UNU Desertification Series No. 2

Water Management in Arid Zones

Proceedings of
the International Workshop
Médenine, Tunisia
18-22 October 1999

The United Nations University
Environment and Sustainable Development
United Nations University

The United Nations University

Institut des Régions Arides

WATER MANAGEMENT IN ARID ZONES

Proceedings of the International Workshop Médenine, Tunisia 18 – 22 October 1999

The UNU is grateful to the Government of the Republic of Tunisia for its support of this workshop and to the Embassy of Tunisia in Tokyo, Japan for its assistance.

Supported by:

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

United Nations Educational, Scientific and Cultural Organization (UNESCO)

Secretariat Of The Convention To Combat Desertification (UN CCD)

The United Nations University

United Nations University, 5-53-70 Jingu-mae, Shibuya-ku, Tokyo – 150-8925

The United Nations University (UNU) is an organ of the United Nations established by the General Assembly in 1972 to be an international community of scholars engaged in research, advanced training, and the dissemination of knowledge related to pressing global problems of human survival, development, and welfare. Its activities focus mainly on environment and sustainable development, and peace and governance. The University operates through a worldwide network of research and postgraduate training centres, with its planning and coordinating headquarters in Tokyo, Japan.

United Nations University
Environment and Sustainable Development
5-53-70 Jingu-mae, Shibuya-ku,
Tokyo – 150-8925
Tel: 03-3499-2811
Fax: 03-3499-2828
Email: mbox@hq.unu.edu
Web: http://www.unu.edu/env

Contents

Introduction to the UNU Project: **Managing Land Degradation in Dry Areas**

Zafar Adeel

United Nations University

Overview of the Project

The project aims to develop activities that can assist in reducing the impact of land degradation and addressing the underlying causes of processes. This project focuses on developing countries in a region that includes Northern Africa, Middle East, Central Asia and China (in the context of this project, "Dry Areas" are defined broadly to include arid, semi-arid, and dry sub-humid regions). This geographical region includes a variety of ecosystems ranging from rangelands, deserts, highlands to mountains. However, the drivers behind the land degradation problems (population stress, economic exploitation, unsustainable development practices) are common to the developing countries in this region and result in a high stress on livelihood of the people and the natural resources.

The solution lies in looking at the overall picture and developing integrated approaches for managing the land degradation problems. Proper management of water lies at the heart of such approaches because the dry areas of this region range between dry sub-humid to extremely arid. Particularly, the linkage between management of highlands and lowlands is an important one to consider for integrated approaches for dealing with land degradation.

Specifically, the project comprises four distinct, but mutually complementary, components that will be implemented in parallel. These include network development, capacity building programmes, research and development activities and dissemination of environmentally sound information.

Background

Land degradation is defined as a process that leads to reduction the productivity of land for useful purposes and is typically a result of soil erosion, wind erosion, water erosion, soil salinization, waterlogging, chemical deterioration, or a combination of these factors. Land degradation is a global problem where marginal lands are turned into wastelands and natural ecosystems are destroyed. The immediate causes include deforestation, poor management of water resources, inappropriate land use practices, overuse of chemicals, fertilizers and pesticides, and disposal of domestic and industrial wastes (UNEP, 1999). The underlying driving forces include rapidly increasing population, economic policies that over-exploit natural resources, and rapid and often poorly managed industrial and urban development. The impacts of land degradation are severe on both human society and the ecosystems.

The UN estimates that some 70 per cent of the 5.2 billion hectares of drylands used for agriculture around the world are already degraded. This impacts approximately 250 million people across the world – some estimates cite number of people at risk as being four times higher than this. As an example, the worldwide area of arable land per person has reduced by as much as 25% during the last quarter of the twentieth century. This has serious implications for food security and livelihood of people dependent on degraded lands. A bird's-eye view of the target region (Figure 1) shows the geographical extent of the problem.

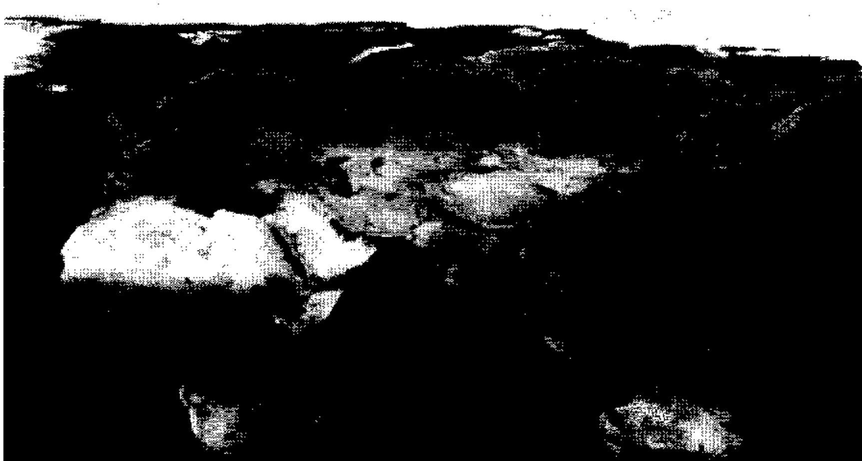


Figure 1. *Satellite image showing project area, primarily located within the tan shaded region.*

The impact of land degradation on ecosystems is apparent in destruction of biodiversity resources. According to UNEP estimates, about 65 million hectares of forest were lost globally during just five years (between 1990 and 1995). The resultant loss in biodiversity at genetic, species and community level is also severe. Most particularly, deforestation in mountains – which are fragile ecosystems to begin with – has contributed to biodiversity loss in rich habitats. Additionally, deforestation and land use change in mountains have resulted in increased runoff, accelerated soil erosion and severe floods. The flooding in China during 1997 is a typical example of such adverse impacts.

The areas most vulnerable to land degradation in any ecosystem are the ones at its periphery. Most of the land erosion, degradation of soil quality, loss of biodiversity, and eventual loss of productivity occurs in these marginal lands. It is important to focus on these peripheral – but high-priority – ecosystems, and the people dependent on them. Sustainable management strategies are needed for protection, preservation and reclamation/rehabilitation in these fragile systems. Such strategies are closely linked to human development and quality of life in these marginal areas.

Water is essential to survival and long-term sustainability in the Dry Areas. It is quite critically linked to human and economic development; it is no surprise that the poorest of the poor nations are situated in Dry Areas. Water plays a key role in degradation of mountain ecosystems through erosion and related loss of productivity and biodiversity. Additionally, most of the watersheds for major rivers originate in mountains, which means water management and land degradation in mountains can have serious consequence downstream – i.e., highland-lowland interaction.

Therefore, it is necessary to develop integrated approaches to address land degradation, biodiversity conservation and water management taking into account socioeconomic, policy, and institutional factors as well as technical issues. There is a need to promote actions for building and strengthening existing institutional capacities for regional, national and basin level agencies to effectively address and integrate cross-sectoral aspects. This should ensure that land and water usage policies address all the important elements for sustainable management of the land, biodiversity and water resources.

Project Objectives

The Project: 'Managing Land Degradation in Dry Areas' will provide an authoritative basis for assessing and identifying the most significant gaps in knowledge and capacity. This can be directly used to develop applied research and capacity building programmes in the participant countries. More specifically, the objectives of the project are:

a. Develop a comprehensive programme on managing land degradation, conserving biodiversity and sustainable utilization of water resources in dry areas of the participant countries.

b. Build the capacity in participant countries to undertake and manage their natural resources in a way that reduces and minimizes land degradation. Participatory approaches, involving local people, are adopted for this purpose.

c. Disseminate relevant information to policy-makers, researchers and the civil society. Building the awareness of general public on land degradation issues and action items is of utmost importance.

d. Develop cross-cutting, replicable solutions and lessons that can be applied to countries outside the project.

Project Description

The project includes the following components – these components will be implemented side-by-side to optimize their effectiveness.

A. NETWORK DEVELOPMENT: UNU has an existing network of scholars, researchers and scientist working on land degradation issues. Members of the network include representatives from Algeria, China, Iran, Israel, Italy, Kuwait, Morocco, Niger, Palestine, Pakistan, Russia, Tunisia, and Uzbekistan. Institutionally, this network is formally supported by ICARDA, FAO, Secretariat of the UN CCD, UNEP, and UNESCO.

This network has convened in the form of a series of workshops since 1998 at various locations to discuss regional issues – for example 'New Technologies to Combat Desertification' in Tehran, Iran (October, 1998) and the current workshop 'Water Management in Arid Lands' in Medénine, Tunisia (October, 1999). Further expansion of this network will be achieved through workshops followed up by publications and Internet communication.

The *modus operandi* of this network involves facilitating South-South collaboration. Participants from developing countries across the region can share experience and technology. Transfer of knowledge is typically much more effective and easily adaptable to local conditions under this format. This also helps in identifying the specific research needs of these countries and in focusing on capacity building efforts.

B. Capacity Building Programmes: The primary focus of capacity building is developing the human resources for implementing various activities to counter land degradation problems. This goes hand-in-hand with developing the institutional capacity to undertake activities and projects related to managing land degradation.

A bottom-up process will be used to identify and implement the capacity building activities through the involvement of local communities. The project network will also feed into this process. These programmes will include training workshops for key personnel and educators working in the area of land degradation. To effectively implement these programmes, their will be an emphasis on development of training materials (textbooks, workbooks, manuals, CD-ROMs). Once developed, these materials could be used in other regions within or outside the project, resulting in increased replicability.

C. Research and Development Activities for Managing Land Degradation: This targeted work would emphasize the importance of integrated management of water and land resources and conservation of biological diversity. Several centers of excellence will be identified in the participating countries to undertake these activities. This will include, but are not limited to, the Institut des Régions Arides (Tunisia), Desert Research Institute (China), and ICARDA's research centers.

There is a strong emphasis on developing multidisciplinary research activities and involvement of local people. Local participation is extremely important for successful implementation of these activities and their long-term sustainability. The main outcome of these activities will be methodologies/techniques that are environmentally sound in a developing-country context.

D. Dissemination of Environmentally-Sound Information: It is critically important to document and disseminate the key findings and lessons from this project to a broader audience. This is helpful in raising the awareness regarding the issues and solutions to land degradation that are environmentally sound.

Additional dissemination media such as the Internet, multimedia CD-ROM, and public meetings are also pursued. The UNU in collaboration with its various partner organizations undertakes this dissemination activity, particularly utilizing its existing capacity under the UNU Press umbrella.

Papers Presented at the Workshop

1

Facing the Challenge of Water Resource Sustainability in Arid Lands – The Role of Network Development and South-South Collaboration

Zafar Adeel

United Nations University

Introduction

Ever since the Earth Summit (1992) significant efforts have been launched at national, regional and global level for reversing the impacts of anthropogenic activities and climatic changes in arid lands. However, presence of sustainable water resources at any given level is crucial to the success of these programmes. With insufficient water resources, the long-term success of these programmes is doubtful and often may even worsen the situation and create new environmental problems. Therefore, it is important to evaluate the long-term (10-30 years) impacts of these programmes on the environment, whether they are positive or negative in nature. Such evaluations should include the existing and projected utilization of water for municipal, industrial or agricultural uses. It is obvious that the presence of reliable and consistent data is the most basic requirement for such rational evaluations. Although sufficient data are often available at a local scale, these may not be properly accessible or utilized at a national to regional scale. It is proposed here that development of a network of researchers, scholars and policy-makers working closely together on a regional basis may address this shortcoming. Additionally, such a network can become a key medium for exchange of information and ideas amongst developing countries. This will enable these programmes to be closely linked to economic and social perspectives peculiar to developing countries, while keeping in view the dynamics of traditional systems in place.

Water Resource Sustainability: The Greatest Challenge of the 21st Century

A major portion of our planet earth is covered with water. However, most of the global water is trapped in sea as saline water and in icebergs as ice. This available freshwater is probably abundant in itself but is geographically distributed so that it's not equally available to all. During the past century (1900-1995), water utilization has increased six times, at twice the rate of population growth (UNEP, 2000). As a result of this uneven geographical distribution and heightened water demand, most countries of the world will be facing a high water stress by the year 2025. A projection by UNEP indicates that the problems will be worst in parts of Africa and Asia, as shown in Figure 1 for Africa. Growth in population and industrial activity are the key drivers behind this water scarcity. It is anticipated that approaches to deal with this problem will attract a lot of attention and resources in the next few decades. Other problems related to water quality include, health-related water contamination, surface and groundwater pollution, heavy metals and man made chemicals in water bodies.

Current global discussion on water issues has already identified critical goals for humanity as a whole. The World Water Commissions outlines these goals for efficient water management and utilization: (i) water should be managed at basin level, (ii) full-cost pricing of water should be enforced, (iii) much more funding be directed for research & development in water-related issues, (iv) international river basins should be managed mutually by relevant governments, and (v) the private sector should have a five fold increased involvement (fiscally) to meet the current challenges. Additionally, it is noted that demand management should be used to maximize the socio-economic benefits. This has to be matched by technological developments needed to cope with the increasing water utilization. On the whole, maximizing of water productivity should be strongly emphasized.

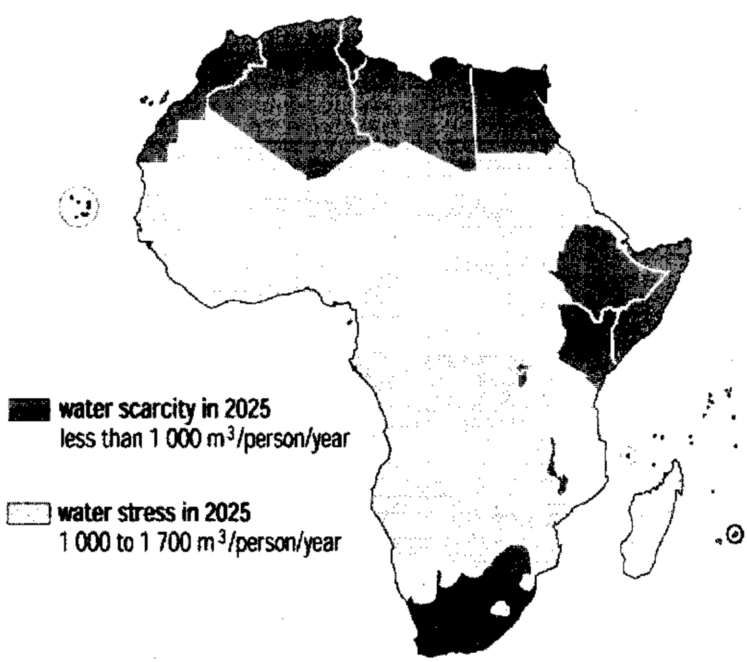


Figure 1. Projected water stress in Africa (Source: UNEP, 2000)

Long-Term Evaluation of Water Resources

Defining what "long-term" means in the context of water resource management is important in itself. Some researchers have suggested that the appropriate minimal time scales are of the order of 10-30 years (Chou and Dregne, 1993). Therefore, evaluation of water availability for use in projects for combating, or perhaps managing, desertification should also allow for a similar long-term evaluation.

