *falaj* irrigation system, water is distributed by time basis. Only in few cases volume basis is used. There are three types of *aflaj*:

1) *Ghaily* (غيلي), where the source is a base flow of *wadi* (dried rivers);
2) *Daudi* (داوودي), where the source is a mother well, like the *qanat* of Iran; and
3) *Ayni* (عيني) , where the source is natural spring.

Traditional Methods for *Falaj*-Water Distribution

Falaj-Water Distribution by Athar

When the construction of *falaj* is finished, farmers establish a committee of experienced people to distribute *falaj* water shares among *falaj* owners. If the government contributed in constructing the *falaj*, it normally owns some shares of water or land. The committees investigate the *falaj* flow rate, water flow fluctuations, soil type, number of owners and their proportional contribution in constructing the *falaj*, etc. In the *athar* basis distribution, the first step is to decide on the irrigation rotation, *dawran* (دوران). *Dawran* is the irrigation cycle, normally 7 to 14 days. However, it can be as short as 4 days or as long as 20 days.

The most important factors when deciding the *dawran* are soil type and flow rate of the *falaj*. For example; *falaj al-Awabi* (العوابي) has a *dawran* of 14 days, *falaj Al-Hageer* (الهجير) in *Wadi bani Kharous*, 7 days, *falaj al-Farsakhi* (الفرسخي) in *Samail*, 8 days and *falaj al-Dariz* (الدريز), in *Ibri* has a *dawran* of 19 days. In all *aflaj* of Oman the *dawran* is divided into many subdivisions of time. After *dawran* is decided, water share is divided between *falaj* owners using unit of share *athar*. Each full day is divided into one or two *badda*. Each day should be equal to 48 *athars*, so if the day is one *badda*, *badda* will be equal to 48 *athars*. If it is two *badda* then, each *badda* will be equal to 24 *athars*. Normally the day is divided to two *badda*, the day *badda* and night *badda*.

Wilkinson (1977) reported a *falaj*, which has 3 *badda* in each day. In this *falaj*, each *badda* has 16 *athars* so the full day is also equal to 48 *athars*. Al-Hajri (1998) reported that the number of *badda* per day differs from one reign to another in Oman, where the existence of three *badda*/day is rare. *Athar* is commonly used in *aflaj* of Oman where each *athar* is divided into 24 *qiyas* (كياس). Practically, *qiyas* is the smallest unit of water share, which is approximately equal to the time required to irrigate one date palm tree with good *falaj* flow. Other units may have different names or length of time. Al-Marshudi (1995) mentioned that *qama* (قامة) equals to 1/4 *athar* and *rabiya* (رابية) equals to 6 *athars*. There are some other units of time like *rabee* (ربيع) which equals to 6 *athars* (1/4 of half-day *badda*) and *riba* (ربعة) equals to 6 *qiyas* (1/4 of *athar*). Smaller units are also used in *aflaj* like *mithqal* (مثقال) and *habah*(حبة) . In *falaj al Awabi, qiyas is equal to* 8 *mithqal;* each *mithqal* equals to 36 *habah*.

Theoretically, an *athar* is equal to 30 minutes, therefore *habah* equals to 0.26 second. Wilkinson (1977) explained a system of dividing water share from the book of *falaj Izki* (in the Interior Region of Oman), in which an *athar* is divided to 24 *qiyas*, and *qiyas* is divided into 24 *daqiqah* (دقيقة), then *daqiqah* is divided into 24 *shariah* (شريعة) and *shariah* into 24 *jalilah* (جليلة). One *jalilah* will be equal to 5.42×10^{-3} seconds. Practically, it is non-measurable; hence, these small units are used only in inheritance. It is noticed that the length of the time-share is inversely proportional to the flow rate and number of *falaj* owners and it is directly proportional to the contribution of the owner in constructing the *falaj*.

When the water is divided between the shareholders, the division never changes but the water and land shares can be sold or rented. When the owner dies, land and water share is distributed among his family according to Islamic regulations. Each farmer will irrigate his farm(s) with same number of *athars* at each *dawran*. The sequence of water shares in the rotation of irrigation does not change if a farmer misses irrigating his land during the rotation

(Norman, et al, 1998b). Most of *aflaj* have special number of *athars* to be rented for *falaj* service and maintenance. In these *aflaj*, some water shares are not fixed with land, so can be sold or rented separately by auction, *Maqouda* (مقعودة). The price of *athar*, for rent or sale, varies depending on the availability of water and auction events. For example, *falaj al-Hageer* (small *falaj*) has 15 *athars* for the *falaj* from a total of 336 *athars*, 7 days *dawran*. A large *falaj* may have more water share to be devoted to the *falaj* or common use, like in *falaj al Awabi dawran* is 15 days (720 *athars*) in which 150 *athars* are allocated for *waqf* (وقف). The water that allocated for *waqf is* to be rented to raise money to be used for mosques, Islamic schools or for other community benefits.

In many Omani *aflaj*, particularly the larger ones, farmers can be classified in 4 types:

i) owners of land and water;
ii) owners of land and renting water;
iii) owners of water and renting land; and
iv) renting land and water.

The existence of each type depends on many factors such as the sizes of the *falaj* community and the amount of water share that is owned by the government (*bait al-mal* بيت المال) *or* located for the community benefits, *waqf*.

Estimated Time Intervals

In some *aflaj* systems, the day is divided into estimated intervals. For example, the full day can be divided into seven intervals, between dawn, sunrise, midday, prayer time in the afternoon, sunset, prayer time at night, and midnight. Farmers therefore share the water using these intervals. However, Al Abri (undated) noted that this method is seldom used because it has no clear length of time or standard unit therefore it causes a lot of conflicts among farmers. Al-Saleemi and Abdel Fattah (1997) described the irrigation time division as of September 1996 of *falaj al-Farsakhi, Samail*. In this *falaj* the full day is divided to six intervals called *riba*, (ربعة) and each *riba is* between 2 and 6 hours in length, as shown in Table 1.

Distributing Water by *Badda*

In *Falaj al-Muhaidith* (المحيدث) , *Ibri*, the *dawran* is divided to 10 days, where each day has two *badda*. In this *falaj* the smallest water share division is *badda*, (half full day).

Table 1. Summer divisions of time for irrigation in falaj al-Farsakhi, Samail

No.	Riba	Time		Total time
		From	To	
1	*Al- Badwah* البدوة	4:15 pm	9:00 pm	4.75
2	*Al-lail* الليل	9:00 pm	3 :00 am	6.00
3	*Al-Athaan* الأذان	3:00 am	7:00 am	4.00
4	*Dhil 6* 6ظل	7:00 am	11:00 am	4.00
5	*Al-Nisf* النصف	11:00 am	2:00 pm	3.00
6	*Al-Aakhir* الاخير	2:00 pm	4:15 pm	2.25

Tasa

In *Jabal Al-Akhdar* mountain, in North-center of Oman, and some surrounding villages, another method of water distribution is used. Farmers use a water timer called *tasa* (طاسة) or *sahlah* (صحلة). In some cases the *tasa* itself is used as a time unit. However, in other places the *tasa* is divided to the common time unit of *aflaj*, *athar*. *Sahlah* is a timing device using water and two containers. The upper container, called *tasa*, is placed on a bigger container, which is filled with water. Figure 1 shows the *tasa* which is used in *falaj* Saiq, in *Jabal Al-Akhdar* mountain. *Tasa* has a small hole through which water fills it up slowly until it sinks. Farmers use the time it takes

Figure 1: Tasa of falaj Saiq

the water to fill the entire container as a single unit of water share, *tasa*. The book of *falaj* Saiq describes the water share of the farming community in which *tasa* was used as a unit of water share. Each owner of water share gets multiples or divisions of *tasa*.

Water Tank

In some parts of Oman, usually in the mountains, for small *falaj* system, the *falaj* water is stored in a large water tank, *Liggil* (لجل), constructed by local cement, *sarooj* (صاروج). Water is then distributed by volume according to the size of the owned farm(s). For example, a farmer with a small farm may have one full tank; another one with larger farm will have more water, like two tanks. In such *falaj* system flow rate is very low and land shares are small. An example is *falaj al Air* (العير) which is located in *Wadi bani Aouf* in *ar Rustaq*. This *falaj* is small *ayni falaj* with a *dawran* of irrigating every 7 days. Each day of irrigation is owned by one or two farmers. In this *falaj*, farmers store water at nighttime and early day time then they irrigate in the afternoon. In case a conflict occurs, the amount of water that was delivered to someone is checked by measuring the height of water in the storing tank. They put a stick made of date palm branch and mark it by date leaves for the height of water that represent half the stored volume. The full tank represents one day (two *badda*), and each half tank represents one *badda*.

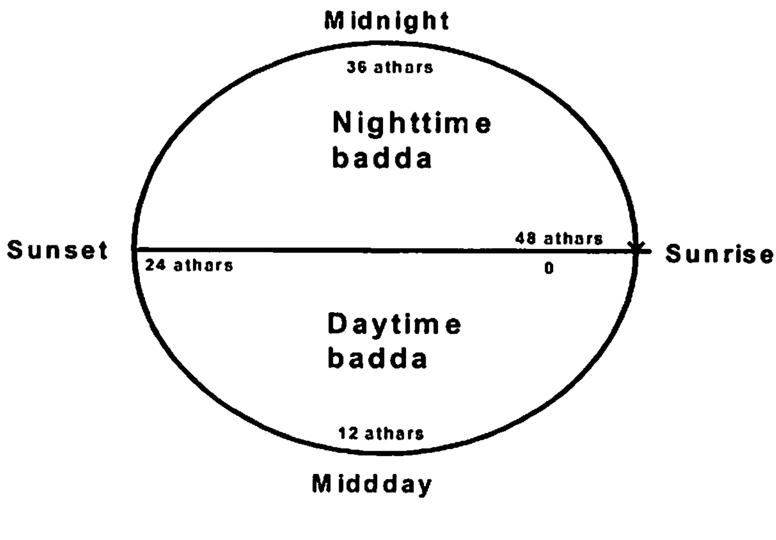

Figure 2: Traditional full day water-share ***divisions***

Irrigation Scheduling

It was developed to verify the *athar*-basis water-share for farmers, on the field. The sundial and stars method was the most common way of irrigation scheduling in northern Oman. In this method, farmers use sundial at the daytime and special stars at the nighttime. The process of inspecting the sundial or the stars for water shares is called *mohaynah* (محاينة) or *mahazarah* (محاضرة). Sundials, locally called *lamad* (لمد) or, *alam* (علم). The place for *mohayanah*, where the sundial is located, should be in the head of the *falaj* system, before any divisions in the distribution system. Usually it is located near the main fort of the village where the *sheikh* (شيخ) (the village head) resides. The schedule of *falaj al Hageer* is an example of schedule for traditional irrigation. In this *falaj* the *dawran* is divided to 7 days that is equal to 14 *badda* or 336 *athars*. Each *badda* is divided to 4 quarters, *riba'* (ربعة), so each *riba'* is equal to 6 *athars (rabee is called riba' in al-Hageer)*.

Table 2 shows a complete schedule of irrigation for *falaj al Hageer*. The table shows the order of farmer as of January 15, 1996 (Monday) to January 21, 1996, (Sunday). Fifteen *athars* are allocated for the organization, mainly for the *falaj* and mosque service (Wednesday, code 16). The rest of the *athars* are distributed among *falaj* owners. The water share varies from 2 *athars* (code 9) to 48 *athars* (code 18) per farmer. In *al-Hageer* a farmer may have his water in more than one day in the *dawran*. For example, farmer with 24 *athars* has 14 *athars* on every Friday and 10 *athars* on every Sunday (code 7).

A farmer may also have water in the same day but in separate *badda*, for example, a farmer on Monday has total of 11 *athars*, 4 *athars* in one *badda* and 7 *athars* in the other *badda* (code 10). Farmers do not have more than 24 *athars* in a single irrigation. So, if a farmer has more than 24 *athars* in one day, he will have a full *badda* and the remained *athars* will be in the other one. An example of this is on Friday. A farmer has 34 *athars*, 24 in one *badda* and 10 in the other one.

Daytime Scheduling

A typical sundial in northern Oman consists of a stick, 8-cm thick and 2 m long, fixed vertically on a flat rectangular area. Special selected stones, which are carefully spaced, mark the area. The stones that represent early and late daytime *athars* are spaced farther apart than the stones that represent midday *athars.* A single stone is called *jamood* (جامود), its plural is *jawameed*(جواميد). Farmers watch the movement of the stick shadow over the set of stones and

count *athars* by the time it takes the shadow to move from one stone to another. These stones are marked to represent each *athar* on the daytime *badda*, so 24 stones are placed in one line in the direction of East-West. The marked line is also called *lamad.*

Table 2. Irrigation Schedule of falaj Al-Hageer

Day	Number of separate irrigation	Farmers codes and owned athars	Badda 1				Badda 2		
Mon		Codes	11	9	10	8	13	10	12
	7	Athars	8	2	4	10	8	7	9
Tue		Codes	14		15		4	2	1
	5	Athars	9		15		14	3	7
Wed		Codes	18				16		17
	4	Athars	24				8	7	9
Thu		Codes	19		20		18		
	4	Athars	14		10		22		2
Fri		Codes	21		7		21		
	3	Athars	10		14		24		
Sat		Codes	1		2		3		
	3	Athars	11		13		24		
Sun		Codes	4				5	6	7
	4	Athars	24				5	9	10

A system like this has more than one line-*lamad* to adjust the location of the stones on the tilt of the earth throughout the seasons, which affect the position of the shadow. There are three line-*lamads,* one for summer, one for winter and one for spring and autumn. The stones with the same *athars* in the three lines are connected with a line (Al-Ghafri et. al., 2000b).

If the village is situated between high mountains; the number of *athars* to be inspected using the sundial will be less than 24, therefore the farmers use the surrounding environment to complete the missing *athars*. This is because the sunshine time on the village will be less than the actual daytime length. Fig. 3 is a sketch of the sundial of *falaj* Stall. Another type of sundial is used in *falaj Al-*

Dariz, Ibri. This version is called, *alam*. It consists of a 30 cm metal stick fixed vertically on a big solid flat rock, which is covered by concrete. The rock is marked permanently for *athars* and subdivisions of *athars* with a minimum division of 1/8 *athar*. This type of *lamad* also has 3 lines for summer, spring and autumn and winter.

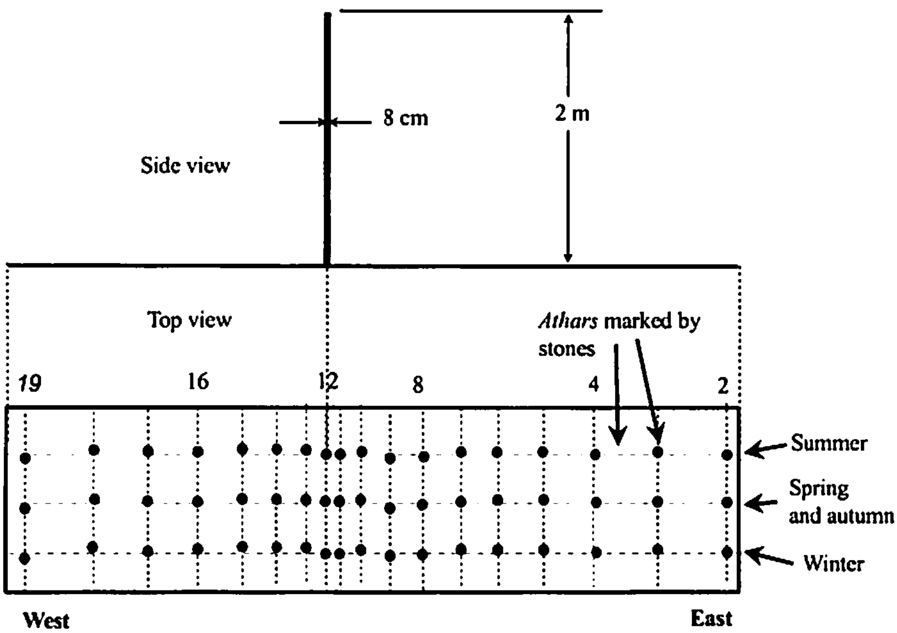

Figure 3: Sketch of the sundial of Falaj Stall

Nighttime Scheduling

At night, farmers use stars in scheduling irrigation. Special set of stars is located for irrigation. These stars are well known by the *wakil* or *arif* of the *falaj*. Farmers use the time between the rises of a particular star(s) to the rise of the following star(s) from this set. It is categorized into principal stars and dividers, *qawasim* (قواسم). Normally, time-share allowed between any of the principal stars is between 1 and 3 *athars*. Table 3 shows the star system of *fajal Stall*. Dividers divide the time between two principals ranging from 2 to 6 subintervals. However, divider stars are not very important in irrigation scheduling. The total number of the principals stars, which are used in each *fajal* is between 20 to 25 stars. This set is fixed for a particular system of *aflaj*. Among *aflaj* of Oman, different nomenclature and dividers between the scheduling stars are used. About half of the total number of the full set is used on every night, depending on the day in the year. In traditional sundial-stars timing the most difficult time to verify *athars* is the transition between the daytime *badda* and nighttime *badda*. The hardship is caused by the fact that the timing depends on the observation of the movement of the sun or stars, it is therefore difficult to decide the start and end of the each *badda* during the sunrise and sunset. The star system for *aflaj* irrigation is very complex and the time set between stars varies from one village to another. Table 4 illustrates the variation of water right, by *athars*, between same stars in 5 different villages in the northern Oman. In cloudy weather, for instance, when the east is covered by cloud, farmers use setting of other stars in the west, which synchronize with the irrigation set of stars.