Such an evaluation needs two essential components: a hydrologic evaluation and an explicit quantification of the costs for using water (e.g., full-cost pricing). The hydrologic evaluation can be performed at the national, regional, or local levels. Some scientists have argued that basin-level evaluation is the best logical and scientific methodology. Nonetheless, it is best to include local-level information in all evaluations because essential details, such as climatic variability within the country, may be lost for large river basins that cover several countries, e.g., the Nile river basin. A simplified evaluation methodology has been suggested elsewhere (Adeel, 1999):

$$\begin{aligned} \textit{Water available} = {} & \textit{Annual Precipitation} + \textit{Transboundary Influx} + \textit{Aquifer Capacity} \\ & - \textit{Evaporative Losses} - \textit{Groundwater Recharge} \\ & - \textit{Transboundary Outflux} - \textit{Annual Water Usage} \end{aligned}$$

The full-cost evaluation, a process that places exact costs on utilization of water resources, may be more difficult than would appear on the surface. The cost evaluation for water comprises three main components: (a) direct costs for usage of and access to water; (b) direct costs for water treatment; and (c) indirect costs in terms of environmental degradation as well as benefits. Typically, it is a complex process to fully evaluate the environmental costs, in part, due to uncertainties in impact and inherent difficulty in assigning cost to a natural resource.

Impacts of Adverse Water Utilization

Previous experiences in national and international policies have shown that mismanagement of water resources can lead to a broad range of problems. To provide a brief overview, a few key impacts are listed here:

- Biodiversity loss through loss of habitat and mono-cropping practices,
- ecosystem damage through loss of soil productivity and land degradation,
- loss of vegetative cover due to land degradation, over-grazing and deforestation,
- salinization due to chemical soil degradation and poor water management,
- water quality degradation due to over-withdrawal from natural resources and agricultural inputs, and
- human health impacts, directly through water and soil pollution and indirectly by adverse impacts on food security and availability.

To emphasize the importance of these environmental impacts, a number of cases can be easily found in the history of efforts to combat desertification. For example, El-Shorbagy (1998) has recorded an excellent overview of adverse impacts of internationally-funded programmes to combat desertification. The case studies described by him include unsuccessful placement of foreign plant and sheep species in Ras El-Hakma (Egypt), failure of shrub plantation schemes in Libyan rangelands, and mechanized farming schemes for sorghum and sesame in the Sudan resulting in encroachment and degradation of otherwise productive rangelands. Similarly, Mainguet et al. (1996) have reported the case of replacement of traditional nomadic practices in the Algerian steppe by a truck-based transportation of fodder, water, and livestock. This policy helped maintain the livestock flocks in the short-term but resulted in such massive overgrazing that the area was unable to recover under natural processes. In part, this land degradation and increasing population has resulted in Algerian dependence on imported food for 50% of its needs (Mainguet et al., 1996).

These case studies indicate that the most significant common factor in failure of the programmes cited here is the absence of long-term evaluation, both cost-wise and in terms of environmental impacts. Additionally, the importance of understanding and incorporating the traditional and cultural customs in effective implementation plans is underlined. Involvement of the local population in design and implementation of such programmes cannot be over-emphasized.

Information Availability and Access: Limiting Factors to Rational Decision-Making

The long-term evaluation of water resources requires a broad range of information. On the hydrological side, this may include mean annual rainfall, transboundary fluxes of water, aquifer recharge rates, etc. This has to be complemented with water-use information for both historical data and future projections. Needless to say, the quality of water available plays an important role its resource evaluation. Similarly, socio-economic factors have to be kept in mind and adequately addressed in the evaluation. These may include per capita income or GDP, water usage level, general level of education and literacy and existing social and political infrastructure. To develop a comprehensive evaluation, there is also a need to understand and document the major ecosystems impacted, as well as other natural resources like biodiversity reserves and forests.

Gathering this diverse information poses many challenges to the potential evaluator. Two of the most important challenges are gaining easy access to the required information and ascertaining its quality. There are several institutional limitations that drive the level of access and availability to information. These include:

- Adequate data management and reporting,
- confidentiality and right-to-access,
- technical constraints in data monitoring,
- lack of time-series data,
- insufficient spatial coverage,
- identification of appropriate indicators,
- divergent definitions of parameters, and
- differences in monitoring techniques.

Similarly, a number of concerns about data quality should also be given due consideration:

- Inconsistencies in information from various sources,
- outdated/inappropriate monitoring technologies,
- ground truth confirmation,
- gap-filling techniques used, and
- validity of projections and extrapolation.

Networking as an Approach to Meeting the Future Challenges

As is apparent in the previous sections, a major challenge to sustainability of water resources is effective long-term evaluation. Adequate access to and ready availability of the relevant information, in turn, is a crucial factor in successfully meeting the challenge. It is proposed here that networks of professionals, academics and administrators working in the field of water management are an efficient mechanism for increases availability of relevant information. A key element of these networks is exchange of scientific and professional information, which may be in the form of sharing of databases. Such sharing also helps in developing consistent reporting practices. At the same time, such networks are essential in identification of research needs and the most pressing issues on local and regional scales. Such cooperation can lead to developing of new research programmes and sharing of technical know-how.

A major concern in dealing with transboundary water resources is mutual distrust amongst the stakeholders. Network development and information sharing can be seen as confidence-building measures in this context. Such networks increase the level of transparency in monitoring and information dissemination. On a more intangible scale, these can be helpful in building professional camaraderie that is often essential to develop trust between stakeholders.

The networks can operation through a variety of modes. More common examples are:

- Joint research programmes,
- professional meetings (such as workshops and symposia),
- periodical and infrequent publications (such as newsletters, journals and edited books), and
- communication through the Internet (such as shared listservers and websites).

The United Nations University (UNU) has historically played an important role in network development, which is seen as its core activity. A major emphasis has been on facilitating South-South collaboration within UNU's networks. Prior experience of UNU in network development in developing countries indeed places it in a unique position to undertake the same for management of land degradation, in the context of water resource management. Additionally, access to dissemination and publication resources, particularly through the UNU Press, is quite a valuable asset to network development.

References

Adeel, Z. 1999. Sustainable Management of Deserts - Environmental Concerns in Combating Desertification, Sixth International Conference on the Development of Dry Lands "*Desert Development: Challenges Beyond the Year 2000,*" ICARDA, Cairo, Egypt, August 22-27.

Chou, N-T. and H.E. Dregne, 1993. "Desertification control: Costs and benefits," *Desertification Control Bulletin*, United Nations Environment Programme, Nairobi, Kenya, Vol. 22: 20-26.

El-Shorbagy, M.A., 1998. "Impact of development programmes on deterioration of rangeland resources in some African and Middle Eastern countries," in: *Drylands – Sustainable Use of Rangelands into the Twenty-First Century*, International Fund for Agricultural Development, V.R. Squires and A.E. Sidahmed (Eds.), Rome, Italy.

Mainguet, M., K. Mersmann, and M. Visser, 1996. Man-Induced Desertification. *The United Nations University Lectures – 12*. United Nations University Press, Tokyo: 24 pp.

2

Global Environment Facility
Opportunities Offered for Combating Desertification

Nora Berrahmouni

United Nations Development Programme

GEF – An Introduction

Global Environment Facility (GEF) is a financing mechanism intended to provide, in the form of grants or in exceptional conditions, funds to support the activities aiming at protecting the world environment. The financing provided by GEF covers the costs related to the adoption of the management and protection measures of the world environment.

GEF was designed as financing mechanisms for the conventions for biodiversity (CBD) and climatic change (FCCC), the Vienna convention for the protection of the ozone layer and the Montreal Protocol, and the convention to combat desertification (CCD).

GEF – The Four Fields of Activity

The fields of intervention of the GEF are:

- Conservation of Biological Diversity
- Climate Change
- International Waters
- Ozone Layer Depletion

GEF also finances the activities of fight against the soil degradation and desertification, which must:

- Be related to the four fields of intervention of the GEF: biodiversity, changes climatic, international water, layer of ozone
- Reach results which cannot be carried out by other agencies
- Supplement and not substitute the already existing financing
- Fall under an effort of collaboration and synergy
- Ensure global benefits

GEF partnerships unite governments, non-governmental organizations, scientists & the private sector behind cost-effective solutions that pave the way for sustainable economic development. Examples of concrete projects implemented in Algeria, and in the Maghreb will be presented.

GEF – Its Organization and Functioning... In Brief

The GEF Assembly consists of representatives of all participating countries, and is responsible for reviewing the general policies of the Facility. Its chair is elected from among the representatives, and all decisions are reached by consensus. It meets every three years.

The Council is the main governing body of the GEF for all issues related to operations. It is responsible for developing, adopting, and evaluating the operational policies and programs for GEF activities. The Council comprises representatives of 32 constituencies; 18 members are from recipient countries and 14 from non-recipient (i.e., developed) countries. Some constituencies include a mix of recipient and non-recipient countries. The Council meets every six months in Washington, D.C.

There are three agencies designated for programme implementation: the World Bank, UNDP and UNEP. These agencies collaborate with the promoters of projects to prepare the projects for GEF financing. The UNDP is primarily responsible of the reinforcement capacities programs and technical assistance to projects.

The Secretariat will service and report to the Council and the Assembly. Its responsibilities will include ensuring the effective implementation of the decisions of the Assembly and the Council; coordinating the formulation, and overseeing the implementation of, the GEF work program; and ensuring that the operational policies adopted by the Council are implemented. The Secretariat operates under the direction of the Director General, who also presides GEF.

The Consultative Group for the Science and the Technology (STAP): is composed of 12 experts that give scientific and technical opinions to the Counci, to Secretariat and to the implementation agencies. UNEP provides the STAP's secretariat and liaise between the Facility and STAP.

The National Focal Point is charged with passing ideas for projects and to certify that the proposals are in accordance with the priorities and to the national programs, to facilitate a wide consultation and to hold the informed GEF of the realized activities in the country.

The Basic Criteria for Project Approval

- The project must obtain endorsement from the National Focal Point of the GEF (for example in Algeria, it is the Ministry of Foreign Affairs). This is to ensure that the project fits in effectively in the framework of national priorities.

- The GEF projects must produce worldwide benefits to the environment. The GEF does not finance the national development projects. The activities financed by the GEF are complementary to the national initiatives for sustainable development. The financing of the GEF typically corresponds to the incremental costs that the country will not be able to bear on its own.

- All the projects integrate a wide participation of the various parties concerned.

- The GEF projects must fall within one of the ten operational programmes (either the programmes individually or combined):

    1. Biological Diversity: Arid and Semi-Arid Zone ecosystems
    2. Biological Diversity: Coastal, Marine, and Freshwater Ecosystems
    3. Biological Diversity: Forest Ecosystems
    4. Biological Diversity: Mountain Ecosystems
    5. Climate Change: Removal of Barriers to Energy Efficiency and Energy Conservation
    6. Climate Change: Promoting the Adoption of Renewable Energy by Removing Barriers and Reducing Implementation Costs
    7. Climate Change: Reducing the Long-Term Costs of Low Greenhouse Gas Emitting Energy Technologies
    8. International Waters: Waterbody-based Operational Program
    9. International Waters: Integrated Land and Water Multiple Focal Area Operational Program

10. International Waters: Contaminant-Based Operational Program

Who can Apply for GEF Financing?

The projects can be undertaken by the governments, national institutions, local organizations, NGOs, academic institutions, international organizations and the private sector. The implementing agencies may make arrangements for GEF project preparation and execution by multilateral development banks, specialized agencies and programs of the United Nations, other international organizations, bilateral development agencies, national institutions, NGOs, private sector entities, and academic institutions, taking into account their comparative advantages in efficient and cost-effective project execution

Types of Projects Supported by GEF

The Micro-Financing Programs: These programs, launched by the UNDP since 1996 in a number of countries, aim to reconcile the global environmental concerns with the interests of the local communities. These programs in certain countries, such as Tunisia and Morocco, have provided support for local organization and NGOs through a maximum amount of US$ 50,000 by project. The micro-financing programs support the vision of 'think globally, act locally'.

Medium-Sized Projects: less than US$ 1 million. The projects can be approved quickly and do not need prior approval of the GEF Council. These are primarily focused at proposal developed by NGOs. The medium-size projects should equally attract co-financing from other sources and notably, contributions in the form of land, equipment and personnel.

The full-size projects: for amounts exceeding US$ 1 million. These projects must obtain approval from the GEF Council. The development of such projects necessitates a consequent investment in times and in efforts to assure their approval by the Counsel. The placement period of such projects varies from 3 to 6 years with a GEF financing generally of US$ 3 to 8 million.

Empowering Activities: The GEF supports the governments in responding to their obligations to the international conventions (particularly, the CBD and FCCC). These programs furnish technical assistance and access international expertise. These activities concern notably development of inventories, strategies and action plans - as well as national communication to the Secretariats of the said conventions.

The programme development fund: To develop the mid-size and full-size projects, GEF advances funds such as that the PDF A up to US$ 25,000 and the PDF B up to US$ 350,000. These funds typically cover organization of local consultations, roundtable meetings with donors, participatory workshops, and technical reports.

Conclusion

Through this brief presentation, we can note that the GEF offers timeliness for the financing of projects in the framework of the Convention to Combat Desertification (CCD). It is important to remember that these activities to combat desertification must have:

- Fall within the four domains of GEF intervention: biodiversity conservation, climate change, international waters and ozone depleting substances.
- Attain results that cannot be realized by available resources
- Be complementary and not substitute the existing financing mechanisms
- Demonstrate a collaboration effort and synergistic approach
- Assure global benefits

3

Water Use and Management in Arid Zones of China

Wang Tao and Wu Wei

Institute of Desert Research, Chinese Academy of Sciences

Introduction

The problems of arid zone development and management cover a considerable field of research and practice in which water resources are involved as the key subjects. One can say that water is one of the most challenging current and future natural resources issues. The important of the role of water in arid zones development process has been recognized in China for a lone time. The arid zones occupy a vast area in the Northwest China, which mainly include the Alxa plateau in the west part of Inner Mongolia, the north part of Ningxia Hui Autonomous Region, the most part of Qinhai and Gansu provinces and the Xinjiang Uygur Autonomous Region, about 2.5 millions km^2, or a quarter of the Chinese territory.