Falaj Water Distributing Equitability

Solution for the change of Athars' length

In the traditional sundial and star method, because of the variation of the length of day and night throughout the year, farmers may have more or less water per *athar*. In northern Oman, where most of the *aflaj* exit, *athar* can be varied in length between 1/3 – 2/3 of an *athar*, according to the change in the day and night lengths around the year.

Due to using non-precise devices like sundial and stars the variation is much higher. For example, *athar*'s length is varied in *falaj al-Hageer* from less than the half of the theoretical length of the *athar* to more than double. Al-Shaqsi (1996) reported a big variation in *athars* length in *falaj al Kasfah* of *ar Rustaq*. In winter, farmers irrigating at nighttime will receive more water than farmers irrigating in daytime and the reverse is true in summer. At night farmers use stars for scheduling irrigation, however they estimate the length of time between stars. Some two stars may have two athars of the length; however, the actual time will be less or more than one hour. Ancient farmers tried to solve this problem by having another rotation within the dawran. It was a day-night rotation.

Table 3. Irrigation Star System of Falaj Stall

No.	Name of star(s)	Number of athars
1	*al-Thuraiya* الثريا	2
2	*Al-Dubran* الدبران	3
3	*Al-Yameen* اليمين	3
4	*al-Shair* الشعاير	3.5
5	*al-Ganb* الجنب	2.5
6	*Al-Thraa'* الضراع	3
7	*Al-Farfarah* الفرفرة	2
8	*Al-Mawatheeb* المواثيب	2
9	*Bu-Gabban* بو جبان	2
10	*al-Ghafar* الغفر	2
11	*Al-Zabanat* الزبانات	2
12	*Kuwi* كوي	2
13	*Al-Munsif* المنصف	2
14	*al-Tayer* الطاير	1.5
15	*Al-Ghurab* الغراب	2.5
16	*al-Adam* الادم	2
17	*al-Sarah Al-Oula* الشعرة الاولى	2
18	*al-Sarah Alwusta* الشعرة الوسطى	2
19	*Al-Sarah Al-Akhirah* الصتارة الاخيرة	2
20	*Al-Kawkabain* الكوكبين	2
21	*al-Fateh* الفتح	2

Table 4. Variations of athars in different star systems of aflaj

Athars	Stars	Falaj Al-Hamra	Samail	Al-Hageer	Stall	Al-Awab
	Kuwi كوي	3	2	2	2	2
	Al-Ghurab الغراب	2	2	2.5	2.5	2.5
	Al-Adam الادم	2	2	2.5	2	2
	Al-Kawkabain الكوكبين	3	2	2	2	2
	Al-Thuraiya الثريا	2	2	2	2	2
	Al-Ganb الجنب	2	2	2.5	2.5	2.5

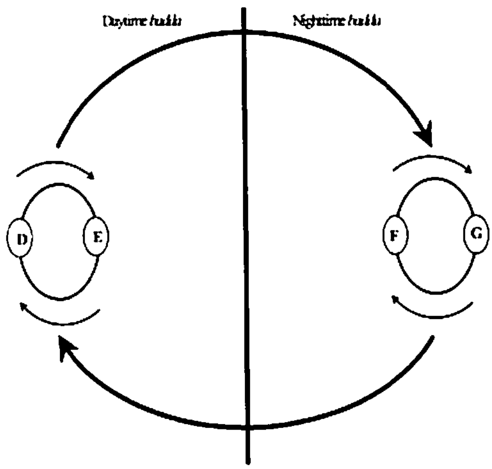

Figure 4: Rotation of farmers

In this rotation farmers keep shifting the irrigation in daytime or nighttime; as well changing their order in the same *badda*. As an example, in *falaj al Hageer*, farmers with shares less than 24 *athars* will have their water at night *badda* or day *badda* only. For instance, during summer if a farmer irrigates at nighttime and loses some water, he will gain more in the following *dawran*, when irrigating during the daytime. In Figure 4, farmers D and E are irrigating in one *badda* and farmers F and G in the other one. In this rotation farmers at same *badda* rotate the order between them each *dawran*, and both groups (D-E and F-G), rotate the irrigation at daytime or nighttime (Al-Ghafri, et al, 2000a). In central Oman some *aflaj* adapted different method to automatically make the farmers receive their water alternately night and day. They designed the *dawran* with an odd number of *badas*, like nine and half days, 19 *baddas*, rather than nine days, 18 *baddas*, (Wilkinson, 1977).

Reaction of Farmers on Flow Rate Fluctuations

Farmers act against the change of *falaj* flow rate by dividing the *falaj* into smaller streams, re-adjusting the *dawran* or store the *falaj* water in a big tank before irrigating. In large *aflaj* systems, the water stream of the main channel is divided into several sub-streams depending on the size of the *falaj* and its flow rate. Farmers can irrigate from one stream or more at once. In dry years, farmers cut the number of sub-streams depending on the reduction in the main flow rate. The process of equally dividing the main flow of the *falaj* is called locally *moghayza* (مغايزة) .The place where this process is done is called *shari'ah* (شريعة). This process can be summarized in the following equation;

The number of *athars* a farmer will receive: $T = t \,.\, N \,.\, n^{-1}$
t = Standard number of *athars* owned by a farmer.
N = Number of equal streams of the *falaj*.
n = Number of streams which farmer use simultaneously.

In this division the farmer who irrigates using the main flow will receive the same amount of water if he irrigates from one or more sub-canals. The amount of flow in each sub-canal is set to be equal. An example of this is shown in Fig. 5. The photo shows the flow division of *falaj Birkat al-Mouz*. By joining A1 and A2 a stream A is formed. In this division A:B = 2:1; so if a farmer has an x *athars* from the main stream and he irrigates from stream B only he will get 3x *athars*, but if he irrigates from stream A, he will get 2/3x *athars*. Big *aflaj* may be divided to 8 streams as of *falaj Daris* in *Nizwa*. *Aflaj* with stable flow usually are divided permanently to major sub-streams. Each stream will be devoted to a specific land area.

The *dawran* is not fixed for all the falaj but each major stream may have its own dawran. Like in falaj al-Dariz, Ibri, the main stream is permanently divided to two streams. In one of these streams the dawran is 9 days, in the other one the dawran is 10 days. The reason for this difference is that the land which is irrigated by the stream of the shorter dawran has a lighter soil than the other one which has long dawran. In this example therefore each stream is treated as a separate falaj system.

In the time of drought, the *falaj* will be joined in one stream only and will be altered between the two in 19 days. During the drought of the late 1980s this solution was adapted, and it was noticed that the farms that were located in the stream of a former short *dawran* suffered more than the other farms. In *falaj al-Ghayzayn* (الغيزين), north of Oman, *falaj* is divided into two streams in normal years. Farmers use both streams at the same time. The *dawran* of this *falaj* is 7 days.

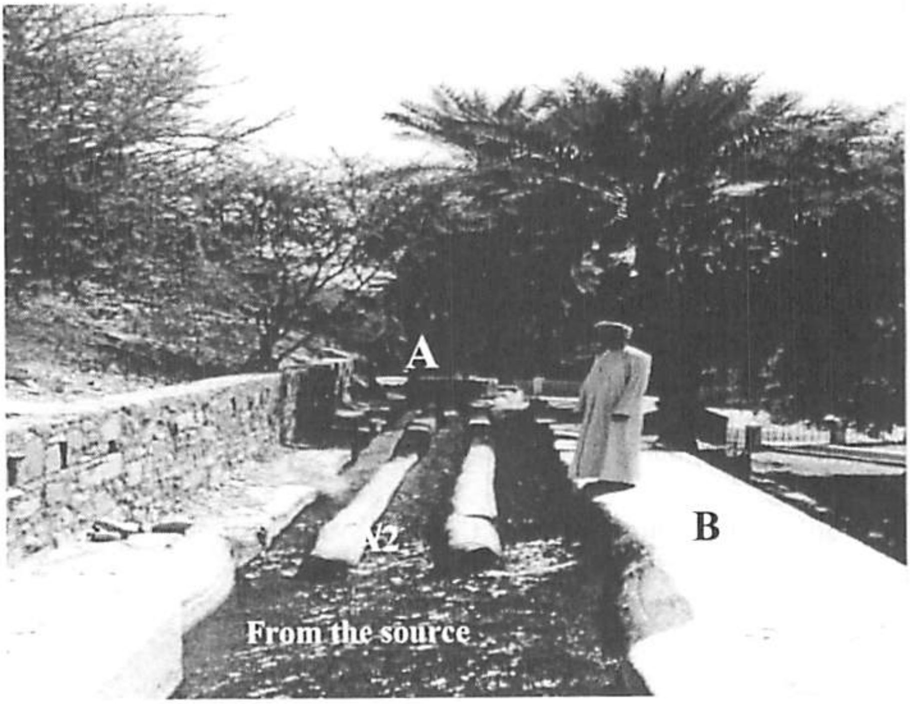

Figure 5: Flow division in Falaj Birkat al-Mouz. Photos: June 1996

In time of drought, farmers irrigate from one stream only at any one time. In this case, they divert the water every 7 days to one of the two canals; hence the *dawran* is doubled from 7 days to 14 days. In very low flow rate the *dawran* is extended to 28 days (Birks, 1977). Wilkinson (1977) reported that the *dawran* is altered annually in some *aflaj* to meet the changing requirements of summer and winter irrigation. He gave an example of three *daudi-aflaj*: i) *falaj Dariz*, ii) *falaj* of *Ibri* and iii) *falaj* of *Buraimi*. The *dawran* in these *aflaj* changes from ten to twelve days, four to five days, and ten to fourteen days, respectively (Wilkinson probably considered only one of the streams of *falaj al-Dariz*).

In *falaj al-Farsakhi,* at *Samail,* farmers adapted simpler method to insure justice distribution of water share. The *falaj* water rights are divided to 8 full days; one day for the *Maqoudah* (مقعودة), allocated for the *falaj* benefits and the other 7 days for individual owners. In the 7 days each day is divided between groups of owners, from 4-8 owners in each group. Each group is always irrigating at same day, however, the order of irrigation of each group changes in every *dawran* (*Al*-Saleemi and Abdel Fattah, 1997). It is a common practice in small *aflaj* systems that farmers store the *falaj* water in a big tank for long time and controls the flow rate for irrigation depending on time desired to irrigate. In some *aflaj*, the village has one or more big tanks made of concrete to store *falaj* water during the time of low flow rate. The time for storing the water is included in the share time that farmers have. It is noticed in this system that they store water only when the water flow of the *falaj* become unmanageable. This method reduces the time required for irrigation and increases the efficiency. During this process, if a farmer couldn't finish using all the stored water in the tank before the start of irrigation of the next farmer, his remained water will be allocated to this succeeding farmer.

Problems of Using Different Units for Water Sharing in *Aflaj*

Due to the developed passive attitude of farmers toward the *falaj*, technical knowledge of *aflaj* is only possessed by older generation. The new generations have no interest to learn about it. In many systems farmers do not know even the time of the construction or the location of the water source. The terminology and names of star system for irrigation and units for water share is too complicated, unorganized and its knowledge is disappearing. It is therefore necessary to standardize the water share units for future development of *aflaj* by applying new irrigation technologies on the existing systems.

Currently, there is no standard unit of time of water distribution for all *aflaj* of Oman. As the traditional way of irrigation scheduling differs from one *falaj* system to another, the standardization of timeshare is likely to be tricky. Even though in most of the *falaj*, farmers use *athars* as a standard unit, the way of inspecting the length of each *athar* varies among *aflaj*. In order to shift into using modern watch we have to change all the existing units of time to standard time, hours, minutes and seconds. Converting all traditional units to the standard time can do this, as shown in Table 5.

Table 5. Some traditional water share units and their equivalent time lengths.

No.	Traditional water share units	Equivalent time length (hr:min:s)
1	*Badda* بادة	12:00:00
2	*Rabia* رابية	03:00:00
3	*Rabi* ربيع	03:00:00
4	*Athar* اثر	00:30:00
5	*Qama* قامة	00:07:30
6	*Qiyas* كياس	00:01:15
7	*Mithqal* مثقال	00:00:09.375
8	*Daqeeqah* دقيقة	00:00:03.125
9	*Habbah* حبة	00:00:00.26

Ghoroobi and *Zawali* Timing

As a rule, in the traditional scheduling method, the daytime *badda* starts at sunrise and ends at sunset, where the nighttime *badda* starts at sunset and ends at sunrise. After the modern watch became available to farmers in the last century, they gradually started to check the time using these watches, and they came to fully depend on these watches in some systems, by adapting first the *Ghoroobi* (غروبي)timing and then the *Zawali* (زوالي) timing. When the modern watch was introduced to Oman, the timing system was known as *Ghoroobi* or sunset timing. In this timing system, the farmers set the watch to 12:00 at sunset everyday. The watch is adjusted everyday according to the change of the occurrence of the sunset. In the conventional meridian timing, called *Zawali* in Oman, the day starts at 6:00 a.m. In the *Zawali* method, daytime and nighttime are fixed to have equal length (12 hours each), regardless the seasonal change. Figure 6 illustrates the difference between using traditional sundial and stars, *Ghoroobi* watch and *Zawali* watch.

In Table 6, 16 *aflaj* systems are listed with information on the type of the *falaj*, estimated size of the *falaj*, length of *dawran* and the method of irrigation scheduling. In all the four *ghaily* type *aflaj*, farmers use modern watch. In two of them *Ghoroobi* timing is used and in the other two *Zawali* timing is employed. In the *daudi aflaj*, it looks that farmers prefer and stick to the sundial and stars system. We can also recognize from the table that only the small sized *aflaj* use tank and scale method; distributing the water on volume basis. It is too difficult to ask the farmers to shift from the traditional way of irrigation scheduling to the use of modern watch.

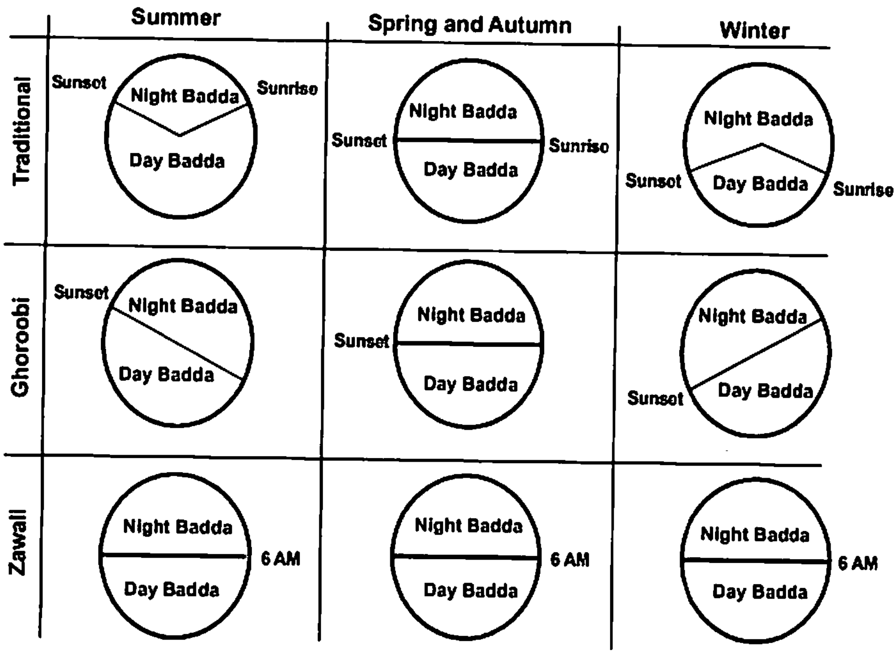

Figure 6: Different methods of irrigation timing in aflaj

Summary

Farmers go through several steps to transfer from using traditional irrigation scheduling to modern watch. The old generation opposes new improvements. Thus, it is necessary to convince *sheiks*, *wakils* and older people of the *aflaj* to convert to using meridian time. It is therefore recommended that all the existing traditional water-share units should be converted to standard time. This necessitates the documentation of all water share of *aflaj*, before further steps and big changes take place in the management or the social system of *aflaj*. Every *falaj* should have a book containing the name of water right holder, amount of water he owns (number of *athars*, volume, etc), and time to start and finish irrigation. It is also necessary to update this database with future changes that may happen to the water system.