Water vapors in most regions of China come mainly from the Pacific Ocean. Part of southwestern China receives water vapors form the Indian Ocean, and to a limited degree moisture from the Arctic Ocean and the Atlantic region after a long journey. In general, the amount of precipitation in a region is inversely related to its distance from the oceans. Thus, northwestern China, the major part of arid zones, is very dry, while southeastern China has considerable precipitation. In the arid zone, mean annual rainfall is less than 250 mm and even less more, like as 50-150 mm in the west plains and less than 25 mm in the Taklimakan Desert. The annual potential evaporation is more than 1,400 mm in general, and about 2,000-3,000 mm in desert areas. Because of the arid climate, an extensive unusable areas, about 70% of total arid regions, was formed, such as sandy deserts, gravel deserts and other wilderness. Although there are enough wasteland and light and heat resources, the local economy only depends on the irrigated agriculture and animal husbandry because of the water limitation. Surface water distribution in China is shown in Figure 1.

Water is not only the most precious natural resources in the arid regions, but also is the most important environmental factor of the ecosystem. Human impacts on the water certainly will cause a chain reaction among the ecosystem. Since ancient times, water utilization always made a decisive support to the local social-economic development. But due to the increased intensity of human activities and overused or misused the water resources, the problems such as salinization, vegetation degeneration and sandy desertification, were caused and developed quickly. The water resources already take on a great pressure for agricultural production in the arid regions at present, and will faces much more difficult situation in the future. Therefore, understanding the relationships between the water and environment, water and development, to recognize how to practice sound water management, are crucial important projects to study for sustainable agriculture and stable environment in the arid zones.

Water Resources Assessment in Arid Zones

In the arid zones of China, the water resources originate from precipitation and are presented as rainfall, glacier, surface water and groundwater. The rainfall is basic supply sources for all kind of water resources. Its variation in time and space controls the water conditions and glacial development, as well as directly influence the formations and distributed regulations of the surface runoff and groundwater. Meanwhile, there are frequently transform and interaction between the surfacewater and groundwater.

Rainfall Resources

The rainfall is varied from place to place in the arid zones of China (Fig.2). Most part of plains receive less than 100 mm annually only, but from 100 to 250 mm in some plains like as Yinchuan plain, east part of Hexi Corridor Region in Gansu and the north area of Xinjiang. However, the mountain areas share much more rainfall during the some period. For instance, there are 500 mm, or even 1,000 mm in the west part of the Tianshan Mountains, and about $400\times10^8m^3$ surface runoff are formed in the mountains and come down the basins. In the Qilian Mountains of Gansu, 350-400 mm can be expected and $70\times10^8m^3$ of the water being supplied to the Hexi Corridor Region every year (Gao and Shi, 1992). According to the isohyet, the annual precipitation in the arid regions (include mountains areas) is estimated over $5,000\times10^8m^3$, which converts into an average rainfall 175 mm and which constitutes the only reliable guarantee for subsistence and development in the arid zones (Qu, 1986).

River Runoff Resources

The rainfall in the mountains and melting-water from glacier are major supply sources to the surface runoff in the regions, and could be used as water resources when they transformed to surface runoff and flowed into the plains and basins. So, in other words in narrow sense, the water resources in the arid regions are the surface water and groundwater in the plains. Based on the annual average runoff volume flowed through the mountain passes to the plains and basins, the surface runoff resources was estimated about 1,400×$10^8$$m^3$(Gao, 1992) in the arid regions of China (Table 1.).

Table 1

The river runoff resources in the arid zones of China

Region	Runoff Volume (10^8m^3)	Total runoff volume (%)	Flow from outside regions (10^8m^3)	Flow to outside regions(10^8m^3)
North Xinjiang	439.40	31.3	30.12	220.98
South Xinjiang	444.90	31.7	60.74	-
Gansu	187.15	13.3	-	-
Qinhai	322.54	23.0	-	-
Ningxia	8.89	0.6	-	344.00
Alxa, Inner Mongolia	0.24	-	-	-
Total	1403.12	100.00	93.83	564.98

Groundwater Resources

Groundwater is a very important component part of water resources and an indispensable form for movement, transform and utilization of water in the regions. Because of the arid climate conditions, very small part of groundwater is supplied by rainfall, and the most part stems from the permeation of surface water. When the rivers come down to the plains from the mountains, a great quantity water seeps to be groundwater, and the groundwater spill over as springs in the lower areas. Such "seeping- spilling" forms the basic pattern of water cycle between surface and ground in the arid regions. For example, in Xinjiang, there is about 185×$10^8$$m^3$ river water flow down ground and 60×$10^8$$m^3$ groundwater overflow to surface again every year. Sometimes, the cycle seems to repeat itself in some places.

The groundwater resources are wide dispersed in the piedmont plains, basins, fluvial plains and desert areas. In the biggest four piedmont plains, the annual natural supply of water to groundwater is about $316\times10^8m^3$ (Table 2) and 60-90% of those are transformed from the surface water (Gao and Shi, 1992).

Table2

The ground water resources in the piedmont plains of the arid regions of China ($\times10^8m^3$)

Plains	Recharged from river, canal and field	Ground runoff	Permeated from rainfall	Total recharged volume
Hexi Corridor Region, Gansu	39.83	2.52	2.42	44.77
Caidam Basin, Qinhai	23.30	5.65	1.02	29.98
Junggar Basin, Xinjiang	53.27	3.77	5.84	62.88
Tarim Basin, Xinjiang	161.92	10.72	6.08	178.72
Total	278.32	22.66	15.36	316.35

Water Use and problems in Arid Zones

Water Use

Agriculture is likely to remain the major user of water in China. The total volume of water used by agriculture, industry and the urban population at present is about 500 cu.km, of which agriculture makes up almost 90%. In arid zones, water utilization has a long history for irrigation agriculture. Since the Han Dynasty (206 B.C.-220 A.D), the regions have been opened out on a large scale. The people have accumulated rich experience and achieved phenomenal success in the development, utilization and protection of water resources. A very good example is an ancient water conservancy, "Karez well", an irrigation system of wells connected by underground channels used in Xinjiang. This system can draw water automatically into the fields, just like artesian springs. There were more than 1,700 channels of the Karez well, about 5,000 km overall length (3-4 km each one in general and 30 km one as the longest) in Xinjiang in 1950's. According to a statistics in 1985 (Study Group on Xinjiang Resources exploitation, Chinese Academy of Sciences, 1989), there were still 1,016 channels which were used and flowed out $4\times10^8 m^3$ to irrigate 20,000 ha farmland in Xinjiang only.

Before 1950s, there was just a few water-conservancy facilities in the arid zones and total irrigated land was only about 1.3 millions ha in 1949. Since 1950's, the constructions of water-conservation facilities have made quite good achievements. Except the two biggest reservoirs of the Liujiaxia and Longyangxia along the Yellow River, there are 1,168 reservoirs in different types with $77\times10^8 m^3$ storage capacity, among them there are 195 large and middle-sized reservoirs with $67\times10^8 m^3$ storage capacity. Many installations have been built, such as 4,300 projects for diverting water automatically, 1,300 engineering for pumping water, 75,700 power-driven wells, 250,000 km channels on different scales (Gao *et al,* 1992). Those installations can irrigate effectively 4.5 millions ha farmland, 127,000 ha rangeland and 429,000 ha orchards and gardens up to 1980s. Table 3 shows the situations of water utilization in the arid zones of China in 1980s.

Table 3

Water utilization in the arid zones of China ($\times10^8 m^3$)

Province	Agri. and Irrigation	Rangeland irrigation	Indust .Use	City Use	Rural Use	Surface water		Ground water	
						Use	Ratio (%)	Use	Ratio (%)
Xinjiang	387.98	9.50	7.49	0.43	2.05	335.6	53.4	63.38	17.0
Hexi Corridor Region,Gansu	63.81	3.95	2.01	0.09	0.69	48.5	69.4	24.10	39.9
Qinhai	5.07	2.33	0.05	0.46	8.09	11.7	-	0.3	-
Inner Mongolia	5.35	-	0.23	0.06	0.57	1.84	6.3	4.37	20.8
Yellow River**	120.0	2.00	8.00	1.00	2.60	106.0	51.4	2.90	22.0
Total	582.21	17.78	18.18	1.63	6.37	500.03	42.0	94.81	20.0
Percentage	93.0	2.8	2.9	0.3	1.0	84.1	-	15.9	-

*Include diverted water from springs.

**Up to the Hekou hydrometric station, Lanzhou.

Problems of Water Use in Arid Zones

In the arid zones, the decisive factor to the ecosystem is the water, which will affect directly the environment by the changes of its quantity, quality and regional distribution. The reclamation and utilization of the water resources in the arid regions played a key role in the development of society and economy. Certainly, the impact of human activities on water management has improved the environment to be favorable for the agricultural development on a large scale, especially thanks to the construction of reservoirs, irrigation and drainage systems. Several dreams have come true, such as to expand the agriculture areas of the old oases, exploiting the wasteland, and increasing the artificial woodland and rangeland. Those brought about a great advance in agricultural production. But, the management the water resources is still the most important task for the sustainable development in the arid zones, not only because the promotion of economic prosperity is limited by the water scarcity but also because water management is involves in exploiting other natural resources and protecting the environment. In view of the lows governing water movement, transformation, and circulation, and the role of water in the arid ecosystem and in sustainable agriculture, there were many harmful effects on the agricultural environment from the poor water management, which can be summed up as follows.

Shortened Rivers, Shrunken or Dried Lakes and Degenerated Water Quality

Every continental river basin in arid regions is an unity constituted by surface and ground water, which forms an independent water resources system and an integrated ecosystem. Given the limitation of water resources, if the channel and water storage were increased excessively in the upper reaches, this would cause not only a decrease of water supply, a river shortened in many cases and the deterioration of water quality in the lower reaches, but also an imbalance in the ecosystem, degradation of environment and destruction of other resources. Unfortunately, many rivers, like as the Tarim, Keriya, Hotan, Yarkant, Konqi, Shule, Heihe and Shiyan in the arid zones are facing such problems. For example, the Tarim river valleys converge to a river system originating from the Kulun and Tianshan Mountains. There was enough runoff so that the Lake Taitema could survive for a long time in the end of the river. But, during the last 5 decades, owing to a sharp increase in the water consumed for agriculture in the upper reaches, the water supply to the lower reaches has decreased constantly, as table 4 shows. The artificial Daixihaizi Reservoir has become "the end of lake". The lower reaches had received less and lees sluice from the reservoir decade by decade. The worse situations appeared from the Daixihaizi reservoir to the lower reaches as the facts of more than 300 km of river beds and the Taitema Lake has been dried up for many years. The groundwater of the both sides along the river courses declined quickly from 3-5 m to 8-10m or more. For instance, the groundwater levels were 3-5 m in two wells of Aragan region in 1950s and descended to 11-13 m in 1985 (Wang, 1986).

There were 52 lakes of every one was over 5 km^2, total 9,700 km^2 of areas in the 1950s in Xinjiang, but decreased to 4,700 km^2 in the early 1980s. The famous Lup Nur Lake (3,000 km^2) dried up in 1964 and others like as the Manas Lake (550 km^2) in 1960, Taitema Lake (88 km^2) in 1972 and Aydingkol Lake (124 km^2) in 1980s dried up in succession. The Ebinur Lake (1,070 km^2) and the Ulungur Lake (745 km^2) have been reduced to one-half and one-tenth their original size, respectively, since the 1950s. In the Alxa plateau of Inner Mongolia, the Gaxun Nur Lake (262 km) in the seventies and the Sogo Nur Lake in the eighties have dried up.

Since expansion of the irrigation areas in the upper reaches has increased the proportion of backwater (recharged from the irrigated land), the water degree of mineralization has increased in the lower reaches, which caused the water quality deterioration, too. The degree of mineralization has changed in the Aral station as follows: 0.33-1.28 g/l and less than 1 g/l around year except on May (the most dry season) before the upper area has been irrigated on a large scale, and after that there were more than 1 g/l around year except flood season, 2.5-5.5 g/l during dry season. The groundwater degree of mineralization from Aragan to Taitema lake has raised from less 1 g/l in 1950s to 2-10 g/l in 1980s along the Tarim river and has reached to over 400 g/l in the Taitema Lake in 1982 (Zhou Xinjia, 1983). In the Borten Lake (1,019 km) the degree of mineralization has changed from 0.39 g/l in 1950s to 1.50 g/l in 1970s and over 1.80 g/l in 1980s, and the lake level has descended from elevation of 1,048.5 m in

1950s to 1,047.5 m in 1960s, 1,046.0 m in 1970s, 1,045.6 m in 1985 and 1,044.8 m in 1986, namely 3.70 m down.

Salinization

The water conservation is an essential prerequisite for constructing new oasis agriculture in the arid regions. A vast area of wasteland has been opened out just dependent on the water supply system. But if the water management was poor and unreasonable, the new productive oasis could become wasteland again. For past long times, much attention has been paid to broad water source but less to reduce waste of water. The waste of water, or overuse water resources in other words, was very common among the irrigation practice, which resulted from the backwardness system, like as the flood and string irrigation. The channel permeation has wasted water in a great quantity, too, since there were only 0.5-1.0 % of total channel has been treated to be waterproof. In such conditions, the high quota of irrigation was impossible to be avoided. Table 5 shows the situations of irrigation in the south part of Xinjiang in 1985. The gross quota of irrigation in the area was more than 14,850 m^3/ha and even 19,000 m^3/ha. Much disadvantageous was the fact that many of irrigated areas were not fitted with drainage system. Such practice not only wasted the water resources but also did not meet the water need for crops in the good time and quantity, and even more caused the raising of groundwater level and creation and expansion of the land affected by salinization. Up to the late 1980, about 1.15 million ha land have been salinized in serious degrees, composed of one third total irrigated farmland in the arid zones of China.

Table 5

Situations of Irrigation in the South Part of Xinjiang in 1985

Region	**Water use ($10^8 m^3$)**	**Irrigation area (ha)**	**Irrigation quota (m^3/ha)**	**Canal utilization Coefficient**
Kizilsu	8.34	49,800	16,747	0.43
Kashgar	87.00	521,100	16,695	0.39
Nongsanshi	10.22	48,400	19,080	0.45
Hotan	39.70	212,100	18,717	0.38
Bayingolin	27.64	186,180	14,846	0.40

Vegetation Degeneration
The unfavorable changes of water supply and degree of minerilization have resulted in the serious vegetation degeneration, especially the woodland (mostly composed by *Populus diversifolia*) degeneration in the regions. Of course, to fell the trees for opening up wasteland and to gather fuelwood for heating and cooking have destroyed the woodland much quickly. But in the lower reaches of rivers, a more important factor was the water. Table 6 collected examples on the degradation of *Populus diversifolia* woodland in the lower reaches of some rivers in the regions.