Acknowledgements

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11

Renovation of Qanats in Syria

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Introduction

Modern challenges for traditional systems

The research project described in this paper looks at the use and values of a potentially sustainable qanat system in a changing modern environment. Lightfoot (1996) defines qanats as *"a form of subterranean aqueduct- or subsurface canal- engineered to collect groundwater and direct it through a gently sloping underground conduit to surface canals which provide water to agricultural fields."* In Syria many ancient qanat irrigation systems have been abandoned due to falling water tables, as a result of the increased use of modern electric and diesel-pumped wells. Lightfoot (1996) stated that *"New and often rapacious water technologies have all but replaced traditional irrigation systems in the Middle East, aggravating an impending water crisis and further complicating regional water compacts [...] traditional, low-impact irrigation technologies can no longer support the region's rapidly burgeoning numbers of peoples."*

In modern times, qanats are not able to provide enough water for large-scale agriculture and therefore loose their importance. Traditionally, qanats should be cleaned on a regular basis to prevent silting, collapsing and disfunctioning. This helps keeping the qanat flowing even in dry seasons. But as soon as qanats are giving less water, young people loose interest and start looking for means to earn for a living in off-farm work. The urban environment is financially much more attractive than traditional qanat farming. This group of youngsters literally abandons qanats. With the abandonment of qanats the indigenous knowledge and community co-operation critical for qanat upkeep also disappears and more qanats collapse or dry up. As a result a valuable cultural heritage is vanishing. Not only are qanats relics of a prosperous past, but also sustainable and environmentally friendly systems of extracting groundwater. In Qarah, Syria, we have seen that combining ancient qanats and modern drip irrigation systems for fruit trees might prolong the life of some qanats and encourage younger generations to commit to their upkeep. Another option to think of is to encourage eco-tourism based around qanats to provide alternative income for the farmers.

Qanats in Syria

In 2001, our team from ICARDA explored qanat sites in Syria guided by a map published by Dale Lightfoot from Oklahoma State University (USA) in 1994. We documented geographical, socio-economic, and hydrological characteristics and interviewed local experts and officials from various institutions. We found a total of 42 qanat sites containing 91 qanats, of which 30 were still actively used. Others were dry or drizzling and almost abandoned. We tried to cover most of Syria, but owing to the fact that Syria used to have a lot more qanats in the past, it was difficult to re-locate all of them.

In Syria, the concentration of running qanats is located around Damascus, Homs and in the steppe areas. The qanats used to provide the main water supply for drinking and agriculture. It is difficult to determine the age of qanats because of the small amount of artifacts that are found inside the tunnels. However we can say through circumstantial evidence that Syrian qanats were already in use during the Roman period. The digging technique and type of the qanats varies considerably throughout the country.

The water of Syrian qanats is used mainly for irrigation since the date they were dug. The division of the water is based on a local system of rights and regulations. The groups of users for each qanat were relatively steady and each user household had an irrigation share measured in time, called "dor" (turn). Irrigation shares can be traded among the users and are usually attached to land.

Case study in Northern Syria

As we have seen in countries like Oman, renovation of neglected qanats is viable. Successful renovation of Qanats in Syria is technically possible but thorough social and hydrological assessment is required in advance of renovation. A pilot renovation was done in 2000 in a village East of Aleppo and our team initiated a qanat cleaning based on the priorities and traditional knowledge of the community. The qanat was dated to be in the Byzantine period considering an oil lamp that was found in the tunnel. The qanat is the only source of water in the village. In collaboration with the museum of Aleppo, the scientists started up the cleaning of their own qanat.

Methodology and approach

The research and development methodology of the case study is based on one of the action models described by Chambers (1985): *"Action anthropology begins with the premise that the anthropologist should operate within the framework of goals and activities initiated by groups seeking to direct the course of their development. The action anthropologist may use his or her technical skills to help a group clarify its goals, but generally avoids the temptation to direct the project."* Action research is a subset of applied research. In this case the action is the actual cleaning and renovation of the qanat system in Shallalah Saghirah.

The project followed an integrated holistic approach led by the priorities and needs of the community. The anthropological action research was supported by other disciplines such as hydrogeology, archaeology, biology, agronomy and soil science. An interdisciplinary team of scientists of both social and bio-physical disciplines thus collected data on various topics. In general the data collection can be divided into a social focus and a technical focus. Initial contacts with the community were established in the second part of 1998, but the actual project started in October 1999. Since then a good rapport has been developed with the local community. Overnight stays during the fieldwork enhanced and strengthened the relationship and mutual trust between researchers and respondents. Hydrological measurements are being taken regularly, the social organisation, history of the village and water rights system in use is being investigated. A genealogy of the households in the village has been finalized. Key informants, both male and female, have been interviewed on their sources of income.

Description of the study area

The village of Shallalah Saghirah is located 65 km SE of Allepo city in the western part of the Khanassir Valley bordering the eastern slopes of the Jabl Al Hass. The Khanassir Valley is located between the 200-mm and the 250-mm rainfall isohyets, while Jabl Al Hass is located between the 250-mm and 350-mm rainfall isohyets (Figure 1). The 200-mm isohyet demarcates the cultivated zone to the west and north and the steppe areas to the east. Shallalah Saghirah is a typical village because it finds itself in time and space in transitional zone. Spatially, because it is located between two different rainfall zones at the border of the steppe area; in time because, as both Lewis and Jaubert describe, this area has known rapid environmental, cultural and economic changes over the past 100 years. The village does not have electricity except from private generators and until recently was not influenced by modern developments.

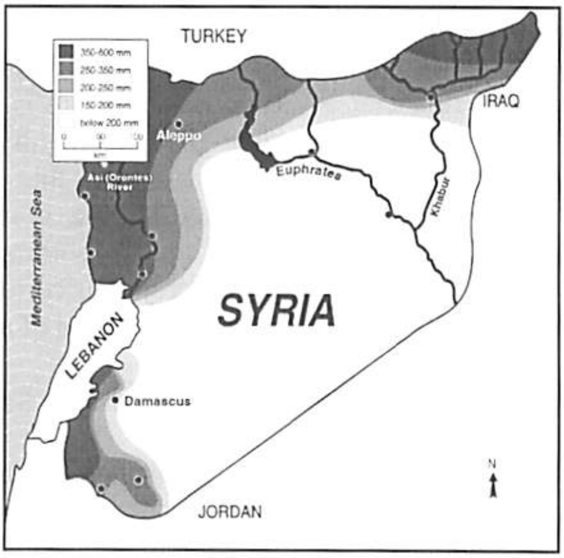

Figure 1: Map of Syria

However, the arm of modernization reaches everywhere; television has made its entrance and the younger generation is traveling in-and outside Syria for off-farm migration work. According to Lightfoot, the qanat system of the nearby town of Khanassir has been abandoned after the introduction of motor-pumped wells. A similar situation could be the future of Shallalah Saghirah. From 1998 until 1999 a groundwater and well survey has been undertaken by Hoogeveen & Zöbisch (1999) in the Khanassir Valley to investigate the groundwater system and its use by farmers. They mentioned that part of the water pumped from the aquifer in the centre of the valley, is replaced by salt water from the Jaboul Salt Lake in the north. Therefore, water tables in the valley are not falling as rapid as in those areas with comparable pumping activities.

The limestone layer from which the qanat in Shallalah Saghirah derives its water is not very productive due to its low permeability and porosity. Therefore it is believed that the nearby pumping activities are having little influence on the discharge of the qanat. Nevertheless, the local inhabitants informed that this ancient qanat system gives less and less water every year. They have mentioned that many shafts of the qanat system are filled with debris collected over the years and that children have thrown stones in the shafts. Yet regarding the physical environment of the qanat, cleaning and renovation of the system could be beneficial for both the people and the environment. Elderly inhabitants and some of their sons expressed willingness for cleaning and renovation, but they do not have the financial ability to do it. There is also a certain reluctant attitude towards cleaning the system by some of the local inhabitants. Birks(1994) mentioned that the change in socio-economic circumstances may be the main reason behind this reluctant attitude. Through applied anthropological research and community development this project tried to overcome the various obstacles that prevent the sustainable use of an ancient qanat system.

Hydrogeology of the Qanat in Shallalah Saghirah

The qanat has been dug in the limestone rock that is dated Middle Eocene. The limestone consists of chalk like clayey limestone and marl. Flint has been observed in the limestone layers exposed to the surface. According to the inhabitants of Shallalah Saghirah the water in the mother well is tapped from a layer where flint is present.

Table 1. Composition of the water of the Qanat compared to the drinking water standards of the WHO. Sources: Appelo (10), Hoogeveen and Zöbisch (4).

Parameters	Observed values 1998	Max. Values For drinking water
EC(at25 °C) (dS/m)	850	
PH	8.2	
Na^+ (mg/l)	91.9	175
K^+ (mg/l)	1.95	
Mg^{++} (mg/l)	27.34	50
Ca^{++} (mg/l)	58.12	
Cl^- (mg/l)	107.77	300
HCO_3^- (mg/l)	170.86	
SO_4^{--} (mg/l)	114.31	250
NO_3^- (mg/l)	26.04	50
IB_err	3.3	
Water type	Calcium Chloride	

After production and transport through the qanat, the water is directed through a small open canal (*saqeh*) running through the village and collected in a reservoir (*birkeh*) at the end of the open canal.

This *birkeh* was built in the 1950's to collect the water that is used for irrigation of a community garden. The *birkeh* can be opened and closed for irrigation from an outlet closed off with stones and cloth. Several discharge measurements of the water entering the *birkeh* have been taken in the winter 1999/2000. The maximum observed discharge was 1.1 l/s. This was measured when the villagers did not use the water from the *saqeh*, and the full discharge of the water production section entered the *birkeh*. In contrast, measurements that were taken when water was drawn from the *saqeh* gave an average discharge of 0.35 l/s. The water extracted by the qanat system in Shallalah Saghirah has been tested and proved to be of good chemical quality. The results of the chemical analyses of a sample taken on June 11, 1999 are presented in Table 1 above. Values are compared with the standards for drinking water given by the World Health Organization.

Social History, Mobility and Income Sources of Shallalah Saghirah

The inhabitants of the village of Shallalah Saghirah are descendants of one ancestor called Musa Oqlah Hariri. Musa originated from the clan of Al-Hariri on the Hawran Plain in the south of Syria. Batatu mentioned that the clan was dominant in eighteen villages on the Hawran Plain. Musa was one of the two sons of Oqlah Al-Hariri who decided to migrate from the Hawran to the Khanassir Valley during the end of the 19th century. The Ottoman Sultan Abdul Hamid, who ruled from 1876-1909, owned estates northwest of Khanassir Valley. Musa worked on these estates to prevent his sons from being sent to the Ottoman army. Lewis describes the area of Khanassir Valley during that time as a frontier area with nomadic Bedouin tribes in the east and Ottoman landowners in the west. After several years, Musa bought the land of Shallalah Saghirah illegally from a local landowner. This transaction was witnessed by a powerful Bedouin *shaykh* from the Feda'an tribe named Mujhim Ibn Muheid.

Two years after he had bought the land, Musa started to clean the Motherwell of the qanat (*ras el nebe'*). Musa's five sons, Rashid, Mahmoud, Qanoush, Khatib and Ali helped him with this. After the cleaning, the water returned. Hearing of this discovery, the former landowner wanted to have his sold share back. Musa obviously refused and went to Mujhim Ibn Muheid. The powerful *shaykh* offered his protection, and from this day on, the protection and settlement of Shallalah Saghirah was established. Musa and his five sons lived prosperously on the benefits they gained from the water of the qanat.

After the land reform which was initiated by the Syrian government in 1958, the land of powerful landowners was divided among individual families and the property of Shallalah Saghirah became officially government property. However, the inheritance rules which were in use before 1958 are virtually still observed among the villagers with regard to landownership.

Until the 1960s the inhabitants of Shallalah Saghirah could be divided into five main households, called *biout.* These are the households of the five sons of Musa: namely Rashid, Mahmoud, Qanoush, Khatib and Ali. The term *bayt,* plural *biout,* is the arabic term commonly used for household. In Shallalah Saghirah it is nowadays used to refer to the patrilinear descendants of a particular *bayt* in the past. The definitions of household and anthropological approaches to the Arab family in family studies have been discussed by Young and Shami. In the case of Shallalah Saghirah, family (*ahal*) refers to all descendants of Musa, which means the whole village is one family. *Bayt* refers either to the patrilinear descendants of the past five households (one of the five sons of Musa) or to the present small nuclear households.

During the times of economic and political change in the 1960s, some villagers left. In 1977 the village was empty for two years because of a dispute with another village. They fled to Raqqa, 150 km east of Aleppo. Currently only the *biout* of Rashid, Khatib and Ali are represented in the village by men. The *bayt* of Qanoush is represented by three women married to men of the *bayt* of Ali. The *bayt* of Mahmoud completely left the village.

There always has been a relatively high level of mobility of people in rural areas of Syria. Kin relations are a very important reason for travel. Of course, the villagers of Shallalah Saghirah have relatives in the Hawran plain from where they originally migrated and they have regular contact with each other. Traditionally, the inhabitants of Shallalah Saghirah are used to travel seasonally with their sheep to northern areas of Aleppo province in late spring and summer to let them graze on areas with higher rainfall. Birks (1994) mentioned that the 1970s international migration in the Arab region had altered the social organization of many villages. With respect to social mobility and relationships, they have connections with the cities of Aleppo and Raqqa, the town of Azzaz (60km north of Aleppo), and Sfeereh, Rasm El Nafl, Fijdan and other villages in Khanassir Valley. Regarding international labour migration, the village has connections in Lebanon and Saudi Arabia. Jordan used to be a target for labour in sheep shaving but this work has shifted to Saudi Arabia. Lebanon is a preferred destination especially by the younger generation, who normally engage in construction work in Beirut.

Table 2. Main Income Categories

Category	Daily income/ person (S.L.)	Location	Seasonal/ Daily
Selling sheep on the market	400	Syria	S
Shaving sheep	750-1500	Saudi Arabia/Syria	S
Construction work	500-1000	Lebanon/Syria	S
Government	250-500	Syria	D

Until 1977, the major source of income was agriculture. Sheep, rain fed barley, irrigated fruit trees and vegetables in the garden of the qanat (*bustan*) provided enough food and income for the people. After the evacuation in 1977, the sources of income changed radically. Alongside with the two year evacuation, in the mid 1970's modernization and rural-urban migration patterns have altered the socio-economic landscape considerably as described by Stevenson. The current income categories are summarized in Table 2 above. Selling sheep on the market is now usually practiced by the older generation. They own most of the sheep and have a long-term relationship with their seasonal contractors in the northern parts of Syria. The amount of income depends on the rainfall during the year. One of our key informants told us that in a good year he would receive a total of 170.000 Syrian Lira (45 S.L. =1

USD) for selling sheep. He estimated that in a dry year he might not receive more than half of this amount.

Water Use and Rights in Shallalah Saghirah

The villagers use qanat water to irrigate a community garden (*bustan*) to grow food crops such as onions, cucumbers, tomatoes and other vegetables for additional nutrition of the households. The garden also contains fruit trees such as mulberry, figs and pomegranates. In addition to that, they grow irrigated barley to provide feed for the sheep. The western part of the *bustan* contains the trees and the eastern part the arable land. Besides the irrigation of the *bustan*, elderly people in the village make use of the qanat water by irrigating small-scale private plots for growing vegetables and herbs.

The division of landownership of the *bustan* is essential to understand the rights for irrigation times. The five sons of Musa divided the *bustan* into five equal parts. They decided that each of them had the right to irrigate his land every five days. The agreed order was: 1. *bayt* Rashid, 2. *bayt* Mahmoud, 3. *bayt* Qanoush, 4. *bayt* Ali and 5. *bayt* Khatib. This order has not changed since then. The descendants of each of the five sons divided the land in mutual agreement according to inheritance laws. The ones who emigrated lost their rights on irrigation water. However, they can claim it back whenever they return, but only if they did not sell their land. Presently, the descendants who hold the right to irrigate and are resident in the village are seven elders: *bayt* Ali, *bayt* Khatib and *bayt* Rashid. These seven are called the *haqoun ("the holders of the right")*.

Action at village level in pilot project

Method of intervention

Together with the local village elders and their sons, the priorities of the community with regard to the use, repair and maintenance of the qanat were discussed and determined. During the focus meetings, participatory tools like community maps were used to facilitate the discussion between qanats users. From these focus group meetings, and based on the local technical knowledge, a plan for the cleaning and renovation was developed and generally agreed upon. This cleaning and renovation took place in the summer of 2000 with financial support of the Dutch and German Embassies in Damascus.

Constraints and reluctant attitudes towards Qanat cleaning

Several focus group meetings have been held with the *haqoun*. In the beginning it was impossible to get all seven of them together due to an internal dispute between family members of different *biout*. Some attempts in the past had made by family members to ease the tension and mediate between the different *biout* through the so-called "wedding alliances." In this case, a son of a particular *bayt* decides to marry a wife from "the other side" as a way of alliance. However, from time to time tensions arise and are expressed in little disputes.