Vegetation has been degraded also by the over-used groundwater in oases, which are located at the lower reaches of rivers. Take the Minqin oasis of the Shiyang River as example. There were 220,100 ha arbor and shrub woodland in the late 1950s, and left 72,600 ha in the late 1980s, which still come on splendidly. That means about 67% woodland has degraded. The vegetation cover degree has decreased from 44.8% to 15% (Zhu and Chen, 1994).

Sandy Desertification
Sandy desertification is a major part of environmental degradation in the arid regions of China, which mainly caused by the excessive human activities facilitating wind erosion. Wind erosion damages the structure and composition of soil and leads to a rapid decline of biomass production and potential productivity of the land. The features of land surface will change to deflated fields. Wind erosion occurred after the vegetation has been destroyed by over-cultivation, over-collection of fuelwood, over-grazing and misuse of water resources (Wang,1997). A very good example here can illustrate what is the misused water resources. In the regions, the salinization was caused principally by the overuse of water in the upper and middle reaches of the rivers, meanwhile the sandy desertification spread because there was no water supply any more in the lower reaches. Many areas of farmland had to be abandoned along the lower reaches since the water had been cut. Those areas were subject to be eroded by the wind and become desertified land in some years later. Since 1950s, more than 132,000 ha farmland has been desertified in the regions along the lower reaches of the Tarim River

and Konqi River, 25,400 ha in the Shiyang river and 30,000 ha in the Hotan river. Also many rangeland and woodland have been degraded in the some period. Totally 343,000 ha abandoned land has been desertified in the south part of Xinjiang (Wang, 1996) and much more in the arid regions.

Table 6

Degradation of *P.Diversifolia* Woodland in the Lower Reaches of Some Rivers in the Arid Zones of China

River	1950s	1980s	Decrease %
Heihe	67,000	-	- 100.00
Shiyang	72,000	2,300	-68.10
Yarkant	171,300	94,000	-44.70
Tarim	54,000	16,400	-69.60
Kaxgar	70,000	28,600	-59.10
Kaxakax	10,700	1,170	-89.00

A Case Study of the Heihe Basin in the Arid Zones

The Heihe Basin, 13000 km^2 in area, is a greater inland river watershed in the arid zones of China. Its main stream, with a length of 821 km, originates in the Qilian Mountain and flows through the Hexi Corridor of Gansu Province and comes into the western part of Inner Mongolia Plateau.

In the arid zone, an inland river basin is a complete ecosystem unit in which surface water and ground water are interrelated. The water resources in the basin is not only an important natural wealth for coordinating the distribution and development of cropping-agriculture, forestry and animal husbandry, but also a significant factor for maintaining natural ecological balance and protecting environment. The Hexi Corridor in Gansu Province, lying at the middle reaches of the Heihe River, is an important developing region. The lower reaches in the western part of Inner Mongolia are the frontier oases. They are badly in need of maintaining ecological balance and formulating production planning. At present, its development and utilization have been affected the scale of oasis establishment in middle reaches and the existence of lower reaches.

The utilization of water resource due to cultivation in the Heihe River Basin has already changed and is still changing the original water system. Since 2,000 years before, the exploitation in the basin fell into interlaced development phase of agriculture and animal husbandry. For the last few decades the water exploitation entered into a transitional phase for comprehensive development of agriculture, forestry and animal husbandry, giving priority to agriculture. Following through restoration and consolidation of agriculture and animal husbandry as well as structural readjustment of farming, forestry and livestock breeding it gradually came into the third phase for comprehensive development. Along with growth of the population and irrigation agriculture in middle reaches, the water use contradiction between middle and lower reaches became increasing acute. As early as in Yunzhen Period of Qing Dynasty (since 1726) it had signed water division agreement. But at present the situation of water use in middle and lower reaches became even more intense, this not only hindered economic development but also caused a series of social-economic and environmental problems. For example, the irrigation agriculture once had set up the famous Juyan-Heicheng Oasis at the lower reach of the Bailanhe river in the Hexi Corridor some 2000 years ago, but had been ruined at desert or become desert.

The water resources in the Heihe River Basin, mainly formed in the Qilian Mountain area, are excellent fresh-water suitable for multi-purpose. According to statistical data of 35 river gullies with water-supply sense, the mountainous runoff volume amounts to 38×10^8 m^3, while the water volume flowing out of mountainous area is 37×10^8 m^3, of which the main course system of the Heihe River accounting for $25\times10^8m^3$ and the present consumption in the mountainous area 29×10^6 m^3. In addition, part of phreatic water in mountainous area and infiltrated precipitation in Plain area form into groundwater resource, which are not repeated in the surface water conversion in depressions of middle and lower reaches of the basin. Its total volume in the whole basin is $3.92\times10^8m^3$, of which the main course system of the Heihe River occupies $3.10\times10^8m^3$, depressions of middle reaches $2.42\times10^8m^3$ and depressions of lower reaches 0.78×10^8 m^3. Accordingly, the total volume of water resource available for making wateruse planning in the whole basin is about 4. 169 ×108m^3, of which the main courses system of the Heihe River makes up 2.783×10^8 m^3 (Du , Gao and Li , 1996).

Present status analysis has been shown that the utilization of water resource of the Heihe River has drawn near the critical state. It has been also known through water balance calculation that the net consumptive requirement of farming, forestry, animal husbandry, drinking water and industrial water of the main course system of the Heihe River total 1.982×10^8 m^3, the evaporation loss of river courses, reservoirs and lakes amounts to 0.498×10^8 m^3, altogether 2.48×10^8 m^3. This figure is quite close to mean annual value of surface water. As considered the non-repeated groundwater it is likely to occur water shortage in the middle drought year. Therefore, at present, the developmental potential of water resource mainly lies in the reduction of evaporation losses of ineffective water surface.

The Heihe River Basin consists of such sub-system as the Qilian Mountain, plain oases and deserts outside the oases. The desert constitutes 70% of the total basin, and the oases only account for 5%, owing to their favorable water condition they are not only the main areas affecting by human activities but also the typical districts for resource utilization and nature transformation. Today the middle reaches of the Heihe River Basin become to artificial irrigation oases or cultivated area. The lower reaches, such as Ejin and Gurinai Lake areas where vegetation are natural species with and affected to a greater extent by natural surface and groundwater, fall into natural oases.

In the middle and lower reaches of the basin the impacts of water on the environment are noticeable. The arid environmental variations caused by the development of water resource in the inland river basin will expand and affect the whole basin through the changes of water system, regional distribution and water table. In the Heihe River Basin, the environmental degradation in lower reaches has led to desertification process. The analytical results of river course and discharge have shown that the terminus of both the Eastern and the Western Ejin Rivers exhibited the most sensible responses. The lower reaches of the Western Ejin river has made the Gaxun Nur(Western Juyan Lake) dry up; its discharge is continuing to decrease, over the past twenty years the water table has descended at least 5 m. The Sogo Nur (Eastern Juyan Lake), situated at the lower reach of the Eastern Ejin River, has experienced many times of drying up in drought years, its water level has dropped down 2.5 m.

Originally river and ground water nourished the riverbank forests and meadow vegetation in lower reaches. But in view of hydrological condition variation, the vegetation regeneration lost balance and further appeared such degeneration phenomena as withering, even large tracts of dying.

So far as present techniques are concerned, the most widespread and greatest impacts of human activity are the effects to runoff. From the fact that the mountain runoff of the Heihe River obviously decreased after flowing out of mountainous area, we know that the effect of irrigation agriculture in the mid-corridor depression on the water resources of lower reaches has always been a problem in the historical period. However, since 1949, especially from early 1960s up to the present, with the increase of agricultural water consumption in the middle reaches, the discharge down to lower reaches decreased considerably. Moreover, annual water consumption has been increasing; the water consumption in 1990s has increased about 3-5 times as against previous twenty years. The increasing water division consumption in upper and middle reaches changed the conditions, affected the annual water distribution, prolonged the interrupting time of water course, cut down the total flood volume during flood period; thus affecting the quality and quantity of water resources even the water utilization in lower reaches.

Desertification is a special process of land degradation in the middle and lower reaches of the Heihe River. Both old and new deltas formed at the lower reaches of the Heihe River were outcomes of historical period. Such changes as water system variation in the old and new oases, discharge decrease, vegetation degeneration and strengthening wind erosion gave rise to the desertification in a short time. There exists not only the desertified land formed in historical period on ancient oases, but the recent desertification is also very strong. Table 7 shows the different kind of degraded lands in the Heihe River Basin in 1980s(Xiao, Gao and Li, 1996).

According to a comprehensive study we drew the following conclusions on the rational utilization of water resources in the Heihe River Basin:

Table 7

Degraded Lands in the Heihe River Basin

Degraded land	Area (km^2)	% of degraded land	% of Basin area
Wind erosion	10571	36.49	8.19
Water erosion	5547	19.15	4.30
Aridization	1169	4.04	0.91
Salinization	10391	35.87	8.05
Vegetation degeneration	1290	4.45	1.00
Total	28970	100.00	22.44

1) Resources such as water, land and grassland etc. in the Heihe River Basin have superior conditions for comprehensive development of agriculture, forestry and animal husbandry. Here land resource has greater potential but grassland potential relies on the artificial amelioration and sowing; however water resource is limited, water-deficient problem may be taken place even in the middle-drought years. The developmental potential of water resource depends upon enhancing water availability reducing ineffective evaporation losses of surface water, underground water and field moisture, storing water of the main stream and rational distribution.

2) Development and utilization of water resource in the Heihe River Basin might be achieved by changing such hydrological conditions as surface water system, water table, water quality and quantity in middle and lower reaches, expanding environmental influences on the whole basin. Despite the plain areas at upper and middle reaches took place greening process, which improved the environment, but in the lower reaches occurred desertification process that made the environment severely degraded. For this reason, at present the development and utilization of water resource must be in harmony with two major objectives of economy development and environment protection; feasible measures must be taken to maintain lower-reach oases.

3) The crux to wateruse in the Heihe River Basin lies in quantitative allotment of regional water amount. Since among the main course system of the Beidaihe River, the Mayinhge-Fenglehe River and the Heihe River have relatively independent water-land relations and hydraulic connexion, they can serve as the bases to establish water-land balance areas for harmonious distribution, management and utilization of water resources. Wateruse of the Heihe River can be divided into three stages, namely stabilizing lower reaches, whole basin's development and completing water resource system to realize new balance of basin's development. As for the water allotment schemes, to select Zhenyixia with is charge occupying 36% of total volume of the main course system of the Heihe River and Langxinshan with $7.00\text{-}7.50\times10^{8}$ m^{3} is a feasible scheme.

4) The key to implementation of water allotment scheme is engineering measure, as establishing large-size trunk adjustment and storage reservoirs and delivery channels. At present it is necessary to put water conservancy projects as quick as possible into and overall development and comprehensive model of the basin, which already set up an overall engineering system of water resource. At the same time, effective measures of macroscopic control and management for the utilization of water resources in middle and lower reaches must be taken, controlling non-return water consumption, establishing basin management institutions, promulgating water laws and engineering decrees.

5) Rational utilization land and water resources are closely related and promoted each other. At present the development and utilization of water resources have affected the construction scale of oases in middle reaches and existence of lower reaches oases, the expansion of irrigation land has also been confined. Therefore, there is urgent need to control oasis construction scale in middle and lower reaches, as well as to establish artificial irrigation farming oases in middle reaches and irrigation grassland oases for develop in the farming, forestry and animal husbandry along the river banks at lower reaches, and strengthen protective systems of oases and mountain protective constructions. Starting out from protecting natural resources such as water and land etc. to develop and establish gradually a territorial environment with well-developed production, stable

ecology, safe life, higher economic benefit and excellent ecological environment.

Improving Water Management for Sustainable Development in the Arid Zones

Water resources are the most important condition for agriculture development and hence, the economy development and society progress, in the arid zones. The water management and utilization have made a great contribution to agriculture, but accompanied by some environmental and social problems because of the misused water resources. At present, to develop the agricultural production is limited by the water supply at the right amount and moment in the arid regions of China. So it is an urgent challenge before us to improve the water management and utilization, which not only requires ensuring the sustainable development of economy but also needs to protect the agricultural environment. Some suggestions based on the good typical examples of water management in the regions can be made as the followings.

1) Taking the continental river basin as a whole ecological system to unify water-use planning with due consideration for all concerned.

In the arid regions, the formation, distribution and transformation of water resources take their rise from each continental river basin through the link between surface and ground runoff, which constitute an integrative valley ecosystem from upper to lower reaches of the river. The oasis agriculture in the river basin depends on the water supply. Any unsuitable water-use will cause the imbalance of ecosystem and environmental degradation, and consequently endanger the agricultural production. So, it is a vital task to take the river basin as a whole ecosystem to unify water-use plan. In accordance with the principles of overall consideration of all factors in the upper, middle and lower reaches of river, of unified management and utilization of surface and ground water resources, of centralized distribution of water supply along the river, the former intensive water-use should be regulated and the scope of land-use should be kept to adopt to the maximum water capability for irrigation, which so called to be limited farmland by available water. A good example is the well management of Manas River basin in southwestern fringe of the Gurbantunggut Desert in Xinjiang in the aspects of water-use, water conservancy projects.

2) To increase the utilization ratio of water-use and establish the stable and high efficient artificial ecosystem in each river basin.

In the arid regions, agriculture can be practised only in the oases and over 90% farmland rely on irrigation. The average grain yield is 2,100-2,500 kg/ha, but 3,700-4,000 kg/ha in many high-yield fields (Wang, 1989). The land production has a great potentiality to be exploited. Under the present conditions of available water and the favorable heat and light resources, along with gigantic efforts for increasing the production such as to increase the multiple crop index, to choose crops in the light of the water supply variation in different seasons, to ameliorate soil and control salinization and so on, the stable and high efficient artificial ecosystem will be not so difficult to be established. Again the example is the artificial oasis ecosystem in the Manas river basin in Xinjiang. Here the utilization ratio of water-use was increased as high as 85% in 1980s. The areas of artificial oasis expanded from 1,200 km^2 in 1950s to 7,200 km^2 in 1980s.

3) To improve the conveyance system and irrigation technique

Although many water conservancy facilities have been built up, yet most of them still need to be completed by conveyance system, and the trunk and branch canals also have to be treated by seepage-proof materials, so that more benefits of water-use could be obtained. For example, in the Shihezhi reclamation area of Xinjiang the irrigation system with over 40% seepage-proof canal has save on water effectively since the canal utilization coefficient had reached to 0.63 and the irrigation quota decreased to 5,460 m^3/ha.

The irrigation technique is very backward in the arid regions, too, such as the flood and string irrigation, which result in the large gross quota of irrigation (Table 5). So, the capital construction on farmland and better technique (furrow and border method of irrigation) should be carried out. A series of experiment in Yarkant river of Xinjiang shows that the gross quota of irrigation could be decreased average 2,300 m^3/ha if the better technique had been practised, and about $3.87\times10^{8}m^{3}$ water could be saved annually if total 167,000 ha land of spring-sown crops had been adopted the border method of irrigation along the river only. The advanced technique of spray and drip irrigation should be spread and applied, although we wouldn't expect to be on large scale because of the higher cost at present.

4) To protect the natural vegetation and develop the artificial shelterbelt for better agricultural environment

The oasis is the foundation of the agriculture. But only 3 %-15 % areas of the river basins are oases in the arid regions (Zhu and Wang, 1996), which are surrounded by the deserts and face many natural disasters like as dry damage, freeze injury, hail, flood, sand storm, dry and hot wind and wind erosion. The vegetation is the foundation to safeguarded the oasis stabilization and to withstand the disasters on the one hand, on the other hand it is a most stable part of production in the arid ecosystem. So it is great necessary to ensure the volume of water-use for woodland and rangeland, which will certainly achieve the actual effects on protection of oasis ecosystem.

According to the experience of oasis shelterbelt construction in the arid regions, the forestry should keep a certain proportion in the oasis area. In Shihezhi reclamation area of Xinjiang, the shelterbelt covers 7-15 % of the irrigation area on the edge of deserts and 5-10 % in the oases. In Hexi Corridor Region the proportion is 5-10%. Under normal conditions, the shelter forest is planted along the canal or around the cropland, so the forest can use the seepage water from the canal and land. Such being the case the forest can fully save and utilize the farmland irrigation water as well as take effect of biological drainage to avoid salinization. At present, the total forestland in the arid regions keeps about 5-10 % of irrigation land, which still should be continued increasing. The water supply for the shelterbelt and woodland should be 10-15% of total irrigation water in the oases.

Conclusion

Water is one of the most challenging current and future natural resources issues in the arid regions. For the sustainable agricultural development and hence, the economy growth and society progress, the water is the key to success. Although there are vast wasteland and light and heat resources, the local economy only depends on the irrigated agriculture mostly and the animal husbandry because of the water limitation. In the arid regions of China, water utilization has a long history, and the human activities on water management have improved the agricultural environment to be favorable for subsistence and development on a large scale. Along with the construction of reservoirs, irrigation and drainage systems and other water conservancy facilities, the old oases has been expanded and the new oases and artificial woodland and rangeland have been exploited. Those brought about a great advance in the agricultural production. But, due to the increase of human requirement and overused or misused the water resources, the agro-environmental degradation was caused and spread quickly, such as the salinization, vegetation degeneration and sandy desertification. The water resources already take on a great pressure of agriculture at present, and will face much difficult situation in the future. However, some typical examples have proved that the agricultural development could be sustained if the water management was improved. But, how to take the sound water management still is the most important task for the sustainable development when we have to face the agriculture, which is limited by the water.

References

Du Hulin, Gao Qianzhao and Li Fuxing, 1996. Trend Analysis of Surface Water Resources and Dynamics in the Interior Drainage Basins of Hexi area. *Natural Resources,* 2:27-35.

Gao Qianzhao and Shi Shengshen, 1992. Water Resources in the Arid Zone of Northwest China. *J. Desert Research (Lanzhou),* 12-4: 1-12.

Qu Ningshu, 1986. Land-use Problem in China's Arid and Semi-arid Region. *J. Desert Research (Lanzhou),* 6-1: 1-5.

Study Group on Xinjiang Resources Exploitation, Chinese Academy of Sciences, 1989. *Water-use and Its Balance between Supply and Demand in Xinjiang.* Science Press, Beijing.

Wang Run,1997. Ecological Environment and Prospects of the Green Corrode in the Lower Reaches of Tarim River. *J. of Arid*

Land Resources and Environment, 11-3: 42-46.

Wang Tao, 1986. Process in Desertification and Predicting its Developmental Trends in Argan Region in the Lower Reaches of Tarim River, Xinjiang. *J. Desert Research (Lanzhou),* 6-2: 16-26.

Wang Tao, 1996. Land Use and Land Degradation in the Tarim Basin, Xinjiang, China. *Journal of Arid Land Studies,* Tokyo, 5: 137-144.

Xiao Honglang, Gao Qianzhao and Li Fuxing, 1996. Development Strategies of Water and Land Resources in Hexi Region. *Chinese Geographical Science,* 6-1: 49-56.

Zhou Xinjia, 1991. The Desert Features and the Desert Environmental Evaluation in Xinjiang. *In ed., The Desertification and Its Control in Xinjiang,* Science Press, Beijing, 1-40.

Zhu Zhenda and Chen Guanting, 1994. *Sandy Desertification in China.* Science Press, Beijing.

Zhu Zhenda and Wang Tao, 1990. An Analysis on the Trend of Land Desertification in Northern China During the Last Decade Based on Examples from Some Typical Areas. *Acta.Geogr. Sin.* Beijing, **45:** 430-440.

Zhu Zhenda, Wang Tao, 1996. The Problem of Desertification in the Marginal Regions of the Taklimakan Desert, *J. J. Arid Land Studies*, 5-2, 131-136.

Distribution and flow capacity of Karez well in 1985 in Xinjiang

County	**Channel**	**Flow capacity (10^8 m^3)**
Turpan	366	1.29
Toksun	80	0.55
Shanshan	254	1.00
Hami	280	0.70
Yiwu and Barkol	15	0.19
Muri	36	0.39
Total	1016	4.03

4

Subsurface Irrigation Experiment In Jericho, Jordan Vally

Ashraf Afaneh

Ministry of Environmental Affairs, Palestine

Palestine in General

Background

Palestine is composed of two separate geographical regions: the West Bank and Gaza Strip. The West Bank is located in the central highlands of Palestine, while Gaza Strip runs along the southeastern Mediterranean. The Palestinian Territories occur at 29° and 33° north latitude, and 35° to 39° longitudes, comprising a total area of 6,065 km^2 where the West Bank covers 5,700 Km^2, and Gaza Strip covers only 365 Km^2.

According to the Palestinian Bureau of Statistics, the population of this combined area is about 2,7 Million. Approximately 1,800,000 live in the West Bank while 900,000 live in Gaza Strip (PCBS, 1998). In recent years the estimated natural population growth rate for Palestinians is around 3 to 5%, comprising one of the highest growth rates in the Middle East.

The climate in Palestine is typical Mediterranean, with along hot dry summer, a rainy winter and a drier-than-spring autumn season. The temperature and the evaporation rates increase towards the south of the West Bank and towards the Jordan Valley, with rainfall ranging from 100-700 mm annually depending on the location (see figure 1,2 for evaporation rates and rainfall averages in the West Bank).

Climatic Regions

The Palestinian Territories are composed of five climatical zones that are described below (figure 3).

1. The Coastal Region (the Gaza Strip):

This zone is located along the eastern coastal plain of the Mediterranean, in close vicinity to Negev, Sinai deserts, to its south and west, determines its semi-arid Mediterranean climate of long, hot summers and mild winters with fluctuating rainfall. Average rainfall rang between 200 mm in the south and reaches 400 mm in far north. The total area of the Gaza Strip is about 365 Km^2, of which nearly 190 Km^2 are currently cultivated.

2. The Semi-Coastal Region:
A narrow strip extending at 100-300 m above sea level in the north and northwestern corner of the West Bank. It has a high average of yearly rainfall (about 600 mm) and has some of the best agricultural lands. Soils in semi-coastal plains and valleys are mostly alluvial soil series as silt or loam. Over half of the cultivated area is irrigated or receives supplementary irrigation.

3. Central Highlands:
These include the area from Jenin to Hebron. The zone is mountainous rising up to 1,000 m above sea level. It is mostly hilly and rocky, and much of its soil is shallow. It receives an average rainfall of 400 mm.

4. The Eastern Slopes Region:
This zone presents the semi-desert climate as transitional zone between the two Mediterranean and desert climate. It is located between the Jordan Valley and the Central Highlands regions. It extends from the eastern parts of Jenin to the Dead Sea in the south. The steep mountains with little rainfall that predominate in this region make it an almost semi-arid to desert zone. It is suitable for grazing and, to a certain extent, is utilized for field crops varieties that survive with the average yearly rainfall of 150-300mm, such a barley and wheat. Recently some olive groves began to thrive on gentle slopes and in valleys where soil moisture can be retained.

The soils in this zone are mostly from Gray Calcareous steppe series. While Rendzina soil series with all varieties especially the gray color are well represented. In the valleys, alluvial soil series are dominant. Terra Rosa may be found also in some patches. The total area of this zone is approximately 1,500,000 dunums, with altitude varying from 800m above sea level to 50m below sea level.

5. The Jordan Valley Region:
This zone has unique topographic and climatic conditions. The approximately 400,000 dunums that comprise this region lie 90-390m below sea level, surrounded by two high series of mountains from the eastern and western sides, and characterized by hot summers and warm winters. Most of the soil is brackish and contains high ratio of sodium.

Water Resources Management in Palestine

Preface

Water shortage is one of the most important problems that will face the Middle Eastern countries in the coming years. Palestine is one of these countries that suffer from water scarcity. As the water resources in the area are very limited and cannot satisfy the expected increasing demands, it is necessary for the Palestinian people to use all possible water enhancement systems.

The major water resources available in Palestine are the Jordan Valley and the ground water. Israel has control over these water resources and uses most of them for its own purpose. Since 1967, the Palestinian people in the occupied territories have had a very limited access to water resources due to the various restrictions imposed by the Israel military occupation.

The Palestinian water demands have surpassed many years ago the amount of water allocated to the Palestinians by the Israelis. Palestinian are not allowed to use more than 20% of their groundwater and do not have access to the Jordan River. According to Oslo agreement the Palestinian, have the rights to access and use their water needs, which is estimated to meet around 280 MCM/year (the present situation). In the Future the water demands estimated to be increase with about 70-80 MCM/year.

Water Resources in Palestine

The two main water resources in Palestime are (a) Surface Water: including Jordan River and surface runoff (Wadis) and (b) Ground Water: Mountain aquifer in the West Bank and coastal aquifer in Gaza Strip.

1. *Water Resources Availability in Palestine:*

West Bank:

Surface water:

Jordan River: Average annual flow 1,311MCM/year (PWA, 1997), Palestinian annual share is estimated to be 20% of the

total annual flow, i.e. it equals 280MCM/year (PWA, 1997), but Palestinians have no access to Jordan River due to Israeli occupation.
Surface Runoff: Estimated to be 70MCM/year (PWA, 1997).

***Groundwater*:** The annual recharge for the mountain aquifer is estimated to be 650MCM/year (PWA, 1997).

Gaza Strip:

The coastal aquifer is the sole source of fresh water. The annual natural recharge is 112MCM/year of which 14MCM/year seepage of untreated wastewater and 30MCM/year return from irrigation (PWA, 1997).

Water Uses and Consumption

West Bank: The Palestinian total use from the groundwater resources in the West Bank has been estimated to be 143 MCM/year. About 86 MCM/year is used for irrigation and the remaining 57MCM/year is used for domestic and industrial consumption (PWA, 1997).

Gaza Strip: the Palestinian total use of water is around 137 MCM/year. About 88 MCM/year is used for agriculture. The remaining 49MCM/year are used for domestic and industrial consumption.

The water crises in Gaza are not limited to the deficit in quantity. However; the water quality is deteriorating and subjected to continuous increase in salinity (seawater intrusion) due to over abstraction and percolation of sewage in the area.

Water Demand

The unique historical water situation in the West Bank and Gaza governerates has resulted in suppressed water demands. Water supplies are generally constrained due to technical, institutional and political limitations. In addition to that, approximately 30% of Palestinian communities are not served with water net works. Thus, the current water demands can not be used for predicting future demands. Table 1 illustrates water demands, water resources and water gaps.

Main Problems Related to Water resources and Water Supply

- Water resources depletion
- Over pumping from the ground water wells
- Ineffective use of springs: Most of springs in Palestine are not exploited completely either, because of military orders of occupation, lake of funding and improper management.
- Pollution (quality deterioration): Many springs are discharging waters through wadis, which is mixed with domestic and industrial untreated wastewater. Groundwater in Gaza Strip is of bad quality (salt water intrusion, untreated wastewater and agricultural activities)
- Unbalanced Distribution of Water between Israel and Palestine: Palestinian is not allowed to use more than 20% of their groundwater.
- Accesses to Jordan River Surface Water: Because of the military closure, Palestinians have no access to the Jordan River.
- Large Losses of Surface Water during Flooding Seasons.

Runoff in Palestine (West Bank) was estimated to be about 70MCM/year. Most of the runoff quantity has not been utilized or controlled on a large scale in the West Bank. Small-scale utilization surface runoff water is practiced in some villages where systems are constructed to capture rainwater. Some farmers use small-scale open ponds for irrigation purposes.

Norewegian Irrigated Farm Model in Jericho

Introduction

The idea evolved following a decision by the NGO's (PARC), Palestinian Relief Agricultural Committees, and the Norwegian government to establish sustainable agricultural pilot projects in the

Palestinian territories. This will talk into consideration that both regions (West Bank and Gaza strip) are suffering from shortage of water quantities. Therefor, there is a need of introducing a Low Volume System (LVS).

Low volume irrigation system is the consumption of less amounts of water through the irrigation system that confirms the Low Volume Irrigation.

Water is discharged from deep water well to be pumped directly into large pool (1500 m^3), then three pumps installed on the pool with screen filters and fertilizers injectors are used to pump pressurized filtered water to the field via buried Polyvinyl chloride (PVC) pipelines, and electrical control valves. Drip-tapes (not emitters) are used to receive water from submains. The polyethylene drip-tapes are buried 20-30 cm in every row and will normally run about 150 m in length. This drip-tape has long irrigation lines and irrigation occur from the beginning to the end of the row. Low Volume Water Irrigation has been used for a number of years in some countries with very good results.

In France, subirrigation system was used to irrigate potatoes, drip-tape installation was done at the same time, when planting and forming the beds under the tubers. The results indicate that the total yield of potato was 70-80 tons/ hectare, compared with sprinkler irrigation system with total yield of 40-50 tons/hectare. Also losses of 10-15% of sprinkler system and 5-7% for subirrigation system from the total yield were noticed. The percentage of losses is greater when using sprinkler system because it breaks the top of the raised bed, which displays the potatoes under sunlight, the potatoes become green, and can not be sold (Fruits et Legumes, Jan. 1993).