With respect to the qanat, the use of rubber pipes for irrigating personal plots outside the rotation system was the subject of such a dispute. The villagers use rubber pipes as siphons to draw water from the *saqeh* for domestic water use. This is allowed throughout the daytime. However when someone uses this pipe for irrigation, it should be done according to the rotation system. Villagers accused each other of the use of these pipes for irrigation without following the rotation system. The village does not have a chief (*mukhtar*) and disputes are not solved immediately by the family themselves. Weak leadership therefore is forming a constraint for the regular maintenance of the qanat.

Despite the latent constraints and reluctant attitudes, a general willingness was felt for cleaning the qanat as was expressed in the group discussions. Also through the discussions and field work conducted, some men of the younger generation became more and more interested. But after sometime it was realized that without getting the *haqoun* together, the cleaning would not take place.

However, the presence of the scientists and the many group meetings had apparently stimulated the *haqoun* to settle their differences during the feast (*'aid al fitr*) after the Islamic fasting, *Ramadan*, in January 2000. Therefore, another focus group meeting was planned, this time with all *haqoun* present. It was felt there was a need to create an informal institution and this was suggested to the *haqoun*. They supported this idea and in the focus group meeting, the *haqoun* made an informal written agreement among them to regulate the maintenance and renovation work of the qanat. They agreed upon regulations for the use of rubber pipes to extract water, and made a list of all the workers that would be available for the cleaning work, and at what times throughout the year. This last point is important because of the seasonal migrant work that many young men are doing. It was also decided that the *haqoun* would be forming a committee that represents the village. With this agreement and a technical work plan/budget, the committee and the researchers will initiate a search for funds necessary for cleaning and renovation.

Priority Activities

Before the informal agreement, several focus group meetings were held with the *haqoun* who had a good relationship with each other. In the first group meeting, a map was drawn of the construction of the qanat by the respondents themselves. This map was used in other group meetings. Because the dispute had little to do with the qanat itself, the *haqoun* gradually came to an agreement on the technical work plan. First of all, the *haqoun* decided that the cleaning work should be done by the villagers themselves. Birks stressed that repair and improvement should be carried out by local communities themselves instead of imported labour.

The *haqoun* put together priority activities for the renovation work using the indigenous terms for the important parts of the qanat. Because the water production section of the qanat is of direct benefit to the *haqoun,* they decided that this should be their first priority of cleaning. They stated correctly that if this dries up, the village will have to be evacuated again. The priorities based on the different sections of the qanat system are summarized below according to activity:

1. It was suggested to start at air shaft A1 called *sunduq ("the box"),* which is closed by debris and boulders from above. This airshaft provides oxygen for workers down in the qanat tunnel. Once this airshaft is cleaned from above, it is possible to observe the damage on the *jub el saghir* .

2. According to the *haqoun*, water well W1 is filled with debris from above and the basalt walls are collapsed at certain places. After cleaning airshaft A1, this well should be cleaned from above and below and a wall should be constructed to enforce the well and prevent future collapsing.
3. Tunnel T1, which leads towards W1 is intersected by a low roofed reservoir of 3 by 3 m. This reservoir, called el *ghurfah ("the room")* is supposed to be filled with water and debris. This room needs major cleaning.
4. An unsuccessful attempt was made in the past to drill an airshaft in the Motherwell (W2), called *ras el nebe' ("head of the spring")*. It was suggested to locate W2 from above and drill a shaft to make it more accessible for the workers. The well needs major cleaning. Next to that the tunnel towards the Motherwell (T) and two shafts (A3, A4) need cleaning.
5. Airshafts A2, A5 and A6 need some cleaning but their construction is completely intact. Also the first water production well (W3) needs cleaning of the walls.
6. S1 is the source of the qanat, where the water reaches the surface (*el a'yn*). This source needs extending of the walls if more water is collected. Also, the canal (*saqeh*) running from the source to the collection reservoir (*birkeh*) needs reconstruction and the reservoir needs to be cleaned from debris.

Table 3. Costs of renovation

Activity	# Working days	Costs
1	10-15	125.500
2	10-15	160.500
3	10	31.000
4	5	13.000
5	5	30.000
6	10	15.000
Total	60	360.000

The technical work plan developed by the *haqoun*, includes the priority activities and the estimated number of working days for each activity. The activities would cost in total 360.000 SYL which is equivalent to USD is 7, 826 $.

Cleaning Work

After developing a research proposal based on the outcome of the group meetings, local funds were granted by the Dutch and German Embassy in Damascus and cleaning work started on 17 June 2000. A group of workers consisted of village committee and a supervisor was chosen from the village community itself. The community work plan was followed and a weekly work programme with names of the workers was prepared by the supervisor. The whole cleaning activity was officially regarded as an archaeological excavation since it concerned a Byzantine site. Therefore on daily basis the worksite was attended by a representative of the Aleppo Museum, who was very instrumental in keeping the work spirit high. In case of difficulties between workers, he would always mediate.

In the beginning of cleaning the sunduq, the work was quite smooth. But six weeks later, things started going down and some problems between the villagers' elected supervisor and some group members were observed. The elected group supervisor thought that it was best if the workers programme was made by the government representative of the Museum. This was done and everything was back on track again.

Impact and Lessons Learned

The technical impact of the cleaning was measured by a flow meter, placed in the open channel running through the village. We measured an increase of water flow in winter time, which means that the recharge from rainfall is directly caught by the tunnel and the water is free to flow. Another promising result is that 16 young men from the community are trained for qanat cleaning and are able to maintain their qanat in the future. Whether that is socially sustainable can only be observed on the long term. When we returned in the summer of 2002, the village was divided in different descendant groups like before the cleaning and social tension was still present, but the qanat was flowing and had given a substantial amount of water throughout the year.

The cleaning raised a lot of attention of Syrian and international officials, which benefits the public awareness on these sustainable water supply systems. From the experience we have had with the cleaning in Shalalah Saghirah, we have developed some feasibility criteria that can be used for any other qanat sites in the Middle East.

These criteria are as follows

A stable groundwater level: pumping is a major threat to qanats. If there is a fast decrease of groundwater level, it is impossible to re-use qanats for agriculture unless the pumping stops within a range of 3.5 km from the qanat tunnel.

Consistent underground tunnel construction: many of the ancient qanat workers died because of the danger of the job and potential collapsing of tunnels. If there is any doubt about the consistency of the underground construction, care should be taken and renovation reconsidered out of safety reasons.

Strong social cohesion in community: this is a condition for any management of qanats as a common water resource. It should be noted that social cohesion differs and that it therefore should be studied on a case by case basis. In the Arab rural areas, a strong village or family leader is usually a condition for good social cohesion.

Clear ownership of qanat: this is a condition, not to have any problems or conflicts about claiming ownership when there is more water coming from the qanat.

Existing system of rights: Water rights and regulations on water, to be used when water increases.

Willingness of users: willingness of users who are the ultimate beneficiaries is critical. For instance if they are not willing to clean, the work is not likely to be sustainable.

Application of results pilot project

Lessons learned from the pilot renovation led to the development of renovation criteria that can be used to decide whether it is profitable to renovate. In 2001 we conducted a national survey of remaining qanat sites in Syria. We used a structured method of observation and reporting that brought together researchers from several disciplines to conduct interviews with knowledgeable farmers and prepare reports on hydrogeology, damage status, irrigated gardens, and gradient of the tunnels.

Figure 2: Selected sites for renovation

From our survey data, we selected three possible sites for renovation (as shown in Figure 2): Dumayr, Qarah and Arak. In March 2002 renovation was finished in Dumayr with the generous support of the Swiss Development Cooperation Fund. The users community is well organised in a traditional system of "water committees" and "water guards" supervised by the farmers' cooperative. The cooperative also paid part of the renovation costs themselves from their credit system. Also actively involved were the General Directorate of Antiquities and the Regional Directorate of Irrigation of the Awaj/Barada Basin that is active in qanat renovation in Damascus Province. This ensured that both the formal and informal institutions are participating. The ultimate responsibility and monitoring of the renovation is with the farmers' cooperative. We hope with this effort to encourage preservation of indigenous knowledge on qanats that still barely exists in Syria and by starting with the community needs and priorities to revive sustainable qanat use for the future.

Institutional Framework

In August 2002 we found some of the qanats we surveyed dried up since the last eight months. The qanats of Qarah were worse off as they were in an alarming state of deterioration. Although an annual budget for qanat maintenance is allocated to the Regional Irrigation Directorate of Awaj/Barada Basin, no national plan for qanats in Syria exists. Qanats officially fall under the Law on Antiquities and the Directorate of Antiquities has just started to register some of the sites. Both Directorates should be working together in qanat preservation. Since 2000, international conferences have been organized, and the IPOGEA/EU project that is developing national research and development plans for the preservation of foggara's/qanats in Italy, Spain, Morocco, Algeria and Tunisia, is a case in point of a regional effort in protection of Qanats in the Mediterranean region.

Conclusions

Cleaning of an ancient qanat is not an easy exercise. Not only is the work itself technically difficult but also the social organisation around a qanat has major implications on the sustainability of a qanat system. In the pilot case of Shalalah Saghirah there is a good hydrological result of qanat renovation that was based on community work plan, however tensions between individuals and weak leadership may hamper the progress and prevent maintenance of the qanat on the long term. Also the changing economic circumstances that force the younger generation to look for other sources of income than agriculture and the high social mobility that is found at village level influences the sustainable maintenance of the qanat.

The project aimed to characterize and describe the social and physical world around a qanat in order to understand the different forces that affect the use of a qanat in a modern environment. The project showed that focused group meetings on community level help in developing successful project proposals. The approach used starts with the direct users of the qanat water. Individuals who expressed the need for renovation but do not have financial resources, can serve as facilitators and key informants to motivate other inhabitants. Focus group meetings can help them to conceptualize their needs, rank their priorities and formulate a work plan and budget. Also focus group meetings can enhance communication between qanat users when problems from the past need to be solved. When there is weak leadership, creation of an informal institution such as a committee of elders, can possibly help enhancing the sustainable use and maintenance use of qanat systems.

Lessons learnt from the pilot renovation led to the development of renovation criteria based on an inter-disciplinary approach. These criteria are: (i) a stable groundwater level, (ii) consistent underground tunnel construction, (iii) social cohesion in community, (iv) clear ownership of qanat, (v) existing system of rights and regulations on water, and (vi) willingness of water users to contribute.

Nationwide, qanats are rapidly drying up in Syria. Three sites were chosen for possible renovation as they still provide a substantial amount of water. The selection of the sites was based on a national survey conducted in 2001 and the knowledge of the pilot study. The Drasiah qanat of Dmeir was chosen to be renovated and was concluded successfully in the spring of 2002.

During a field survey in the summer of 2002 further rapid drought among qanats was observed. A thorough plan should therefore be developed at national level where all stakeholders are represented. This should provide an institutional framework that is vital in the sustainability of the use of the ancient qanats of Syria.

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12

Comparison of Traditional and Contemporary Water Management Systems in the Arid Regions of Tunisia

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Introduction

Water is vital to every human community and is an essential resource for economic development, agricultural productivity, industrial growth, and human well-being. The availability of a clean, safe, and secure water source has been, and will always be, a major concern for human populations (Kierche, 2000).

Middle East and North Africa (MNA) region is by far the driest and most water scarce region in the world. The situation is expected to worsen due to rapid population growth, increase in household income, and irrigation expansion. The water issues are increasingly affecting the economic and social development of MNA countries (Renard *et al.*, 1996; Oweis *et al.*, 2001).

Water management forms the most critical process in dry areas, as it impacts livelihood, food security, land conservation and productivity and society in general. Most of the MNA countries are dry and all in the developing world. These developing countries often do not possess the technical know-how, financial capacity or the social structure to undertake modern water management approaches. On the positive side, societies in dry areas have learnt to cope with water shortage through the centuries (Oweis *et al.*, 2001; Ben Mechlia & Ouessar, 2002).

In the southeastern region of Tunisia where the annual rainfall ranges between 150 and 230 mm, the areas treated with traditional water harvesting techniques (WHT) (mainly jessour: small retention dam) were limited to the upper parts of the *wadi* catchment zones (El Amami, 1984). However, with the independence there has been a gradual extension of the cultivated fields, mainly olive trees, to the neighboring areas thanks to the confection of *tabias* (same as *jessour* but practiced on foothills) and water spreading structures in the foothills and surrounding plains *(jeffara)*, exploited normally as rangelands. In parallel, the soil and water conservation service of the Ministry of Agriculture has also introduced new techniques (gabion units, ground water recharge wells, etc.) especially during the last decade, which witnessed the implementation of the national soil and water conservation strategy and the water resources mobilization strategy (Mini. Agri. a & b., 1990). Then, the enrichment of the existing traditional techniques has raised the question of the nature of the linkages between the traditional and the newly introduced WHT, are they complementing or conflicting with each other? What are the perceptions of the local communities of these changes in the landscape occupation?

General Characteristics of the Watershed of Wadi oum Zessar

The study watershed (SWS) belongs to the region of south eastern Tunisia (province of Médenine). It stretches out from the south-west, in the mountains of Matmata, the highest point (Kef Mzenzen 690 m) near the village of Béni Khdache, going into the Jeffara plain, via Koutine, into the Gulf of Gabès, and ends in the saline depression (Sebkhat) of Oum Zessar (Figure 1.). The general characteristics of the SWS are mentioned in Table 1.

Table 1. General characteristics of the study site.

Area (km^2)	367
Annual rainfall (mm)	180
Mean annual temperature (°C)	20
Altitude (m)	0-690
Population (inhabitants)	24188

By its position, the climate in the SWS is of the Mediterranean type. It is influenced by that of the Dahar and the Matmatas (*continental arid*) on the one hand, and by the presence of the Mediterranean Sea (Gulf of Gabès) (*maritime arid*) on the other.

The temperature in the SWS is affected by the proximity to the sea and the altitude. The coldest months are those of December, January and February with occasional freezing (up to -3 °C). June-August is the warmest period of the year during which the temperature could reach as high as 48°C.

Having an arid climate, the rainfall in the SWS is characterized by low averages, high irregularity (both in time and space) and torrentiallity. It receives between 150 and 240 mm per year with an average of 30 rainy days (Derouiche, 1997). The 'wet' season stretches out over the months of November, December, January and February, and the remaining period is dry. The summer months (June-August) are almost rainless. Highly intense showers (more than 50 mm/h) could occur at any moment during the period September-March (Fersi, 1976).

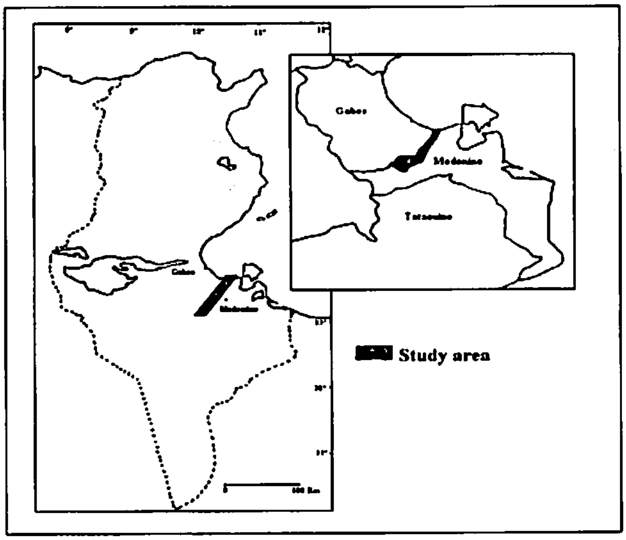

Figure 1: Location map of the watershed of Wadi Oum Zessar

The farming systems are marked by their diversity from the upstream to downstream areas of the SWS. These systems are essentially distinguished by (Sghaier *et al.*, 1997; Labras, 1996; Rahmoune, 1997):

- a non regular agricultural production that varies from a year to another depending on the rainfall regime,
- the development of arboriculture and the extension of newly cultivated fields at the expense of rangelands,
- gradual transformation of the livestock husbandry systems from the extensive mode, highly dependent on the natural grazing lands, to the intensive mode,
- development of the irrigated agriculture exploiting the surface and deep ground water aquifers of the region,
- the predominance of the olive trees (almost 90 %) and the development of episodic cereals.

According to Sghaier *et al.* (2002), the main farming systems are:

The "Jessour" System

These are essentially developed in the upstream areas of the SWS in the mountainous zone of Beni Khédeche. These systems are based on runoff water harvesting thanks to the millennium technique of "Jessour". They are marked by the fruit arboriculture notably the olive. Annual crops such as cereals, vegetables and some annual crops (beans, small pea, etc.) are also occasionally practiced. The cropping areas are extremely small and rarely exceeded 0.25 ha. Tree densities are relatively high and can exceed 60 trees/ha. The average parcel number by farmer is 6. Recent researches (Labras, 1996; Sghaier, 1997) have revealed that the annual agricultural income by farmer is estimated to 1,195 TND with 69 % of the vegetable production source. The gross margin per hectare is relatively low floating around 110 TND (Labras, 1996). The yearly non agricultural income is estimated to 200 TND with 69 % due to migration.

System of Irrigated Perimeters

Two subsystems could be distinguished:

The subsystem of private irrigated perimeters: It is based on surface wells. It is localized in the upstream area of the SWS (at Ksar Hallouf) and in the downstream areas as well. The agricultural production is based on cash crops, greenhouses, vegetables and fruit tress. The cropping area varies between 0.2 and 10 ha (Rahmoune, 1997).