Also, subirrigation system (buried tape) was used to irrigate Asparagus. Buried drip irrigation results in higher yield than the control plant, "non-irrigated and over head system (solid set)". Fertilization is made through buried irrigation system, less weeds and diseases (leaves are dry), irrigation can be done during windy weather, compared with sprinkler irrigation (Fruits et Legumes, Jan. 1993).

Maintenance of soil productivity

The primary objective concerning subirrigation was to increase yields. To accomplish this goal, it was necessary to take into consideration the following critical points.

Salts management

Subsurface drip-tape, if used properly, will have a dramatic impact on salt management, by placing tubes below every listed bed, salts have been pushed away from the seed or seedling with the witted front when irrigated.

Also Scott Tollefcon (1985) noted substantial decline in salt soil level from year to year. When he used subsurface irrigation instead of furrow irrigation, "the application of water every row at the root zone", this process pushed salts away from the plants root zone to the lower layers. Also subsurface irrigation decreases the amount of water used for irrigation by 50% compared with the furrow irrigation, which means that half of the salts are also applied table 2 shows salt soil level in furrow and subsurface irrigation.

Table 1

Soil salts levels, EC mmohs/cm in subsurface vs. furrow fields water salt levels ranging from 800 - 3000 PPM

Field N°	Furrow irrigation		subsurface irrigation		
	1992	1993	1993	1994	1995
16	7.00	7.00	-	2.75	2.00
17	6.80	-	2.00	2.00	1.50
18	6.50	-	1.500	1.75	1.25
21	11.90	-	3.30	3.25	1.75

Minimum tillage

The use of subsurface drip irrigation in any farm is necessary to evaluate the way fields are tilled. In this pilot farm four-wheel tractor, plows, disks, rotovators and cultivators were used. By using subsurface irrigation half of these operations became not necessary, we were also forced to adopt the concept of minimum tillage. The objective is to shred stalks, kill roots and incorporate residue in the top 10-20 cm of soil just above the drip lines. The shift to reduce tillage has resulted in less compaction, cut tillage costs by more than half, with no effect on the yield. Since removal of the irrigation system is no longer necessary, after each planting, a considerable amount of time, energy and labor is saved. Another advantage of subsurface irrigation is that Polyvinyl chloride (PVC) and polyethylene materials are shielded from extreme temperatures, Ultra Violet (UV) light and mechanical damage.

Crop Rotation

Experience has proven to the farmers that if one particular crop is grown year after year on the same piece of land, the yield gradually decreases. The soil becomes less fertile, structure-less and is more easily carried down-slope by rainwater. More weeds appear and there is an increase in pests and diseases. This situation can be avoided by crop rotation.

Crop rotation is a regular pattern of planting crops, which makes different demands on the soil each season. Crop rotation minimizes problems of diseases and pests. Depending on the farmers' needs, three, four, five years or even longer rotation pattern is also possible. Thus, crop rotation requires careful planning for both the seasons and the plots where each crop will be planted. Subsurface irrigation system is permanently buried in the soil, so it is easy to be managed during the crop rotation, which have row crops.

Soil chemical and physical properties
The used soil texture class is clay loom, it has 39% of sand, 33% silt and 28% clay. Soil pH is 7.3 and electrical conductivity is 35 mmohs/cm, which means that it has a dangerous amount of salt, and it needs special management. Moreover, the soil has a hazardous

amount of Na, Cl and B which are 180 meq/L, 354.5 meq/L and 1.46 PPM respectively, which are very toxic. Also SAR is very high, it equal 16.3, this value clarify that the soil has very week structure, massive when it becomes wet and dusty after plowing.

The amount of P and K is medium, which is a bout 37.1 PPM, and 6.2 meq/L respectively, also it has high percentage of CaCO3, which equals about 48% (Table 2).

Table 2

Soil chemical and physical properties

Soil property	Value
pH	7.3
EC(mmohs/cm)	35
P(PPM)	37.1
K(meq/L)	6.2
CaCO3(%)	48
CaCO3 active (%)	18
Cl(meq/L)	354
Na(meq/L)	180
Bo(PPM)	1.46
NO3	662.4
SAR	16.3
Bulk density(gm/cm3)	1.35
Sand (%)	39
Silt(%)	33
Clay(%)	28
Texture class	clay loam

Irrigation water analysis

Electrical conductivity of irrigation water used is 3.25 mmohc/cm, which is saline water, and therefore severe problems often a rised with most crops were grown. Also, there was a slight toxic effect because of the relatively high concentration of Cl which is equal to 20.7 meq/l, and Na which is equal to 8.0 meq/l and SAR which is equal to 3.10. Also nitrate was very high and equals 167 PPM, table (3) illustrates physical and chemical properties for water irrigation.

Table 3
Irrigation water analysis

Property	Value
pH	7.2
EC (mmohc/cm)	3.25
Cl (meq/l)	20.7
Na (meq/l)	8
SAR	3.1
K (meq/l)	0.99
P (PPM)	0.9
NO_3 (PPM)	167

Management and technique of subsurface irrigation
A reservoir for mixing the salty well water 3.25 mmohc/cm with fresh well water was used, from this reservoir water is out to the fields, through a screen filter for algae and sands. Venturi injectors for fertilizers and air injection as well as valves for controlling which plot should be irrigated.

Filtering is something that must be done on all irrigation systems. Since we are using a drip tape with SDR equal 0.4 m^3 /hr/100m, buried in the ground, our filters are at a 150 mesh using venturi for air injection is a simple method and very effective. This process of air injection to the water stimulates the microbiological organisms, which exist in the water, and contributes to the water abilities to penetrate soils, especially heavy soils such as silt or clay. By stimulating the microorganisms in the water and in the soil, this also contributes the stimulation of the root system. The plants begin to absorb water much sooner, but only the amount the plant needs, so this process contributes to the ability of using this amount of water. Although we must irrigation more often per day, the irrigation is done 2-4 times daily at 5-10 minutes per irrigation.

The main lines are buried to each plot as best fit the area. From these main lines we come up with small tubing which is connected to the drip-tapes. The depth of the tape depends upon which crop is irrigated. But we have chosen 20 cm, since the plants of the project are vegetables, so we install the tapes permanently. By burying this tape or drip-lines, we are putting the water at the plant heart " the root system". This allows much less water usage, since penetration is eliminated. The water is at the root system immediately. Other advantage is the reduction of above ground water, for example, there will be no standing water that attracts undesirable insects and enormous algae growth above ground. Water from sprinklers contributes to these problems as will as different from fungus types, which can be hazardous to the plant life.

Considering the management of the system is irrigation scheduling and control is done properly.

Organic farming

Organic farming is going back to the basics of nature. Now a day's chemical are used in agriculture to fight diseases and pests. The problem is that the more you use chemicals the more you believe you must have them. But the opposite is true. Since misuse either by accident or on purpose creates another type of sickness we believe there must be another type of chemicals to fight the new problem. However, if chemicals were not used most diseases would not exist.

Today on the Norwegian project in Jericho and Gaza, we are using an organic agricultural method. As of Today we use no chemicals in some areas and very little in others. To minimize the use of chemicals, we have used soil solarization for disinfecting the soil, which has an excellent result; also we cover the plant with a special mesh - as physical barrier - to protect the plants from insect injury and diseases, with no damage done to the environment.

The organic farming are based on the concept of using materials, which come from the soil return to the soil. All organic materials that are not sold in the market are return backs into the soil. This process increases humus in the soil, and aids the life to the soil. The first couple of years can be difficult for plant life. The reason is that most of soils, which have much chemical use are dead of life, this means that natural fertilizers must be used by returning the leafage and plant residue back to the soil we are increasing the natural organic matter. Green and animal manure is used in organic farming free for charge since it is available on site. This is a fertilizer, which has been used from the beginning of life, and nowadays societies in some places of the world have become build up. But organic on the soil contributes mostly to the soil constituents, it improves the physical properties, it increases the ability of soil to store water, and enriches the good life in the soil.

Conclusions and Recommendations

Although, in this project we forced to use another type of irrigation, drip irrigation, in the surface of each row because there was a severe problem resulted from the huge amount of salts founded in the soil (EC 35 mmohc/cm). This problem resulted in damaging and stopping the growth of the seedlings in the beginning of the planting duration, so we use drip irrigation to *washing* the salts from the upper layer of the soil. After a certain time the seedlings were able to continue without the aid of drip irrigation. Nevertheless, there was a reduction in the irrigation water to 25-30% in a comparison with the control field, which leads us to use this type of irrigation in more areas and try to improve subsurface irrigation under the same condition (Jordan River region).

5

Irrigation in Arid and Semi-Arid Zones of Iran:
Present Status, Challenges and Suggestions

Hamid Siadat

Soil and Water Research Institute

Abstract

Natural diversity of Iran is similar to that of a continent. Nevertheless, most of the Iranian territory is located in the arid belt of the earth. Out of the total of 165 Ha, by far the greatest areas are very arid (35.4 %), arid (29.2 %), and semi-arid (20 %). In these areas, the ratio of annual evaporation to precipitation varies mostly between 10 to 30; reaching values as high as 80 in certain years.

Therefore, irrigation of agricultural lands is imperative for an economical crop yield. Presently, more than 90 % of the water used in Iran is applied to a total of 7.9 MHa of land, including 6 M Ha of arable crops and 1.9 MHa of orchards. Most of these lands are under gravity irrigation methods, including furrow, corrugation, basin, and border strip. Pressurized irrigation systems have been used only on a relatively small area of less than 5 % of total irrigated land. There are a number of reasons for this, including economical constraints, instrumental failures, poor field designs, and improper water management.

Low efficiency of water utilization, particularly in agriculture, is one big challenge facing the country. Environmental impacts of inefficient water use in agriculture have been dramatic. Soil degradation by salinization , water logging, as well as lowered groundwater quality, are the most obvious consequences prevailing in many areas of the country. Other results are low yields, poor crop quality, higher energy for pumping, and intensified drought impact.

It seems that the national scientists and policy makers should re-orient their priorities in the light of the consequences of the present trend in agricultural water utilization. Otherwise, the future costs in terms of the quality of our soil and water resources will, by far, exceed the present national income obtained from crop production under poor water management. A new school of thoughts, with emphasis on education at different levels and sustainable use of soil and water resources, should replace the age-old belief that in arid and semi-arid zones, supplying of water--by construction of storage dams or extraction from groundwater--is the number one priority.

Introduction

The natural diversity of Iran is similar to that of a continent. This is mainly due to the differences in latitude, altitude, and geological formations. Most of the country, however, is located in the arid to semi-arid belt of the earth, between 25 to 40 degrees N latitude. Two long and high ranges of mountains separate the northern and western parts of the country from the central plateau and the southern coastal areas. There are also many localized ranges of mountains scattered throughout the country. The variations in altitude and latitude together with the coastal areas in the north (the Caspian Sea) and in the south (the Persian Gulf and the Sea of Oman) provide for drastic differences in air temperature and humidity between various locations.

Nevertheless, due to low precipitation and high rates of evaporation, irrigation is essential for crop production. In fact, irrigation is an age-old practice in Iran, with many innovations, such as Persian Wheel used for lifting water from a low-lying surface, and Qanats, or horizontal wells, used for conveyance of groundwater by gravity from distant locations to agricultural and residential areas.

Many ancient water diversion or storage structures such as dams, on the rivers, or covered ponds at low-lying points for collecting rainfall runoff, are still functional. Even their remnants demonstrate the technical achievements of Iranians in harnessing and managing water for different uses in old times. Some examples are Band Mizan (1700years old), Band Amir (1000 years), and Khajoo Band and bridge (about 500 years).

The existence of such national heritage in the country is very valuable as sources of inspiration for innovative engineering designs, and more important, for taking lessons from the past experiences. This is particularly true in the case of diversion dams and water distribution networks. Also, documents and writings of historians on Iran are full of other examples, including different types of water measuring devices and hydraulic time-determining instruments. All of these support the fact that water and irrigation have been among the focal points of our past civilization.

Climatic Zones and Extent of Aridity in Iran

The National Water Plan (Jamab Consulting Engineers,) divides the country into 8 climatic zones as follows:

1. Very Arid: Very hot and dry, having mean annual precipitation (m.a.p.) of 150 mm, potential evapotranspiration (ETo) of 2700-3000 mm (or more).
2. Arid: hot and dry in summer warm (south) and cool (north) in winter having m.a.p of 150-250, (ETo)=2400-2700 mm.
3. Semi-arid: hot in summer and cool in winter, m.a.p.=250-350, Eto=2000-2400 mm
4. Mediterranean: warm in summer, cool in winter, m.a.p. =350-450 mm, Eto=1700-2000 mm
5. Semi-humid: warm in summer cold in winter, m.a.p. =450-550 mm, Eto=1400-1700 mm.
6. Humid: warm in summer cool to cold in winter, m.a.p.=550-700 mm, ETo =1200-1400 mm
7. Very humid (type A): Warm in summer, cool to cold in winter, m.a.p.=700-1000, ETo =1000-12000 mm
8. Very humid (type B): Warm in summer very cold in winter at high altitudes, m.a.p. =1000-2000, Eto=800-1000 mm.

The area covered by these different zones is shown in Table (1). Overall, only about 10% of the country receives annual rainfall in excess of 500 mm.Area-wise,17% receives between 350-500 mm, 61% between 100-350 mm, and 13% has an annual precipitation of less than 100 mm.

Table 1

Areas of different climatic zones of Iran according to NWP

Climatic Type	Area (M.Ha)	% of total area
Very arid	57.4	35.4
Arid	47.3	29.2
Semi-arid	32.5	20.0
Mediterranean	8.0	4.9
Semi-humid	5.5	3.4
Humid	5.8	3.6
Very humid (A)	4.8	3.0
Very humid (B)	0.8	0.5

Water Resources

By far, the greatest portion of our annual water resources comes from precipitation both in the form of snow and rain. Some water also enters the country through the rivers on the borders with the neighbouring countries. The main rivers have their origin in one of the two major chains of mountains in the north and western parts of the country, namely, Alborz and Zagros, respectively. The most important groundwater storage is in the alluvial plains, with a total number of about 600 registered aquifers. Sources from which water is taken for use are in different forms of rivers, qanats, shallow and deep wells, springs, and some freshwater lakes. However, groundwater use is more common, constituting about 60% of the total water use in the country.

The latest estimate of the average annual precipitation is 416 km^3. Out of this volume, nearly 300 Km^3 directly evaporates from soil surface or is evapotranspired from forest canopies, rain-fed crops, etc. The annual surface streams with internal origin are about 105 km^3, including 13 km^3 of surface water, which enters the country from the neighboring states. Direct recharge of the alluvial aquifers amounts to 25 km^3/year. Also, 29 km of utilized water returns to the surface streams and ground water each year. This means that the total potential volume of water for annual use is 159 km^3. (130 km^3 of renewable water resources and 29 km^3 of return flows). Presently, the annual volume of water used in different sectors is as follows: agricultural sector 81 km^3, urban and industrial sector 6 km^3 (2).

Irrigated crops

Considering the diverse climatic conditions of the country, it is no surprise that a wide spectrum of agricultural crops and native vegetation grow in the country and they are associated with many different production systems. Table(2) shows the irrigated area under different crops. A general division between the production systems may be drawn between irrigated and rain-fed production of crops. Although the latter is practiced in many parts of the country, but the share of irrigated agriculture in total crop production is many times greater. The latest agricultural statistics (1998) indicates that the total annual production under irrigated conditions is close to 56 MT while rain-fed production is only about 8 MT.

As such, Iranian agriculture is basically irrigated and its success in feeding the rapidly growing population as well as its significant contributions to the national economy, are dependent on the efficiency and adequacy of this operation.

Table 2

Areas of irrigated crops in Iran (MHa)

Crop	Area
Wheat	2.20
Orchards	1.90
Barley	0.70
Rice	0.60
Industrial Crop	0.57
Vegetables	0.40
Melons	0.29
Fodder Crops	0.77
Corn	0.16
Pulses	0.15
Other	0.05

Irrigation methods and efficiencies

Gravity irrigation is by far the most common irrigation method employed by Iranian farmers. Accurate data on the area under different methods are not available because, among other reasons, in recent years, the government has been encouraging the farmers to convert their traditional irrigation methods into pressurized systems. Therefore, the situation is dynamic and changing. Nevertheless, it can be stated with great certainly that more than 90% of the irrigated fields in Iran are under surface gravity methods of irrigation. Among these, basin and, more recently, furrow irrigation have the greatest share. Border strip and corrugations methods are relatively limited and are found mostly in governmental farms or in the fully mechanized private farms.

Pressurized irrigation methods, including different types of sprinkler and drip irrigation, are mostly used in orchard and, in fewer cases, for industrial crops like sugar beet and vegetables. Generally, irrigation efficiency in Iran is in the order of 30-35%. Some causes of low efficiency in irrigation, particularly for gravity irrigation are, as follows:

- Poor land leveling and shaping.
- Poor seedbed preparation.
- Irregular flows
- Irregular field shapes
- Fragmented land ownership
- Small land holdings.
- Seepage through unlined canals.

In drip irrigation, poor filtering, clogging of long-path emitters, and high variations in discharge , particularly in the case of pressure compensating emitters, have been reported as the main causes of low irrigation efficiency (Mostafazadeh,et al 1999). Recent estimates of irrigation efficiency under different conditions in Iran are shown in table(3).

Table 3

Irrigation efficiencies considered for the year 1997 (%)

Irrigation methods and farm conditions	Efficiency (%)		
	conveyance	application	total
Traditional gravity irrigation	70	50	35
Gravity + land consolidation and leveling	70	60	42
Gravity +canal lining (no leveling)	85	50	42.5
Sprinkler irrigation	85	70	60
Drip irrigation	85	90	76

Prevailing problems

Irrigation problems encountered in Iran may be divided into natural problems and management problems. As to the former, undoubtedly, the most important natural factor facing the irrigation of arid and semi-arid zones of Iran is the ratio of evaporation demand of the atmosphere to the actual amount of precipitation falling in any given location. This ratio is usually very high, which means that there is a naturally negative balance between water input and output. In these areas, the ratio of annual evaporation to precipitation varies mostly between 10 to 30; reaching values as high as 80 in certain years.

Besides, land topography, irregular slopes, some soil characteristics such as extreme rates of infiltration, and salinity of water are among other important natural factors which pose problems in irrigation of lands in certain parts of the country.

Management problems are also numerous and rather wide-spread. These could be categorized into (1) technical problems, (2) socio-political problems, and (3) economical problems. Technical problem include the following:

1. Inadequate research data on crop water requirement, irrigation scheduling, and water production functions for different crops.
2. Changes in the cropping pattern of the projects in contrast to the original plants which were used for the design and construction of the projects.
3. Deterioration of the canals and hydraulic structures due to aging and poor maintenance operation.
4. Inadequate canal lining and land leveling, both of which contribute to drainage problems.
5. Accumulation of soil erosion sediments in the canals and other structures.
6. Insufficiency of structures and instruments for controlling water flow rate.
7. Inadequate agricultural extension activities on proper use of water.

Besides the foregoing problems, the situation is aggravated by a number of socio-political problems. For example, some farmers try to increase the rate of water flow allocated to them by making unauthorized changes in the canal off takes or other structures. There is some lack of feeling responsibility toward maintenance of the network structure. Many access roads of the projects are used by the farmers as an ordinary road for commuting and transportation. Moreover, some people try to influence management of water in the project to their own benefits, thereby jeopardizing services of the whole project.

Another category of problems stem from economical/financial policies. First, the price of water per se is very cheap in many projects. One reason is that when some of these projects started in 30-40 years ago, the government policy was mainly concerned with the attraction of farmers to the then-new lands to increase crop production. There was almost no regard paid to the price of water as a commodity by itself. At the same time, the environmental impacts of poor water management were not recognized. Therefore, farmers grew accustomed to cheap water in these irrigation projects and it is not easy to change the situation, although the low price of water is considered as one of the main factors contributing to the present low efficiency in water utilization.

Another point is that the government budget allocated to maintenance operations are usually limited and these operations have been inadequate. Seepage losses of water from the networks, inadequate and untimely delivery of water, and gradual deterioration of hydraulic structures are some of the consequences of such financial policies.

Furthermore, budget allocation within the water sector is also biased. Most of the budget is channeled into the construction of reservoirs rather than distribution networks (Ghaffari Shirvan, 1999). The priority given to the construction of new dams has always overwhelmed the start or completion of the distribution networks downstream from the dams. This is unfortunate, particularly when we consider the low efficiency with which water is used in agriculture. Under such conditions, a new source of water for irrigation is a new source of drainage and salinity problems.

Present and Future Challenges

Presently, the most important challenge is that of prioritization between two main policies in water resources, namely, providing new water or utilizing the present available water more effectively. As stated previously, many policy-makers tend to emphasize the former. They believe that activities leading to development of a new source of water allows a quick way to expand irrigated agriculture, which has a higher production and income. Besides, such programs provide physical symbols of development, particularly in the case of dam construction. This attitude would have been great, if irrigation efficiencies were high. But this is not the case. The official estimates show that almost two thirds of the water provided for use in agriculture is wasted and lost, with deteriorating effects on environment and crop production. As such, under present conditions, any new source of water for irrigation is a new source of land drainage and salinity problems. Therefore, our present challenge is to collect adequate data and evidences to convince the policy-makers and those in charge of the national budget that, in water sector, the number one priority is to increase utilization efficiency of the already available waters.

Irrigated agriculture in Iran also faces two other major challenges. The first is food production for the increasing population, and the second is sustainable utilization of soil and water resources. It is unfortunate that to some people these challenges seem independent of each other and they regard them as two different issues. Some agricultural policies are clear evidences in this respect. For example, the emphasis on increasing crops production per se, without a parallel emphasis on the protection of natural resources and the environment, is a reflection of such an attitude. This can have, and has had, catastrophic consequences. Many examples of such consequences have been reported for different countries around the world. (State of the World, 1998), and Iran is no exception. In order to increase food production in the country, one of the policies adopted in the last two decades has been to expand irrigated agriculture. Accordingly, during 1983-95, our irrigated land increased by an estimated area of about 2.5 Mha. To do this, the regulations governing installation of wells were either relaxed by the government or ignored by some people. Extraction of groundwater increased dramatically and water levels in the wells started to drop. Presently, due to ground water over draft, there is a negative annual balance for these resources amounting to more than 5 km. Other consequences of this situation are the increase in water salinity (Siadat,1994) and drying up of many Qanats. Furthermore, irrigation with saline water has increased soil salinity, and this has been one of the factors restricting crops yield.

Therefore, future development plans should aim at decreasing ground water extraction and increasing recharge into these resources. Sustainable use of these resources is vital both for our agriculture and our soils. The challenge to decrease groundwater use is not easy. It requires education and training of farmers to utilize water more efficiently, water pricing to discourage over-use, and rehabilitation and modernization of the existing irrigation systems to minimize large-scale losses of water. Without action programs along these lines, not only agricultural production will be unable to meet the country's needs and demands for food, but our soils will continue to degrade, our water resources will loose their quality , and water extraction from wells shall require more energy.

Another serious threat to Iran's water resources and irrigation projects comes from soil erosion. This phenomenon has also had strong negative and destructive effects on our agricultural production, and rural as well as urban environment. It is beyond the scope of this paper to discuss the extent and the severity of soil erosion in Iran. However, it should b e emphasized that our water development programs and irrigation projects have been badly affected by this process. Part of the consequences of soil erosion in Iran is silting up of our dams' reservoirs and irrigation canals. Other results are flooding of agricultural fields and residential areas close to some rivers. Recent flooding of agricultural fields bordering the central desert (Kavir) has shown that this threat is not limited to areas with high rainfall, rather, it can happen wherever land has been managed improperly. Therefore soil erosion is yet another important challenge facing sustainable use and management of our soil and water resources.

Finally, it should also be noted that defining sustainable use of water in quantitative terms is a challenge by itself. Iran is a country with drastic variations and differences in climatic, and socio-economic conditions. It will be unwise to use a single quantitative definition for sustainable use of water throughout the country. Instead, research and educational organizations should be encouraged to study this concept for different regions and to come up with some practical guidelines for each environment. Sustainability of crop production systems is site-specific and highly dependent on both natural and socio-economic conditions prevailing in each location. Policy makers of irrigated agriculture in arid and semi-arid zones should be very careful in adopting a sustainable development program. In many developing countries, that part of the population living in the arid zones are usually in the lower layers of the economic and financial pyramid of the whole nation. Therefore, the short-term costs of a sustainable irrigated agriculture to the farmers should be weighted carefully against their benefits both in the short- and in the long-term. The big challenge is to find a sustainable method of water utilization that is acceptable to the users in the particular location under consideration and not harmful to the environment.

Suggestions and Recommendations

- For the future, development plans and educational programs on water resources management and utilization should receive the highest priority in agricultural sector. Such programs should be carefully designed for different levels (universities, extension agents, and farmers) in such a way that the actual water problems presently encountered at the farm and project levels and the alternative approaches for their solutions are fully discussed and understood by the trainees.

- In allocating the budget for water sector, the software aspects i.e. research, education, and extension, should receive much greater share than before.

- Development programs for soil and water resources need to be integrated at the watershed level, watershed level, and even at the basin level throughout the country.

- Rehabilitation and modernization of the present irrigation projects should be given priority compared to new projects.

- Serious attempts should be made to decrease the use of groundwater both by development of surface water resources and increased efficiency in irrigation. Recharge of ground waters should also be taken more seriously.

- For any surface water development program, serious and adequate attention should be paid to the control of soil erosion, particularly in upstream areas of the irrigation projects.

- In locations where saline waters or waste waters from industrial and urban areas are used for irrigation, a network of sampling sites should be installed to monitor changes in soil properties and crop's yield and quality. This is very essential for protection of the environment and health of the consumers of the crops grown in these areas.

- The role of small volumes of water in arid areas should not be overlooked. Such waters could come from springs, shallow groundwater, or from surface depressions, which receive rainfall runoff from neighboring areas. Careful management and utilization of such waters will help in developing oases of different sizes in arid environment.

- The rich bio-diversity of Iran presents an excellent opportunity for selecting plant species tolerant to drought and arid environment. Research on this subject should be expanded.

References

Agricultural statistics of Iran (1997-98). Ministry of Agriculture. Bureau of Statistics and Information. Publication No.78.01. April, 1999. (In Persian).

Bybordi, M. Problems in planning irrigation projects in Iran. 1989. In Rydzewski, J.R., and Ward, C. F., Editors. Proceedings of the international conference on : Irrigation: Theory and practice. Uni. Southampton. London. Pentech Press.p:115-123

Ghaffari Shirvan,J. A review on the status of water resources utilization in Iran. 1999.Ninth Symposium of Iranian National

Committee on Irrigation and Drainage, Proceedings.P:395-405 (in Persian)

Jamab Consulting Engineers. National Water Plan.1991. Ministry of Energy, Water Commission. (In Persian).

Mostafazadeh, B., M. Ataie, and S.S. Eslamian. Evaluation of tickle irrigation systems in Isfahan province and possible improvements. 1999.Ninth Symposium of Iranian National Committee on Irrigation and Drainage, Proceedings. P:289-301 (in Persian)

Siadat, H. Environmental impacts of irrigation projects : Some warnings and recommendations. 1994. First National Congress for Policy Massing on Soil and Water Resources. Min. of Agriculture. Tehran. Iran (In Persian).

Siadat, H.. Agronomic alternatives for irrigation and drainage problems of Iran. 1999.Ninth Symposium of Iranian National Committee on Irrigation and Drainage, Proceedings.P:381-394 (in Persian).

6

Abstraction and Recharge Impacts on the Ground Water in the Arid Regions of Tunisia:
Case of Zeuss-Koutine Water Table

Houcine Yahyaoui and Mohamed Ouessar

Commissariat Régional au Développement Agricole and Institute of Arid Lands

Abstract

The Zeuss-Koutine water table represents the main water reservoir for water supply (drinking, tourism, irrigation, industry, etc.) of the two provinces (Médenine, Tataouine) of southeastern Tunisia. Its potential resources are estimated to 350 l/s.

The exploitation of this reservoir has started in 1962, but effectively only in 1972. Its continuous monitoring has shown that the abstraction rate increased from 102 l/s in 1974 to 420 l/s in 1996. It resulted in a decline of the mean piezometric level (PL) of 11.3 m. However, the intensification, especially since 1990, of the construction of soil and water conservation (SWC) structures in the watershed resulted in the stabilization and even amelioration of the PL since 1997. On the other hand, the pumping of this reservoir induced a vertical homogenization of the chemical characteristics that resulted then in an increase in the salinity of the surface layers. It is expected that the SWC works will attenuate this tendency with additional supply of runoff water.

Further research needs are indicated.