The subsystem of public irrigated perimeters: It is based on collective drilling created normally by the State. The water management is insured by a collective interest association known by the 'AIC'. These perimeters are situated in the downstream zone of the SWS, such as the irrigated perimeter of Kosba.

The System of Olive Trees

This system is marked by the dry arboriculture dominated by the olive trees. It is mainly encountered in the plain and in the piedmonts. The area varies from 5 to 46 ha. Other tree species such as, almond and apples are also present.

The System Multicrops - Breeding

This system is weakened by the climatic irregularities. The agriculture is of the rainfed type associated to an important livestock husbandry component. Two subsystems could be identified:

The subsystem of the marginal agriculture: It is marked by its small area and the most part of income is of non agriculture sources.

The subsystem of the agro-breeders: They are former breeders which are transforming their system by introducing an agricultural component which becomes increasingly important at the expense of livestock husbandry. It is mainly found in the downstream area of the SWS on fragmented average areas of 25 to 85 ha. The livestock is comprises 20 to 150 goats and sheep, and 100 dromedaries grazing in the saline range lands of the *sebkhats* (saline depressions).

Water Harvesting: Description and Inventory

Wide varieties of water harvesting techniques are found in the SWS. In fact, the hydraulic history of this watershed is very ancient. Carton (1988) witnessed by the remnants of a small retention dam, supposed to be built in the Roman era, near the village of Koutine and the abandoned terraces in the uphills of wadi Nagab in addition to numerous flood spreading based structures (henchir Zitoun, henchir rmadi, etc).

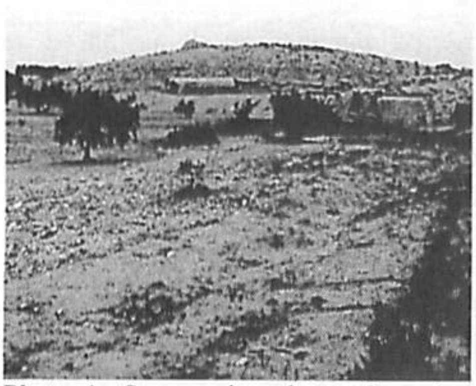

Photo 1: *Storage dam dating from the Roman era near the village of Koutine.*

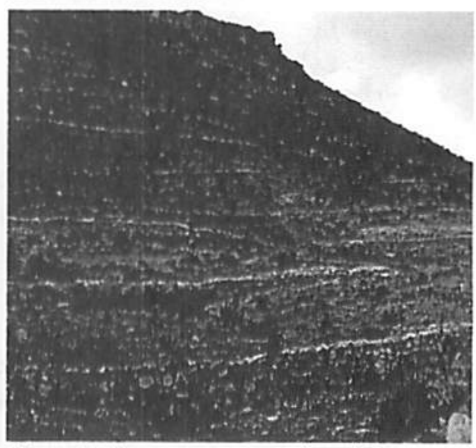

Photo 2: *New terraces on the jebel of Tajra.*

Terraces

Like in other regions of the country and the world they are constructed on steep slopes. They are formed of small retaining walls made of rocks to slow down the flow of water and control erosion (Oweis *et al.*, 2001). It seems that this technique is the oldest adopted WHT in the area. However, they are completely abandoned and only some remnants are still found in the upper extreme area of wadi *Nagab*. Nevertheless, they have been recently readopted for small scale afforestation works or olive trees plantations in the mountain ranges (Photo 2.).

Jessour

This system is also an ancient WHT widely spread in the region of the mountains of Matmata (Ben Ouezdou *et al.*, 2001). It is practiced in the inter mountain and hill water courses to intercept runoff and sediments. The *jessour* is the plural of a *jesr* which is a hydraulic unit made of three main components; the dike, the terrace and the impluvium. The impluvium is the area destined for collecting and channeling of the meteoric water. It is bounded by the natural water dividing line.

The terrace is the cropped area. It is formed progressively by the decantation of the carried sediments. Generally, the fruit trees (olive, fig, almond, date palm, etc) and the legumes (pea, chickpea, lentil, broad bean, etc) are planted in the neighborhood of the dike while the remaining areas are cultivated with cereals (barley, wheat).

The dike *(tabia, sed, katra)* is a barrier destined to block the sediments and run-off water. Its body is made of earth equipped with a central *(masraf)* and/or lateral *(manfes)* spillway assuring the evacuation of the excess water.

The jessour are mainly found in the upstream mountain area of Béni Khdache and Moggar (Photo 3).

Photo 3: *Traditional typical Jessours of the region.*

Photo 4: *Newly installed tabia on the piedmonts area.*

Tabias

Tabias are essentially situated in areas with more or less profound soils with the slope not exceeding 3%. In the Oum Zessar watershed this means the area between Bhayra and Koutine. The tabia is formed by a principal bank situated along contour lines, of 50-150 m and at the ends lateral bunds with a length of about 30 m. Water is stored until it reaches a height of 20 to 30 cm, after which it is diverted, either by a spillway or at the upper ends of the lateral bunds. The tabia gains its water directly from its impluvium (K values between 6 and 20), or by diversion of wadi runoff by a *mgoud* (Alaya *et al.*, 1993). In general annuals and fruit trees are cultivated on it (Photo 4).

Cisterns

These techniques, locally known by *fesquia* or *majel*, are built for the collection of rain water and its storage for different purposes like animal drinking, domestic uses and irrigation.

A cistern is a hole dug in the soil with a gypsic or cement coating to avoid vertical and lateral infiltration. Generally, each unit is made of three main components; the impluvium, the decantation basin, and the storage and pumping reservoir.

Small to large (5 to 50 m^3) cisterns can be found in the entire SWS (Photo 5).

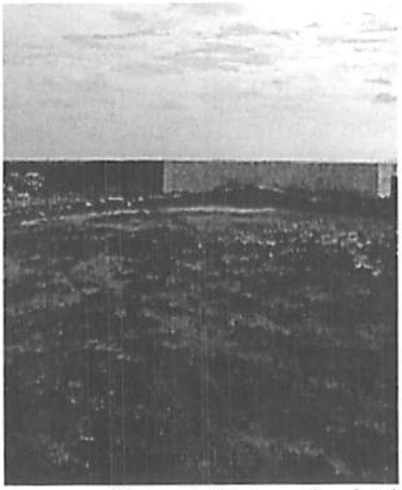

Photo 5: *Cisterns for drinking water and animal watering.*

Gabion units

These structures are made of blocks of galvanized nets (gabion) filled with rocks. They are built in the wadi beds. In general, they have the form of a rectangular spillway. They are used for two purposes:

- slow down the runoff flow so as to increase the infiltration rate to the underground water tables; and/or
- divert a portion of the runoff to neighboring cultivated fields (tabias).

These units are encountered as small check dams on the main intermittent water courses (Photo 6).

Photo 6: *Gabion unit on wadi Naguab.*

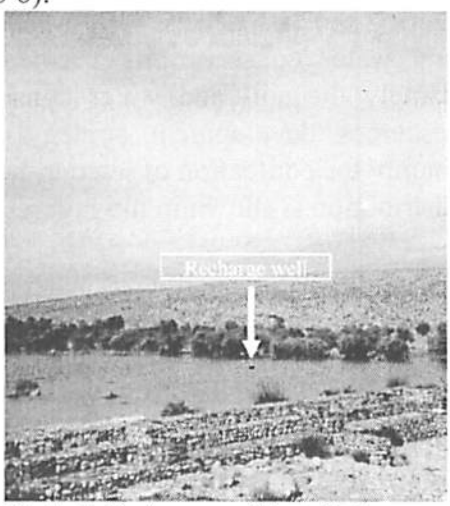

Photo 7: *Recharge well installed behind a gabion unit on wadi Koutine (after a rainfall shower).*

Recharge wells

When the permeability of the underlying bedrock is judged too low, casting tubes could be drilled in the wadi beds to enhance the infiltration of runoff water to the ground aquifer. In our SWS, these recharge wells were installed behind gabion units at the level of Koutine (Photo 7).

Water Harvesting Realizations

The massive water harvesting projects in the province of Médenine, and particularly in the watershed of wadi Oum Zessar, started in the 1980s. During the period 1990-1997, this intervention has concerned the micro watershed treatment and the maintenance of existing structures over an area of 35918 ha (7200 ha in the SWS) and 39147.5 ha (11000 ha in the SWS), respectively. Besides, 271 recharge and spreading units (238 units in the SWS) have been installed (Table 3). These interventions have required, during 1980-90, the mobilization of an investment of 9.71 millions TND for the province and 2 millions TND in the SWS. There has been the generation of 4,300,000 working days (WD) of which 96, 4615 WD in the SWS (CRDA, 1998). Then, the SWS represented a main focus for the implementation of the various practices undertaken. In fact, more than 70% of the water mobilization units have been installed in this watershed and the remaining works represent more than 20% of the total carried out actions.

During the last decade (1990 - 2000) the regional services of soil and water conservation executed two main national programs, namely the soil and water conservation strategy and the water resources development strategy. The works undertaken were mainly the confection of jessour, tabias and terracing. The temporal distribution is shown in the Figure 2.

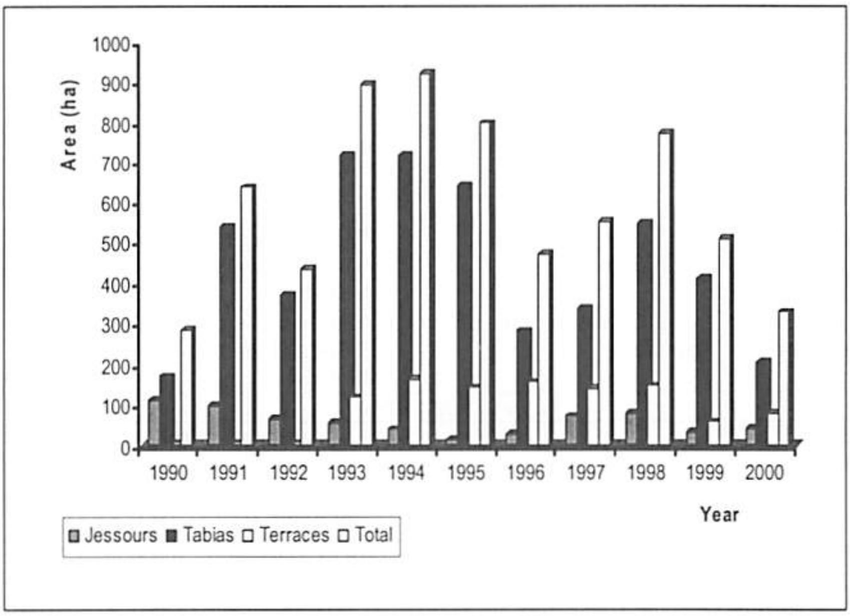

Figure 2: Undertaken works for the period 1990-2000.

The work related to the mobilization of surface water was mostly undertaken between 1990 and 1993. By the end of year 2000, they concerned in fact the confection of 243 recharge units and 27 spreading units in addition to the installation of 3 recharge wells.

Water Harvesting Techniques Perception

Methodology

The local community's perception towards each technique (traditional or modern) concerned:

- land use and tenure,
- production and productivity (yields, incomes, charges, etc.),
- appreciation of the newly introduced techniques compared to the traditional ones (efficiency, land use, farming systems, incomes, environment, well-being, etc.)

The SWS were divided, at the level of the village of Koutine, into two main zones: upstream area and downstream areas. Agro-socio-economic surveys were prepared and carried out. The geographical distribution of the surveys is indicated in Table 2.

Table 2. Composition of the inquired groups.

Region	Zone	Inquired farmers
	Upstream area	
Bénikdache	Extreme upstream area: - Sub watershed of wadi Naguab. - Sub watershed of wadi Hallouf	*Beneficiaries of the WH works * Surface wells * herders
Bénikdache + Méd Nord	Piedmonts	*Beneficiaries of the WH works * Surface wells * herders
Méd Nord	- Sub watershed of wadi Koutine	*Beneficiaries of the WH works * Surface wells * herders
	Downstream area	
Sidi Makhlouf		* Irrigators on borehole wells * Irrigators on surface wells * Beneficiaries of the WH works
	Sebkhat: Halophyte ranges	* herders
	Coast	* Fishing men

The farmers were asked whether the works have had some impacts or not on:

- Yield increase,
- Water erosion control,
- Ground water recharge,
- Runoff reduction,
- Flooding control,
- Cropping diversification,
- Biodiversity improvement,
- Clovis (sea food) population reduction.

Results

The preliminary conclusions of this first investigation are summarized in the following Table 3.

Table 3. Preliminary results of the farmers' appreciation of the WH work impacts in the SWS.

Group	WH impacts[a]					
	Yield∩	Erosion ∪	Recharge∩	Runoff∪	Flooding ∪	Diversification∩
Beneficiaries of WH works	56%	100%	100%	33%	100%	100%
Irrigators on drillings wells	87%	100%	100%	38%	75%	88%
Irrigators on surface wells	100%	100%	100%	50%	75%	100%
Herders	Rangelands degradation	Rangelands area∪	Species disappearance	Runoff∪	Flooding ∪	Diversification∩
	80%	60%	0%	75%	100%	-
Fishing men	Clovis∪	Erosion ∪	Recharge	Runoff∪	Flooding ∪	Diversification∩
	50%	100%	100%	75%	100%	-

[a]: *expressed as percentage of inquired farmers in favor of the statement.*

The WH works beneficiaries are largely in favor of the positive impacts regarding ground water recharge, soil erosion control and cropping diversification. H owever, they are still skeptical on the role of these works on yield improvement and runoff control. The livestock breeders and the irrigators have been found to be less sensitive. In fact, they are considered the first 'losers' of this intervention because the runoff waters are almost totally retained in the watershed which affected negatively quantitatively and qualitatively the halophyte vegetation of the *sebkhat* used as the main grazing area for camels during the winter.

With regard to the order of preference of the different techniques (jessour, tabias with natural impluvim (NA), tabias on spreading unit (SP) and gabions), here also the farmers reacted differently as shown in the Figure 3.

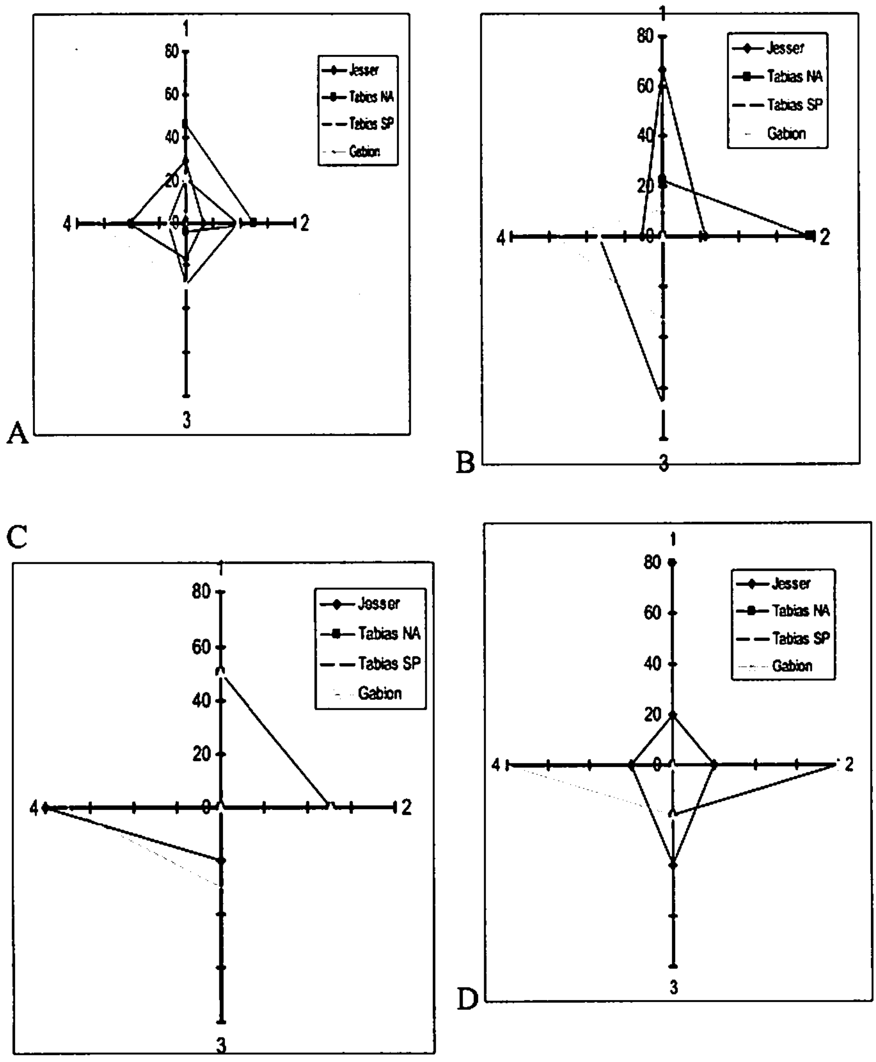

Figure 3: Order of WHT preference (1: first order; 2: second order, etc...) in the different compartments (a: whole watershed; b: upstream; c: downstream; c: piedmont) of the watershed.

In fact, in the upstream area and since the farmers are used to the jessours, the first order (67%) is given to this technique followed by the tabias and then the gabion. In the piedmont zones, however, the priority is given to tabias NA (80%) and tabias SP (80%) then jessours. In the downstream area, the order is reversed and both tabias are ranked first (50%) followed by gabion and then jessours.

It is clear that perception of the population of the used techniques depends largely on the tradition of the group and its location in the watershed.

Conclusions

In the arid regions of Tunisia, considerable investments are being made in maintaining the old water harvesting techniques (WHT) and introducing new ones to capture the scarce amount of rainwater (100 to 230 mm annually) for agricultural, domestic and environmental purposes.

A large variety of traditional (jessour, cisterns, etc.) and contemporary (gabion, tabias, recharge wells, etc.) WHT are encountered in the area. They have been playing various roles with regard to the mobilization and exploitation of rainfall and runoff waters (soil water, vegetation, flooding, aquifer recharge, etc.).

The local population is, in most of the cases, aware of the environmental impacts of the introduction of new WHT. However, the real perception depends largely on the activity of the farmer (rainfed farming, irrigation, livestock, etc.) and his location (upstream, piedmont, downstream, coast) in the watershed.

However, further refinements are needed to better include all possible impacts (positive and negative) that would occur as a result of the installation of the WH structures. The interactions between upstream and downstream areas have to be addressed thoroughly to ensure equitable sharing of natural resources between different end users.

The use of geographical information systems (GIS) and information technology (IF) would be of great value in transforming the obtained results as tool for decision-makers. The latter will be used in order to assess under which agro-ecological and socio-economic conditions, investment in water harvesting measures could be a viable undertaking in dry areas.

Acknowledgements

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Sustainable Management in Marginal Drylands
A Programmatic Overview

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Background

Desertification is a land degradation problem of major importance in the arid and semi-arid regions of the world. The lack of sufficient water coupled with the high population growth rates is leading towards a serious water crisis. The situation is likely to be much worse in the forthcoming years, particularly for water resources shared across national boundaries (UNEP, 2002). Therefore, there is a need to develop projects that will help to avert the serious water problems experienced in these areas. Management of water resources in drylands should be promoted in such a way that society's needs are met while at the same time protecting these resources, giving due consideration to both supply and demand (Adeel, 2001).

Deterioration of soil and plant cover has adversely affected nearly 50% of the land areas as a result of extended droughts and the human mismanagement of cultivated and range lands. Woodcutting and overgrazing are responsible for most of the desertification of rangelands; cultivation practices including accelerated water and wind erosion are responsible for most of the desertification in the rain-fed croplands; and improper water management, leading to salinization and water pollution, is the cause of the deterioration of irrigated lands. In addition to vegetation loss, erosion and salinization, desertification effects can also be seen in the loss of soil fertility, soil compaction and soil crusting. Combating desertification by rehabilitating degraded lands can be done successfully, using techniques already known, if financial resources are available together with community-based organizations and an enabling institutional environment that includes a political willingness to act (Schaaf, 2001).

In addition to combating desertification, it is now widely recognized that there is a need to conserve biological diversity. However, high population growth rates in most developing countries, and associated needs to provide food and income opportunities for the growing populations using biological resources, often impede environmental conservation efforts. The consequent land use conflicts concerning protected areas, *vis-à-vis* the economic use of lands for agricultural, forestry, grazing, settlement, industrial and other purposes, need to be solved by providing local populations with means to manage their natural resources in a sustainable and income-generating manner. In doing so, strictly protected areas (such as national parks) cannot be dissociated from their surrounding environments, inhabited by humans who need to satisfy their immediate needs for improving their livelihoods. Biosphere Reserves under UNESCO's Man and the Biosphere (MAB) Programme go beyond the confinements of strictly protected areas, including core protected areas for biodiversity conservation and buffer and transition zones where sustainable economic development is fostered in direct collaboration with local dwellers (Schaaf, 2001).

Many well-meant innovation schemes to combat desertification and to halt land degradation have shown less than satisfactory results because they took into account neither the specific needs and aspirations of dryland farmers and pastoralists, nor their socio-cultural values, norms and behaviours. While many studies in the past have focused on soil enrichment techniques, improved water retention and irrigation schemes, erosion control, sand dune fixation, introduction of drought-resistant xerophytes, etc., they have often done so from a purely natural sciences point of view, with little, if any, considerations given to the readiness of dryland dwellers to adopt new desertification control techniques. In addition, traditional knowledge on the conservation and sustainable use of natural resources has been largely overlooked or ignored as being "non-scientific".

This paper describes a participatory research project involving farmers and pastoralists of marginal areas and drylands, coupled with capacity building and information management. This project, intended to start in 2003, will enhance information exchange among scientists and custodians of local and traditional knowledge. This, in turn, would lead to increased food security and efficient environmental and water conservation, even in the world's marginal lands.

Definitions

Drylands: In the context of the project described in this paper, drylands are defined as the geographical regions climatologically described as arid, semi-arid or dry sub-humid. In these regions the ratio of annual precipitation to potential evapo-transpiration falls within the range of 0.05 to 0.65. Drylands can be considered all those areas which do not provide adequate quantity and year-round distribution of precipitation to sustain enough water resources to meet the society's livelihood. Obviously, drylands are predominantly located in arid and semi-arid climatic zones, however they may be found also under temperate or cold, or even locally within predominantly humid climatic zones.

Marginal Drylands: Marginal lands are understood primarily in a socio-economic sense, where biological and economic productivity are low due to adverse climatic conditions (high precipitation variability), edaphic conditions (low organic matter in soils) and topographic terrain (slopes). Species diversity in marginal drylands is much lower than in the more favoured humid zones, although plant and animal species have developed remarkable adaptations to severe ecological and climatic conditions such as salinity and aridity. Additionally, people living in these areas typically suffer from poverty and are vulnerable to threats related to food security.

Land Degradation: As defined in the text of the UNCCD, "land degradation" means the reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands, resulting either from excessive land use or from a process or combination of processes, including those arising from human activities and habitation patterns, such as: (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical, biological or economic properties of the soil; and (iii) long-term loss of natural vegetation. Land degradation is a global problem in which marginal lands are turned into wastelands and natural ecosystems are destroyed.

Focus on Marginal Areas in the Drylands of Africa and Asia

For the purpose of the project described here, the focus is on marginal lands in the arid, semi-arid and dry sub-humid zones of northern and western Africa, as well as Asia. From the purely floristic point of view, arid, semi-arid and dry sub-humid zones are rather poor. Species diversity is much lower than in the more favoured humid zones, but plant and animal species have developed remarkable adaptations to severe ecological and climatic conditions such as salinity and aridity. In a similar manner, humans have developed traditional systems of territorial planning and management in order to benefit as much as possible from the diversity of available resources.

This merits special attention, in particular for the maintenance, sustainable management and enhancement of gene-pools and natural resources found in adverse conditions. From a conservation point of view, however, many species in dryland Africa and Asia are in serious danger. Owing to mismanagement and overexploitation (overgrazing, burning, over-cutting of wood species, exploitation of medicinal herbs and plants, ploughing of the steppes for agriculture, over-pumping of groundwater, etc.) many plant species are now on the verge of extinction (UNEP, 2002). Traditional crop species and wild relatives of crops are also under threat, due to the introduction of high yielding cultivars. Regarding wildlife, most of the large mammals and game species are on the verge of extinction due to the alteration of their natural habitat and food supply, and to over-hunting in recent times. The rehabilitation of degraded drylands becomes, therefore, a necessity.

The availability of quality freshwater resources is a decisive factor in dryland ecosystems. Due to the pronounced climatic variability in the drylands, with their extremely varying temporal and spatial precipitation patterns, the conservation and sustainable use of freshwater resources is crucial for the continuation of human, as well as plant and animal life. The rational use of freshwater resources, based both upon traditional technologies and scientific knowledge, needs to be addressed in an encompassing manner that does not dissociate water from its dryland ecosystem (Oweis and Taimeh, 2001).

Drylands in Africa and Asia show many similar characteristics, for example in terms of seasonal precipitation variability, pronounced diurnal temperature differences, poor soils with low organic matter and mineral contents, fragile vegetation covers and vulnerability to erosion, which make them interesting from a comparative point of view. However, they also show marked differences concerning their cultivation patterns and socio-economic as well as political parameters determining land use and land management.

Objectives of the Initiative

With the view that this project is focusing on developing countries in dry areas – particularly the region comprising Northern Africa, the Middle East, Central Asia and China – the following over-arching objectives have been identified:

a. Improved and alternative livelihoods of dryland dwellers.

b. Reduced vulnerability to land degradation in marginal lands through rehabilitation efforts of degraded lands;

c. Improved productivity through identification of wise practises using both traditional knowledge and scientific expertise.

The project aims to achieve the following targets:

- To facilitate the sustainable and integrated management of marginal drylands and their natural resources, including land, water and biodiversity resources, in collaboration with dryland users;
- To investigate alternatives and non-conventional sources of water and encourage their use to better match the water demand and supply in these water scarce zones;
- To support efforts of researchers and scientists working in the targeted region in strengthening the conservation of their natural resources and protecting the environment through rehabilitation of degraded marginal lands and increased knowledge sharing;
- To support on-going scientific capacity-building programmes, with emphasis on south-south collaboration for the transfer of environmentally-sound technology and expertise, including the incorporation and development of traditional knowledge;
- To disseminate scientific findings through a publication which will be diffused globally ensuring transfer of knowledge to other arid and semi-arid regions of developing countries. Local outreach will take place through national workshops which involve local stakeholders, government officials and scientists.

General Approach

This project will adopt a systematic approach for the long-term in situ conservation of natural resources by involving and supporting local populations in their efforts to use their natural resources in a sustainable manner, and through the application of scientific methods for improved management of marginal drylands. To evaluate the effectiveness of existing practices, a common methodology will be applied to all the selected study sites within the project.

On the whole, the project relies on existing activities within institutional networks such as the World Network of Biosphere Reserves of UNESCO, research institutions associated with UNU, and the ICARDA network of field stations and integrated research sites in the West Asia and North Africa (WANA) region; thereby avoiding an *ad hoc* approach. It aims *inter alia* at creating a coordinated network of study sites linked by a common understanding of purpose, which will provide benefits to each participating site in a synergistic fashion. It is expected that the collaboration of the three complementary partner institutions will also lead to methodological advances in comprehensive dryland research, management and conservation, which will benefit other dryland regions not covered by the project. This will be ensured through the application of rigorous quality criteria in the selection of the study sites.

The inter-disciplinary approach will be ensured through the participation of ICARDA's expertise in dryland agriculture, UNU's expertise in dryland ecosystem research, and UNESCO's applied field studies on desertification and environmental conservation. Participating partners will encompass a variety of scientific disciplines, including ecologists, experts in agriculture, pastoralism and forestry, soil and water scientists, economists, sociologists and protected area managers.

Framework of Assessment Methodology

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

A. State of Existing Natural Resources – water, soil, biodiversity

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

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

B. Characterization of Stresses

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

C. Description of Indigenous, Adaptive and Innovative Approaches

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

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

Quality Criteria for Selection of Study Sites

For the study sites affiliated with this overall project, the following basic criteria are a must:

- The site is representative of marginal lands as defined in this project as well as of the wider region of the country concerned so as to function as a testing and demonstration site, and should include major types of land degradation and communities affected by such processes;
- The activities at the study site must demonstrate the integration of disciplines and approaches;
- The group undertaking the work is interdisciplinary in its composition, and should involve experts of traditional technologies, and possibly NGOs;

- The scientists in the group must be recognized, in their respective, field for the quality of their research work;
- There are clear prospects for the continuity and sustainability of the sub-project itself, in particular with regard to the income-generating activities;
- There are clear mechanisms for the transfer of knowledge to other, similar activities in other countries;
- The research work must include explicit mechanisms for the exchange of expertise between custodians of traditional knowledge, scientists and local communities.

Project Activities and Outcomes

Under this project, several project study sites and integrated research programmes will receive support in order to strengthen their research capacities on sustainable dryland management and rehabilitation of degraded areas.

During the project, the following activities will be undertaken to accomplish the project objectives:

a. A **comprehensive assessment methodology** for integrated natural resource management will be developed.

b. For each study site, an assessment will be made of the current **status of integration** between the conservation of natural resources, community development and scientific information as well as the mechanisms for management and co-operation, all of which can then feed into an overall dryland management concept. This assessment will include socio-economic surveys aimed at identifying and understanding people's adaptation to management approaches, at evaluating strategies adopted by dryland stakeholders, and at identifying dryland management approaches which promote sustainability, based on a balance between human needs and resource conservation.

c. **Practices for sustainable soil and water conservation** will be identified with the local communities, and promoted via a site-specific approach. Practices involving traditional knowledge as well as modern expertise, or a combination thereof, will be tested with a view to combating environmental degradation, increasing dryland agricultural productivity, and enhancing resource conservation. An **information-base**, both in electronic (searchable) and hard-copy form, that emphasizes sustainable soil and water conservation practices based on traditional knowledge and modern experiments, will be made available for eventual further diffusion to other regions and countries affected by desertification.

d. Associated **training** on the handling of data collection and inventory techniques as well as on proven management technologies will be carried out, based on the specific needs identified at each study site.

e. At each site, one to two **income-generating activities**, based on the sustainable use of dryland natural resources, will be explored and supported within the financial means of the project. Long-term income-generating activities for local populations are expected to continue beyond the termination of the project.

f. National, sub-regional and regional **workshops and group training programmes** on dryland conservation issues, land management, rehabilitation of degraded areas, and the rational and sustainable use of natural resources, using both traditional knowledge and modern science, will be organized at the study sites, and targeted specifically at local populations at the grass-roots level and at scientists. An active, **inter-regional network**, facilitating cooperation between African and Asian scientists in the environmental field and biosphere reserve managers will be developed.

g. The project results will be published and widely distributed by UNU, UNESCO and ICARDA, in order to achieve multiplier effects.

Future Outlook

The development of this project is an outcome of the many years of networking activities in the region and active collaboration between UNU, UNESCO and ICARDA. It is intended to play a major role in conservation and rehabilitation activities while ensuring availability of sustainable livelihood alternatives. The mode of information and knowledge exchange is designed in a way to facilitate South-South exchanges. At the same time, leading experts from the North are also involved. By design, the generic findings of the project can be synthesized in a manner that they are applicable to other sites in the region targeted by this project.

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Summary Report of the Workshop

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Workshop Overview

The 5th International Workshop: "Sustainable Management of Marginal Drylands - Application of Indigenous Knowledge for Coastal Drylands" was jointly organized by the United Nations University (UNU), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Center for Agricultural Research in the Dry Areas (ICARDA), in cooperation with the Bibliotheca Alexandrina, Egypt.

The workshop comprised a two-day field investigative excursion in Northern Egypt, followed by two and a half days of technical sessions in Alexandria including paper presentations and discussions. The field excursion was coordinated by Dr. Fatma Abdel Rahman Attia and also supported by Dr. Boshra Salem.

This workshop focused on the strategies for sustainable management in marginal drylands. These strategies are most critical for protection, conservation and reclamation or rehabilitation of these fragile ecosystems. Such strategies are closely linked to human development and quality of life in these marginal areas. The workshop also emphasized the use of indigenous knowledge and traditional technologies for sustainable management of marginal drylands. Some work undertaken on this issue by UNU and its partners was presented. In keeping with location of the workshop, a secondary focus was on management of coastal drylands; this was adequately reflected in the organization of the field excursion and the workshop presentations.

Summary Report of the Field Excursion

Day 1: Saturday, 21 September 2002
(*See Photo 1*)

Wadi El-Natrun Area

Wadi El-Natrun ("Natrun" is derived from the Latin word "natrium" for the element sodium) is a part of the Western Desert adjacent to the Nile Delta. It is a narrow depression located approximately 90 km south of Alexandria and 110 km northwest of Cairo. The history of the area dates back to the Pharaohs, who used salts from the lakes for the process of mummification. The Romans extracted silica for glass from here. During the British era, a railroad system was built to move the salt from Wadi El-Natrun to Cairo. The importance of the wadi to Christians dates goes back to the 4th century, as Wadi El-Natrun was one of the stops during the Holy Family's visit to Egypt.

The climate of Wadi El-Natrun is arid (low and very variable rainfall, a long dry summer, a high rate of evaporation, low humidity, etc.). The annual average rainfall is about 55 mm, mostly in November and December. The mean annual temperature varies from 22.8°C in January to 28.8°C in August. Wind velocities usually range between 11 km/h and 20 km/h in winter and summer, respectively. Winds are usually from the north, northeast and northwest.

The wadi is oriented in a NW-SE direction between the latitudes 30° 17' and 30° 33' N; and between longitude 30° 02' and 30° 30' E. Its length is about 50 km, and it is narrow at both ends (2.6 km in the north and 1.24 km in the south) and wider in the middle (8 km). The wadi lies 23 m below sea level and is characterized by a series of 20 small disconnected lakes in the bottom of the wadi. Ten of these lakes are relatively larger in size and have permanent water reservois in all or some of their parts. The largest lakes are Lake Al-Gaar in the northwest side of the depression and Lake Umm Risha in the southeast direction. Other smaller, but almost permanent, lakes are Al-Hammra, Al-Fasda, Al-Bida, Al-Khadra, Al-Zugm (Zaagig) and Abu-Gubara.

Water enters the Wadi through two routes, as springs in some of the lakes, like the one found in Lake Hamara, and as very small streams on the sloping edges of the lakes (*See Photo 2*).

The main geological feature is the Wadi El-Natrun anticline, which trends in a northwest direction for about 35 km, from Ras El-Solymania in the north to Deir Macarious in the south. The axis is sinuous passing through most of the lakes of Wadi El-Natrun. The main geological formation of interest is the Moghra formation, which covers a wide area of the northern portion of the Western Desert, comprising sand and clayey sandstone with siltstone intercalations.

Groundwater quality is moderate (1,000-2,000 ppm, TDS) in the south and southwest, changing to poor (2,000-5,000 ppm TDS) in the east. The increase in salinity is also encountered at greater depths. Groundwater is a mixture of fossil and renewable groundwater. The main recharge source is groundwater lateral seepage from the Nile delta aquifer system and the infiltrating rainfall water.

About 4 billion m^3 of brackish groundwater is believed to be stored in the region. No utilization of such groundwater is practiced at present. In theory, this brackish water can be used for agro-industrial development and for potable water supply after desalination. However, such utilization must only be considered after proper evaluation of its impacts, as most of the water resource is non-renewable.

Al-Anba Saint Bishoy Monastery

This is a Coptic Christian Monastery located near the Beni Salama village. Most of the monasteries in the area have been rebuilt and restored between the 8th and 11th centuries (*See Photo 3*). The early churches had Roman/Coptic Architecture similar to the Bishoy Monastery. The monastery is divided into three sections, including communion, reading catechism, and a basin for sinners to bathe.

There are five monasteries that are designated as important archaeological sites by the Egyptian government. Tourist numbering in thousands, both local and from overseas, visit the monasteries each year. The most important monasteries are Saint Macarious Monastery (Abu Makaar), Saint Bishoy Monastery, El-Suryan Monastery, the Virgin Mary Monastery (also known as Al - Adrah), and the Monastery of Saint Bermos.

These monasteries were attacked several times by the barbarian expeditions from the Sahara believing that they are full of treasures with treasures. After the Arab conquest of Egypt, the Arab Caliph gave Christian monks in Egypt the amnesty to practice their religion. At that time the Christians used the area as the official residence of the Coptic patriarch. Even now the patriarch is elected from Wadi El-Natrun monks. A Coptic monk has to wait for ten years before being considered as a hermit monk. This tradition has been carried out for centuries among Coptic Christians.

El Alamein Museum
El Alamein is a small town about 120 km west of Alexandria. This museum is devoted to the battles that took place in the region during the Second World War. In 1942, the Germans, led by Rommel, and the Allies, led by Montgomery, fought one of the most decisive battles of World War II: The Battle of El Alamein. The victory, which went to the allies, saved Egypt for the Allies and led to the ultimate defeat (1943) of the Axis powers in North Africa. As a result, this area is now full of war artifacts, and land mines which still are scattered in the adjoining desert.

The outside area of the museum carries a display of war-time lorries, vehicles, cannons, tanks and other war remains. The interior of the museum contains a broad variety of exhibits, including charts, maps, plans, uniforms, and medals. Separate sections are devoted for Italian, German, British and Egyptian armies. The visit also included a stop at the British World War II Cemetery in El Alamein.

Baghush Area (Dam and Roman wells)
The dam is located within Bagush village, about 48 km from Matruh, along Matruh-Alexandria road (*See Photo 4*). The dam was initially constructed by the Ministry of Housing and reconstruction (Desert Authority) in 1980. After the transfer of water works to the Ministry of Water Resources and Irrigation (MWRI) in 1982, it is overseen by the Matruh Directorate of the MWRI.

The main functions of the dam include: (i) conservation of flash flood water that was previously lost to the sea; (ii) recharging the geologic formations thus creating a potential for fresh groundwater skimming using roman wells (radial wells); (iii) provide additional water for the ground reservoirs in the upstream portion; and (iv) satisfying the water requirements of the Bedouin settled here.

The dam is constructed with clean compacted sand layers with an external layer of stones along the upstream face to help resisting the flash flood flow. The community benefiting from the reservoir lives in Bagush village, consisting of 600 persons and their cattle. The agricultural area served is about 600 acres (during the dry season).

About 20 Roman wells are located upstream of the Bagush dam. The wells are shallow, reaching the fresh water table (not continuous). The main formation containing groundwater is the limestone. The wells are connected through a fractured Karst medium. The wells are managed by the Bedouin in Bagoush village to skim fresh groundwater from the floating lenses. The main water requirements are for irrigation and drinking purposes.

Day 2: Sunday, 22 September 2002

General Overview of the Matruh Governorate

Matruh Governorate is the western-most governorate in Egypt. It covers a physical area of about 212,000 km^2 (20% of Egypt's physical area). The northern boundary of the governorate is the Mediterranean Sea, with a total length of 450 km. The international border with Libya comprises its western boundary.

The main physiographic characteristics of the Matruh Governorate are the coastal plain, the plateau and the sand sea. The Coastal plain extends along the Mediterranean Sea characterized by offshore hills extending in the sea (e.g. Ras el Hikma). The plateau is characterized by high hills and depressions, e.g., Quattara (-69 m, amsl) and Siwa (-17 amsl) depressions. The sand sea is one of the major sand dunes in the world. It extends from Siwa oasis southward.

The climate of the governorate is characterized by major differences all over the region, being mild along the Mediterranean Sea and semi-arid in the south. The annual mean precipitation in the coastal zone is about 140 mm (mostly during winter), occurring along the coast, and decreases rapidly towards the south. However, there is a remarkable interannual variation. Years with abundant precipitation alternate with those of poor rainfalls and even several consecutive dry years are common.

Some tribes settled in the narrow coastal fringe with rainfed agriculture. Adequate to the climate conditions, the major parts of the region consist of rangeland. It is the basis of the traditional animal wealth. About one million sheep, goats and camels are raised in the area. With the introduction of agricultural mechanization, parts of former rangelands were ploughed for cereal cultivation, exposing soils to wind erosion. Simultaneously, the number of animals raised on the remaining rangelands has increased as well. Large amounts of shrubs are cut annually for fuel wood denuding soils and impoverishing range vegetation. These factors add up to the degradation of rangelands.

The surface of the coastal zone is essentially occupied by Quaternary and Late Tertiary calcareous sandstone (Kurkar) overlying Miocene marly limestone beds. These form the main aquifer, where groundwater exists under phreatic conditions. The fresh water forms a thin film floating on the saline-brackish water. The Kurkar is developed into a series of elongated ridges arranged parallel to the present coast and represent a receding of the Mediterranean in Late Pliocene and Pleistocene times. The ridges alternate with shallow depressions filled with calcareous loamy deposits as well as lagoonal saline deposits.

The littoral zone is dissected by a great number of wadis which essentially drain into the Mediterranean Sea. Water conservation has been very successful as reported historically (e.g., during the Roman era). Such methods included cisterns, dikes and circular or horse-shoe open basins (Kurum).

Reservoir on the Matruh-Siwa Road

The reservoir we visited is situated along the Matruh-Siwa road (*See Photos 5 and 6*). It mainly serves the following purposes: (i) rainwater harvesting; (ii) provision of safe water supply for the community including domestic and agricultural requirements; and (iii) help the Bedouins to settle and form stable communities.

The reservoir consists of two main parts: (i) a settling basin at the upstream portion to reduce water velocity and help settling of fines; and (ii) a storage reservoir to store the water provided with opening for aeration and to help water provision. The community benefiting from the reservoir consists of 500 persons. The agricultural area served is about 150 acres (during the dry season). The capital investment for this reservoir was about L.E. 250,000 (ca. US$55,000).

Abu Grouf Watershed (Matruh Project site)

This watershed development project is part of the Matruh Resource Management Project. The rainfall varies from 50 to 270 mm per year, with an average annual rainfall of 145 mm. The regional plateau leads into the coastal plains on the Mediterranean side.

Historically, the area was severely degraded and was marked with a low productivity.

Under the current project, a number of activities are undertaken for improved management of water, control of soil erosion and improved livelihood of the local community. The local inhabitants, about 2,000 in number, are closely involved in the management activities and share the costs of construction and rehabilitation (*See Photo 7*).

Dams, typically about 20 m wide, have been built to retard the flood torrents coming from the plateau (*See Photo 8*). Terracing is also used for the same purpose. Some non-traditional crops and fig trees are planted downstream of the dams. Feed and food crops are grown rotationally during the crop season (typically November-March). Raising sheep also provides another source of food and income to the villagers.

Omayed Biosphere Reserve

The Omayed Biosphere Reserve lies between latitudes 30°38' and 30°52' N, and between longitude 29°00' and 29°18' E. It is located at about 70 km to the west of Alexandria and about 200 km to the east of Matrouh. The protected area is about 700 km^2. Its average width (north to south) is 23.5 km and average length is 30 km (east to west).

The Omayed area was declared as one of the UNESCO-MAB global network of biosphere reserves in 1981. Egypt declared the Omayed area as protectorate in 1986 by a Prime Ministerial Decree and the boundaries were modified in 1996.

Six major habitats are distinguished in the Omayed area: coastal calcareous dunes, inland ridges with skeletal shallow soils, saline marshy depressions, non-saline depressions and inland plateau (*See Photos 9 and 10*). From the stand point of biodiversity, the most importance habitats are those of Khasm El-Eish ridge and its transitional area with the no-saline depression; it is an area that supports a maximum number of annual plant species. Its depression is rich in mammalian species, rare insects and endangered molluscs. Around 220 plant species exist in the protectorate, 70 of which are medicinal plants, and 40 are of environmental importance. The

Omayed area is habitat to a total number of 217 species, three of which are endemic and 14 of which are threatened.

Local communities in the Omayed area are sedentary nomadic Bedouins, depending on the rain-fed cultivation, quarrying and grazing. The coast has been settled since Mesolithic times, in turn by the Tehenu (ancient dwellers of that coast), Greeks, Romans (marked by two brief but destructive Persian invasions), Byzantines, Berbers, Arabs and modern Egyptians. It is possible that it served as a corridor for domesticated sheep and goats from Palestine to the Atlas Mountains in the early Neolithic period, although no material evidence exists to prove it. There still are 33 Roman wells scattered all over the protectorate. With the Arab conquest in the 7th century, the population gradually adopted a grazing land use pattern. Under the Mamelukes, after the year 1251, Arab tribes began settling along this coast.

In the management plan for the Omayed Biosphere Reserve, the following elements are included:

- Control of capture and trade in birds of prey, and prevention of quail netting inside the reserve.
- Coordination with the Ministry of Agriculture and Land Reclamation in the management of the New-Hammam canal.
- Provision of appropriate stoves to replace the use of woody & dried plants for heating and fuel.
- Provision of financial and technical support for establishing a sanitary drainage system as an alternative to the current sewage system.
- Enhanced study of rare and endangered species.
- Reintroduction of species and subspecies which have disappeared or decreased in number in the area.

We also visited the Visitor Center for the Protectorate. It comprises a meeting room, the local natural history museum, a laboratory for data management, and rooms for scientists. This Visitor Center receives about 20 groups each year, including scientific expeditions, student visitors from schools and universities, and non governmental organizations (NGO's).

Summary of the Workshop Technical Sessions

Monday, 23 September 2002

Opening Ceremony of the International Workshop
The workshop was inaugurated through a formal opening ceremony. All the participants received a warm welcoming statement from Dr. Ismail Serageldin, Director of the Bibliotheca Alexandrina. The Egyptian Minister of Water Resources and Irrigation, His Excellency Dr. Mahmoud Abu-Zeid, urged the workshop participants to focus on the strategies for sustainable management of marginal drylands (*See Photo 11*). Other speakers at the opening ceremony included Prof. Motoyuki Suzuki (Vice Rector, United Nations University), Dr. Thomas Schaaf (UNESCO Division of Ecological Sciences) and Dr. Theib Oweis (ICARDA Natural Resources Management Programme)

First Session: Overview of Sustainable Management of Drylands
This session comprised five presentations focused on general issues of sustainable management approaches in marginal drylands. First, Dr. Radwan Al Weshah provided an overview of UNESCO's activities in the Arab region. The presentation focused on water resources management in the region, particularly in the context of UNESCO's International Hydrological Programme (IHP). A number of projects and professional networks in the region were introduced.

Second, Prof. Iwao Kobori provided a historic perspective of sustainable management practices in the region. He highlighted some of the success and failure stories of management approaches. These perspectives spanned a period of over 40 years during which he has been actively involved in research in this area. Third, Dr. Salah Tahoun provided his perspectives on the utilization of traditional knowledge in meeting the challenges of sustainable management. Fourth, Dr. Abbas Keshavarz presented a detailed review of the drylands agricultural practices in Iran. These included figures for productivity and agricultural output at the national level. Fifth, Dr. Vito Sardo presented a paper focused on the principles of sustainable agriculture through improvements in cultivation, fertilization, irrigation and pest control. A lively discussion on these subjects ensued in the discussion time.

Second Session: Special Issues for Coastal Drylands

This session comprised four technical presentations focused on coastal drylands. First, Dr. Sobhi El Naggar gave an overview of the Matrouh Resource Management Project carried out with technical assistance of ICARDA. Specific emphasis was put on the participation of Bedouin communities, their settlement and rural development. One of the initial challenges of the project was the lack of data; but the data collection network is now greatly improved.

Second, Dr. Abdel Bari Salkini discussed the interdisciplinary and holistic methodologies of ICARDA in their technical assistance to the Matrouh Project. He also stressed the importance of challenges in terms of social conflicts within communities. Third, Dr. Fatma Abdel Rahman Attia explained the systematic approach of the MWRI in their research and development efforts. Emphasis was put on management of groundwater resources and of brackish water. The northwest coastal region is most promising in Egypt; however, urban settlement and tourism development is threatening the hydrological environment. It was highlighted that one needs to look carefully at the utilization of brackish groundwater, for activities like fish farming.

Fourth, Dr. Hassan el-Shaer provided an overview of the activities undertaken by the Desert Research Center. It works through research stations covering all of Egyptian dryland regions. Major achievements include the application of remote sensing to groundwater exploration in Egyptian desert, environmental mappings systems, successful sand dune stabilizations techniques, and water harvesting techniques development. He emphasized the use of halophytes in saline habitats for soil fixation and erosion reduction.

The general discussion for the session can be summarized as the following key points:

- The need for coordination of activities and data sharing in the northwestern coastal region of Egypt was emphasized. Regional and interdisciplinary exchange of information on similar environments should be strongly sought after; this could materialize through a data-sharing network between desert research centers throughout the region.

- Urban expansion and tourism development along the seashores are major threats to the coastal areas and should be addressed in order to protect the coastal environment and ensure sustainable use of natural resources.
- Alternative sources of income, sanitation, local education and land-use outside of conventional agriculture should be considered in order to satisfy the community needs.
- Renewable energy, reuse of groundwater and exploitation of brackish water can give good unconventional alternatives to practices that are not environmentally sound. However, the energy and water balance should be carried out on a large scale.
- There are three major issues in desert environments: drought, salinity and water. Halophytes can solve many of these challenges posed to cultivation in dry, saline habitats.
- Projects should involve local beneficiaries from project planning through implementation. Economical returns for local beneficiaries should not be the sole basis for implementation, the benefits for environment and the enhancement of social capital must also be considered.

Tuesday, 24 September 2002

Third Session: Indigenous Technologies for Drylands Management

There were four presentations in this Session. First, Dr. Pietro Laureano presented an introduction and review of the history of traditional water management technologies. He pointed out that the knowledge system is based on the common classification of social groupings used in archaeology and anthropology (like hunters-gatherers, farmers-breeders and agro-pastoralists).

Second, Mr. Abdullah Ghafri presented his study on irrigation scheduling of aflaj of Oman, and discussed their modernization. He provided an overview of the types of Aflaj and various water distribution systems. Third, Ms. Joshka Wessels explained her study on restoration of qanats in Syria. She spent six months in a remote village for better understanding of the geographical, socio-economic, hydrological characteristics, and for assisting the local community in qanat restoration work. The water from Syrian qanats is used mainly for irrigation since the date they were dug. But as soon as the qanats productivity reduces, the indigenous knowledge and community cooperation critical for qanat upkeep also disappear. As a result of this cyclical process more and more qanats collapse or dry up. Fourth, Mr. Ouessar Mohamed presented his research results for the comparison of traditional and contemporary water management system in Tunisia.

The general discussion for the session can be summarized as the following key points:

- There are some key issues that need to be considered for traditional technologies, including maintenance of water quality over longer time periods, control of flow on as-needed basis and effective collection of flood water.
- A cost-benefit analysis should be carried out between "modern" and traditional technologies. Such analysis should include the long-term "carrying capacity" as well as the level of acceptability by the local communities.
- The impact of global warming on diminishing water resources needs to be carefully looked at. The technologies adopted must have the capacity to cope with these changes.

Fourth Session: Integrated Approaches

During this session four papers were present. First, Dr. Theib Oweis highlighted challenges for integration of various management approaches. He emphasized the need for public participation at all levels. Second, Ms. Sanaa Hassan Mabrouk presented an overview of the management approaches in the coastal drylands of Egypt. Her particular emphasis was on methods and success stories for public participation. Dr. Abdel Salam Jouma presented an overview of the drylands management activities undertaken by the Arab Center for the Studies of Arid Zones and Drylands (ACSAD). Fourth, Dr. Zafar Adeel presented an overview of a project that is being jointly developed by UNU, UNESCO and ICARDA.

During the discussion session, a major focus was on the failure of many projects in drylands settings. After considerable investment of financial resources, there is still rampant poverty in the region and the management practices are less than successful. In an effort to improve the situation, the following ideas were suggested:

- There should be an exchange of lessons learnt between developing countries (through a South-South cooperation mode). This requires dissemination of results in a harmonized manner.
- Project should, whenever possible, build on existing experience in the region.
- The implementation agencies and institutions should be present *in situ* and advance step-by-step together with the local community.
- Sustainability of project activities can be ensured through involvement of NGO's in the implementation process.
- Project should build on indigenous knowledge and technologies; improvise them when necessary, without losing their cultural, esthetic or technical values.

The trilateral project presented in this session can be regarded as an excellent basis for formulation of the next phases of many ongoing projects in the region. However, care must be exercised in the following respects:

a. careful selection of project sites;
b. generation of interest amongst the local community;
c. incorporation of a multi-disciplinary approach;
d. emphasis on livelihood approaches that are not solely limited to agriculture;
e. identify livelihood activities that match changes in economic, social and physical context (e.g., grow crops that require less water); and
f. increase public awareness through a variety of popular media and programmes.

Wednesday, 25 September 2002

Formulation of Workshop Findings
The final discussion session was utilized to synthesize the findings of the workshop and formulate some recommendations. These can be divided into the following four categories: (a) importance of marginal drylands; (b) challenges to drylands; (c) research and development Issues; and (d) institutional issues. Each one of these is further elaborated in the following section.

Summary of Workshop Findings

The discussions by workshop participants were focused on the subject area of the workshop and ranged from describing the most critical issues to identifying solutions that have been demonstrated to work. In keeping with this approach, the following recommendations are synthesized.

Importance of Marginal Drylands
Marginal drylands are indeed critical anthropogenic systems, and are quite unique in terms of their social, economic and geophysical characteristics. We need to adopt integrated management approaches in order to minimize wastage of natural resources and to optimize water resource utilization. It was, therefore, proposed to adopt the following philosophy for integrated management of marginal drylands:

a. Focus must be on drylands (rather than importing ideas from other ecosystems);
b. Integration of approaches is critical to success;
c. There must be a balance between new technologies and traditional knowledge; and
d. Awareness-raising about key issues must be central to any management approach.

Challenges in Management of Marginal Drylands
The following set of challenges was identified based on the various presentations and in-depth discussions during the workshop:

a. Selection of suitable plants and crops in accordance with prevailing conditions and water resources.

b. Converting knowledge (indigenous) into useful and applicable technology.
c. Overcoming scarcity of data through networking and data sharing across the board.
d. Identifying that urban expansion and development of unsustainable tourism activities in the coastal drylands are major threats.
e. Recognizing that it is critical to have the involvement of local communities in project planning and implementation.
f. Incorporating the issues related to social cohesion and potential for social polarization into activities.
g. Identifying the following criteria for initiating new projects:
    - Appropriate site selection;
    - Engagement and interest of local people; and
    - Involving various disciplines.
h. Identifying that the following criteria must be met for ensuring sustainability of management approaches and conservation activities:
    - Long-term viability of livelihood activities;
    - Careful utilization of natural resources (intergenerational equity);
    - Ownership by local people;
    - Viability in the absence of external support; and
    - Incorporation of approaches into the broader national planning processes.

Research and Development Issues

A number of avenues were identified for further research as well as development for marginal drylands. These include the following:

a. Investigate innovative approaches for use of brackish water and seawater based on socio-economics.
b. Improved water-use efficiency.
c. Development of renewable energy (esp. solar and wind) resources that can be good alternatives to conventional approaches.
d. Investigate use of halophytes for solving challenges to cultivation in saline habitats.
e. Development of methods to incorporate the benefits for the environment and the enhancement of social capital into the more conventional economical returns.

f. Investigate carbon sequestration in drylands ecosystems.
g. Investigate region-by-region the impacts of climate change on availability of water resources.
h. Investigate and further enhance drought mitigation and forecasting approaches.

Institutional Issues

The workshop participants also identified a number of institutional and policy issues that need to be addressed. These issues, listed below, must be carefully addressed to be successful in meeting the challenges outlined earlier.

a. Important role the international institutions can play in promoting research and development activities.
b. Developing mechanisms for improved coordination between various stakeholders, i.e., donor-recipient, recipient-recepient and donor-donor coordination. Integration and coordination at national level are also important.
c. Creation of information exchange networks at national and regional levels. Regional and interdisciplinary exchange of information on similar environments be strongly sought; e.g., a data network between desert research centers throughout the region should be established.
d. Summarize the lessons learned and develop guidelines based on the previous successes and failures – synthesize these in a way to facilitate transfer of knowledge to other areas.
e. South-south collaboration must be strongly endorsed.
f. Role of NGO's in development and conservation activities should be identified.
g. Emphasize influence on and involvement of policy makers in addressing key drylands issues.

Photographs from the Workshop
[*Photo Credits*: Dr. Thomas Schaaf (UNESCO and Dr. Zafar Adeel (UNU)]

Photo 1. Ready for departure on the field trip (Cairo, 21 September 2002)

Photo 2. Lunch at the shore of Lake Hamara (Wadi El-Natrun, 21 September 2002)

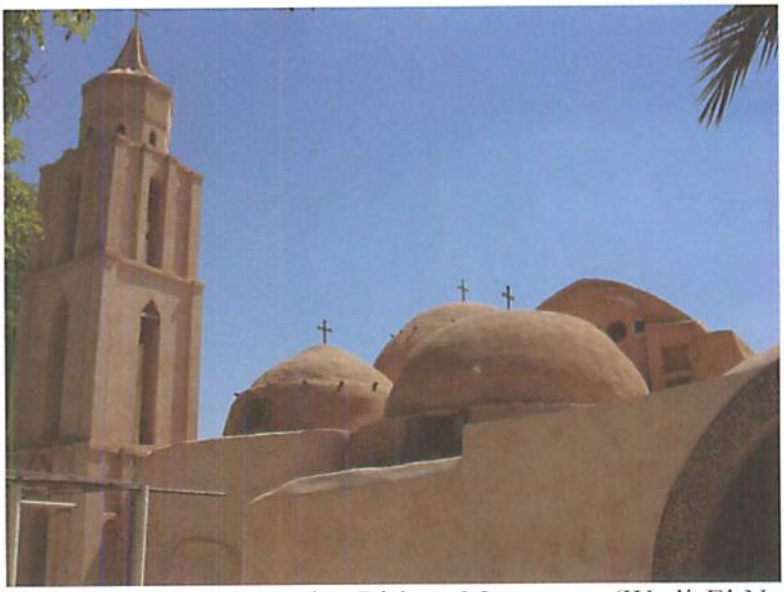

Photo 3. Al-Anba Saint Bishoy Monastery (Wadi El-Natrun, 21 September 2002)

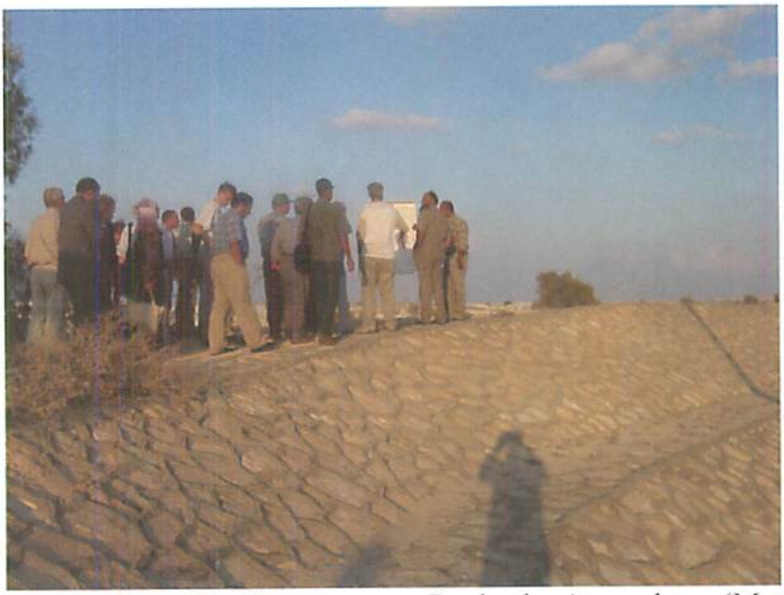

Photo 4. Standing on top Baghush Area dam (Matruh, 21 September 2002)

Photo 5. In front of Matruh-Siwa reservoir (Matruh, 22 September 2002)

Photo 6. Water well in the vicinity of the Matruh-Siwa reservoir (Matruh, 22 September 2002)

Photo 7. Local inhabitants in the Abu Grouf watershed (Matruh, 22 September 2002)

Photo 8. A typical dam in the Abu Grouf watershed area (Matruh, 22 September 2002)

Photo 9. A vantage point in the Omayed Biosphere Reserve (Omayed, 22 September 2002)

Photo 10. Active discussion about the Omayed Biosphere Reserve (Omayed, 22 September 2002)

Photo 11. Opening Ceremony of the Workshop – The workshop is inaugurated by H.E. Dr. Mahmoud Abu-Zeid, Minister of Water Resources and Irrigation, Egypt (Alexandria, 23 September 2002)

Photo 12. A lunch break during the workshop (Alexandria, 23 September 2002)

Photo 13. The workshop meeting room (Alexandria, 24 September 2002)

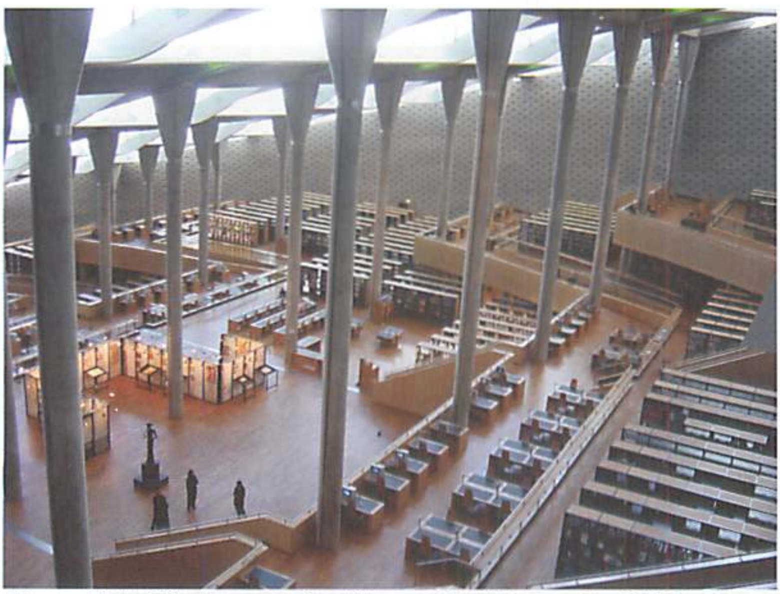

Photo 14. The impressive library facilities at the Bibliotheca Alexandrina (Alexandria, 24 September 2002)

Acknowledgements

Several individuals and institutions were instrumental in organization of the workshop, its field trip and the subsequent publication of this book of proceedings. We are grateful and indebted to these partners for supporting this successful activity.

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The field excursion was organized by the Ministry of Water Resources and Irrigation, Egypt under the guidance of Dr. Fatma A-R Attia. The excursion to the Omayed Biosphere Reserve was organized by Prof. Boshra Salem (University of Alexandria, Egypt) and Prof. Kamal Shaltout (Tanta University, Egypt).

Ms. Esther Dungumaro (UNU intern) greatly facilitated the publication of this book by collecting papers from contributors, reviewing and formatting them. Putting together this book would not have been possible without her contribution.

We are also grateful for the institutional support provided by UNESCO (particularly the Man and Biosphere (MAB) programme and the International Hydrological Programme, IHP) and ICARDA for organizing this workshop.

Workshop Programme

20 September, Friday

Arrival of participants in Cairo

21 September, Saturday

Field site in Wadi Natrun
Excursion in El-Alamein and Marsa Matruh
(Overnight stay in Marsa Matruh)

22 September, Sunday

Field sites in Marsa Matrouh area
Visit to Omayyed Biosphere Reserve
(Overnight stay in Alexandria)

23 September, Monday

09:00-09:45	**Opening Ceremony** Dr. Ismail Serageldin (BA) Dr. Mohmoud Abu Zeid, Minister of Water Resources & Irrigation, Egypt Prof. Motoyuki Suzuki (UNU) Dr. Adel El Beltagy (ICARDA) Dr. Thomas Schaaf (UNESCO)

First Session: Overview of Sustainable Management of Drylands

Chair: Suzuki and Attia

09:45-10:05	Role of UNESCO in Sustainable Water Management in Drylands: The Case of the Arab Region *Dr. Radwan Al Weshah* (UNESCO-Cairo Office)
10:05-10:25	Link of Traditional and Modern Approaches for Drylands Management *Prof. Iwao Kobori* (UNU)
10:25-11:00	Coffee Break
11:00-11:20	Traditional Knowledge in the Context of the UN CCD *Dr. Salah Tahoun* (University of El-Zagazig)
11:20-11:40	Agriculture and Drylands Management in Iran *Dr. Abbas Keshavars* (SPII)
11:40-12:00	In Sustain of Sustainable Agriculture *Dr. Atef Hamdy* (CIHAEM) and *Dr. Vito Sardo* (University of Catania)
12:00-12:30	Discussion on First Session
12:30-14:00	Lunch Break

Second Session: Special Issues for Coastal Drylands
Chair: Tahoun and Wessels

14:00-14:20	The Activities and Achievements of the Matrouh Project *Dr. Sobhi El Naggar* (Matrouh Project)
14:20-14:40	Integrated Watershed Management Approach: Theory and Application in Semi-Desert Environment of the NWC, Egypt *Dr. Abdul Bari Salkini* (ICARDA)
14:40-15:00	Water Management in Egyptian Coastal Drylands *Dr. Fatma A-R Attia* (Ministry of Water Resources and Irrigation)
15:00-15:30	Coffee Break
15:30-16:00	A Regional Comparison of Coastal Drylands *Dr. Hassen El-Shaer* (Desert Research Center)
16:00-16:30	Discussion on Second Session
19:00-21:30	Reception (BA)

24 September, Tuesday

Third Session: Indigenous Technologies for Drylands Management
Chair: Wang Tao and Oweis

09:00-09:20	A History of Traditional Water Management Technologies *Dr. Pietro Laureano* (ITC)
09:20-09:40	Irrigation Scheduling of aflaj of Oman: Methods and its Modernization *Mr. Abdullah Al-Ghafri* (Hokkaido University)
09:40-10:00	Restoration of Qanats in Syria *Ms. Joshka Wessels*
10:00-10:30	Coffee Break
10:30-10:50	A Comparison of Traditional and Contemporary Water Management Systems in Tunisia *Mr. Ouessar Mohamed* (IRA)
10:50-11:20	Discussion on Third Session
11:30-15:30	Lunch Break and excursion in Alexandria

Fourth Session: Integrated Approaches (Indigenous technologies)
Chair: Salkini and Raes

15:30-15:50	Challenges in Integration of Water Management *Dr. Theib Oweis* (ICARDA)
15:50-16:10	Sustainable Management in Drylands: A Programmatic Overview *Dr. Zafar Adeel* (UNU)
16:10-16:40	Coffee Break
16:40-17:00	Status and Needs for Public Participation in Strategic Development of Coastal Dryland Areas *Ms. Sanaa Hassan Mabrouk* (University of Alexandria)
17:00-17:20	An overview of Wadi Hydrology Network *Dr. Abdalla Droubi* (ACSAD)
17:20-17:45	Discussion on Fourth Session

25 September, Wednesday

09:00-10:30	Formulation of Workshop Recommendations Adeel and Schaaf
10:30-11:00	Coffee Break
11:00-11:30	**Closing Ceremony** Prof. Iwao Kobori (UNU) Mr. Sharif Riad (BA) Dr. Thomas Schaaf (UNESCO) Dr. Abdul Bari Salkini (ICARDA)

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Application of Indigenous Knowledge for Coastal Drylands

Edited By **Zafar Adeel**

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