General Characteristics

The water table (WT) of Zeuss-Koutine (ZK) spreads over an area which drains the watersheds of the following oueds: Zigzaou, Zeuss, Sidi Makhlouf, Oum Zessar, Oum Tamr and Smar. It is located between the Matmata mountains and the Mediterranean sea. It covers an area evaluated at 785 Km² (Ben Baccar, 1982).

Table 1

Min, Max and Mean precipitation at some rain gauge stations.

Rainfall	Station			
	Médenine	Koutine	Zeuss	Loudyette
Max	471.7	591.1	262.1	257
Min	37	73	176.7	119.4
Mean	152	210.6	214.2	171.4
Years	85	18	5	3

The climate is of Mediterranean type. The rainfall regime is very variable (Table 1). The average annual rainfall is estimated to 170 to 190 mm.

The water table of Zeuss-Koutine is lodged in the following lithostratigraphic levels:

- limestone and dolomite of the upper Jurassic (Callovian - Oxfordian),
- limestone and dolomite of the Albo - Aptian,
- dolomite and calcareous dolomite of the Turonian,
- limestone of the lower Senonian which can be subdivide into two entities:
  - The intermediate chalky unit of the marly gypseous Senonian (B horizon),
  - The upper chalky unit (A horizon).

It is a multi aquifers system with communicating compartments through faults and eventually upward leakage. The limestone and dolomite of the Jurassic and the Albo-Aptian of this aquifer system are unconformable on sandstone of the Trias (Gobbi, 1988).

Its renewable resources have been estimated at 350 l/s.

Abstraction and Recharge

This WT has been exploited since 1962, but effectively during the 70s, for water supply (drinking, irrigation, industry, tourism) of the two provinces of southeastern Tunisia. The average annual abstraction rate (AR) increased steadily and exceeded the renewable resources in 1989 (Fig. 1). Since then, the WT became overexploited.

It is in this framework that an ambitious program for surface water mobilization has been implemented since 1990 in order to ensure the replenishment of this overexploited WT (Smaoui *et al.,* 1997). More than 300 recharge and flood spreading units have been realized on the watersheds of oueds Om Zessar, Zeuss and Oum Tamr (Table 2.).

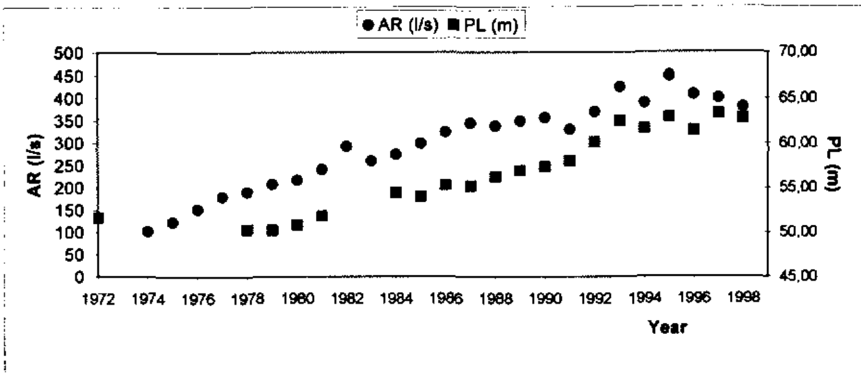


Figure 1: *Evolution of the abstraction rate (AR) and the piezometric level (PL) between 1972 and 1998 (Adapted from Yahyaoui (1999).*

Table 2:
Realized recharge and spreading structures on the watersheds of Zeuss Koutine.

Watershed	Sub-watershed	Realized units up to:					
		31/12/96		31/12/1997		31/12/1998	
		R	S	R	S	R	S
Oum Zessar	Boualah	11	-	17	-	17	-
	Nkim	44	7	44	7	44	7
	Battouma	39	2	39	2	39	2
	Hallouf	15	8	20	8	25	8
	Moggar	12	5	12	5	12	5
	Nagueb	35	4	35	4	35	4
	Lahimer	6	1	6	1	6	1
	Koutine	26	-	39	-	39	-
	Moussa	7	-	7	-	-	-
	Sub-total	201	27	219	27	224	27
Zeuss		35	1	35	-	39	-
Oum Tamr		-	-	3	-	11	-

R = recharge
S = spread
Source: Adapted from Yahyaoui (1999).

It is worth to mention that besides this ground water recharge role, these structures will contribute to the extension of the cropping area by the installation of 1200 ha of fruit trees.

The piezometric level fluctuations have been monitored by the piezometer of Glib Tine since 1965. It has recorded between September 1972 and December 1998 (26 years) a PL decline of

11.3m due mainly to the abstraction rate (Fig. 1). Monthly observations show that PL increases with the decrease in AR during winter periods and/or the humid years. However, the PL decline started to slow down and even tending to stagnation since 1993. It coincides in fact with the intensification of the SWC works and also the stabilization of the abstraction rate.

As long as the water salinity is concerned, the WT behavior was not straightforward because of the geometry of the reservoir. In fact, there has been an increase in the salinity of the saline layers and a decrease of the salinity of the relatively fresh layers. For example, if we consider the aquifer levels of the lower Senoniaen of the horizon (B), which are the deepest, the most salty and the least recharged, the salinity evolution shows a gradual decrease. The average value of this reduction is approximately 52 mg/l/year. This indicates an increasing feeding from less deep and salty aquifer levels by the intermediary of faults and upward leakage. On the opposite, for less salty levels which benefit from rain replenishment, the water salinity increases. Between 1984 and 1987, this rate has been 213 mg/l/year and it dropped later to 41 mg/l/year. It was concluded that during exploitation, the fresh water quantity coming from the infiltration of rainfall decreases while that coming from underlying salty deep aquifers increases.

The watersheds of oued Kouitne and oued Zigzaou are now totally treated with soil and water conservation measures. Between 1982 and 1995, the monitoring of water quality has revealed a gradual increase in salinity (42 mg/l/year) which reflects a vertical salinity exchange phenomenon. In fact, pumping exhausts gradually the fresh water resulting from the infiltration of surface water. This abstraction generates a depression cone and an upward movement of deep salty waters inducing a gradual increase in the coming flow from the geological reserves of the water table.

Conclusion

The water table of Zeuss-Koutine is lodged within several aquifer compartments with different water salinity. The overexploitation of this water table has resulted in a PL decline of 11.3 m and a salinity homogenization of different aquifer levels. It ended with an increase of water mineralization, notably at the surface aquifers replenished by runoff.

Though the AR has been maintained stationary since 1993, the recharge induced by the soil and water conservation works has resulted in a net stagnation of PL.

The vertical variation of salinity and its evolution as a function of time depend on the pumping and the hydrogeologic functioning of the reservoir. In our case, the replenishment provoked by the soil and water conservation structures has not yet induced a significant evolution of the ground water salinity. However, it is expected that this 'artificial' recharge will, in the long term run, be able to damp and/or stop the salinity increase phenomenon.

It is important to note that the intensification of the soil and water conservation programs do not concern only the ground water but it has multiple impacts such as flooding and erosion control, extension of cultivated farms, rangelands use, etc. especially when addressing this problem at the level of the whole watershed. (Ouessar *et al.*, 1999).

References

Ben Baccar B. (1982) : Contribution à l'étude hydrogéologique de l'aquifère multicouche de Gabès-Sud. Thèse de doctorat de 3e cycle, Université de Paris Sud.

Gaubi E.B. (1988) : Evolution de la piézomètrie et de la géochimie de la nappe de Zeuss-Koutine. Mémoire de fin d'étude de cycle de spécialisation en hydrogéologie. Faculté des Sciences de Tunis.

Ouessar M., Sghaier M., Barneveld R. & Zerrim A. 1999. Watershed of oued Oum Zessar: State of knowledge & research methodology. Proceedings of the starting-up seminar of the INCO-DC project WAHIA.

Smaoui A., Yahyaoui H. et Boufalgha (1997) : Nappe de Zeuss-Koutine - Situation actuelle et plan quinquennal de recharge - CRDA, Médenine.

Yahyaoui H. (1999). Impacts des travaux de conservation des eaux et des sols sur la recharge de la nappe Zeuss Koutine. DGRE, Tunis.

Acknowledgements

The authors are grateful to DGRE and CRDA - Médenine for providing the data.

7

Groundwater Utilization and Management in the State of Kuwait

Fawzia Al-Ruwaih

Kuwait University

Abstract

The main brackish groundwater resources in the State of Kuwait are the groundwater located in the Kuwait Group and the Dammam limestone aquifers. Most of the groundwater used in the State of Kuwait is for irrigation, some part of it is used for domestic purposes and for small scale industries. Since rainfall is seasonal and is less than the annual evaporation, the recharge from rainfall is negligible. Extraction of groundwater in the State of Kuwait takes place through 10 water well fields. The average daily production of fresh groundwater and distilled water is about 3.0 $x10^5$ m^3, and that of brackish groundwater is about 2.0 $x10^5$ m^3. The total fresh groundwater and distilled water production, increased by about 247 $x10^6$ m^3 from the year 1965 to 1997, while the total consumption increased by about 249 $x10^6$ m^3 during this period. The gross brackish groundwater production increased by about 73 x 10^6 m^3 through the years 1965 to 1997, while the total consumption increased by about $91x10^6$ m^3 during the period 1965 to 1997. Water levels in both aquifers are highly affected by the pumping rate from each well. Groundwater is extracted under mining conditions resulting in a rapid decline of water levels and the deterioration of groundwater quality. Improvement of the groundwater management is essential for maintaining long-term productivity of the aquifers in the State of Kuwait.

The salinity of the Dammam aquifer ranges from 2,500 to 10,000 mg/l, but locally a maximum of 150,000 mg/l occurs in the direction of groundwater movement toward the north-northeast. The increase in salinity is attributed to dissolution process, as indicated by the increase of Cl, SO_4, Ca and Na ions in the direction of flow. the major hydrochemical water types are Na_2SO_4, $CaSO_4$ and NaCl. Lenses of fresh groundwater, in which the salinity ranges from 200 to 1,400 mg/l, occur in the depression of Al-Rawdhatain and Umm Al-Aish fields, in the Upper Dibdibba Formation of the Kuwait Group aquifer. The aquifers are directly recharged by local precipitation, and fresh groundwater is slightly mixed with brackish waters. These aquifers contain $Ca(HCO_3)_2$ and $NaHCO_3$ type water, in which $HCO_3 > SO_4 > Cl$.

Introduction

The State of Kuwait is located in an arid region which is characterized by a mild to cold winter and a hot , dry summer . It occupies an approximate area of 17,818 km^2 (Fig.1). Kuwait's climate has a significant effect on the amount of precipitation, surface runoff and evapotranspiration, which in turn has a direct or indirect influence on the replenishment of groundwater resources.

The rainfall record over 35 years (Fig.2) shows that the precipitation is lower than evaporation. The annual means of precipitation and evaporation are about 114.56 mm and 216.71 mm respectively. This low value precludes rainfall as the dominant direct source of recharge to the aquifer due to a considerable thickness of the overlying formations, the prevailing evapotranspiration and the soil moisture deficit. The water losses through evapotranspiration increase during the summer and decrease during the winter months.

Due to the scarcity of water resources in Kuwait, groundwater constitutes a critical resource, which may set the limit on consumption rate, density of population and ultimately the standard of living achieved in these regions. During the last decades, the State of Kuwait has been comprehensively developing in agricultural, industrial, social and constructional sectors. The government has been supporting and encouraging farmers to contribute to securing Kuwait's food supply.

A major problem associated with the development and management of groundwater is the continued excessive extraction which does not confirm with the natural replenishment.

Hydrogeology of the Aquifer Systems

The regional aquifer systems in Kuwait are limited to the Neogene-Quaternary (Kuwait Group) and the upper part of the Eocene (Dammam limestone) aquifers. These aquifer systems start in the west as sandstones then change gradually eastward to carbonate formations which are dominant near the coast of the Arabian Gulf. The groundwater flows from west to east and some upward leakage takes place through aquicludes (Fig.3).

Kuwait Group Aquifer : The Neogene-Quaternary aquifer system is represented by the Kuwait Group aquifer, with a thickness varying from 150 m in the southwest to about 400 m in the northeast. This aquifer is divided into three formations: Dibdibba, Lower Fars and Ghar Formations as shown in Fig.4. The initial piezometric head of Kuwait Group aquifer is about 100 m above M.S.L. in the southwestern corner of Kuwait. The piezometric head slopes downwards with relatively uniform gradient in the southwest - northeast direction towards Kuwait Bay (Fig.5). Groundwater flows out convergently towards Kuwait Bay and is discharged by evapotranspiration at marsh lands along the shoreline and ultimately into the Kuwait Bay and Arabian Gulf, may be intercepted by a series of wells. The recharge to the Kuwait Group aquifer is due to upward leakage from the underlying Dammam limestone aquifer, while some recharge may be received from infiltration during occasional winter rain storms.

Dammam Limestone Aquifer : The Eocene aquifer system is divided into three formations: the Dammam and Umm Al-Radhuma Formations, separated by Rus anhydrite Formation (Fig.4). The Eocene aquifer system is considered as one aquifer because of the hydraulic continuity and the balanced pressure of these two aquifers, especially where karst or faults are abundant. The Dammam limestone aquifer is the representative of the Eocene aquifer with a thickness varying from 150 m in the southwest to nearly 275 m in the northeast. The initial piezometric head of the Dammam aquifer is about 115 m above M.S.L. in the south-western corner of Kuwait sloping towards the northeast (Fig.6). The head in the Dammam aquifer was 3 to 20 m higher than that in the Kuwait Group aquifer. As a result of the above setting, a vertical upward leakage between the aquifers is observed.

The salinity of the Dammam aquifer ranges from 2,500 to 10,000 mg/l, but locally a maximum of 150,000 mg/l occurs in the direction of groundwater movement toward the north-northeast. The increase in salinity is attributed to dissolution processes, as indicated by the increase of Cl, SO_4, Ca and Na ions in the direction of flow. The major hydro-chemical water types are Na_2SO_4, $CaSO_4$ and NaCl. Lenses of fresh groundwater, in which the salinity ranges from 200 to 1,400 mg/l, occur in the depression of Al-Rawdhatain and Umm Al-Aish fields, in the Upper Dibdibba Formation of the Kuwait Group aquifer. The aquifers are directly recharged by local precipitation, and fresh groundwater is slightly mixed with brackish waters. These aquifers contain $Ca(HCO_3)_2$ and $NaHCO_3$ type water, in which $HCO_3 > SO_4 > Cl$.

Recharge and Discharge of the Aquifers

The brackish groundwater in the State of Kuwait is mainly produced from three water fields namely Al-Shagaya fields (A,B,C,D & E), Al-Sulaibiya and Umm-Gudair, where most of the water wells penetrated the main aquifers, the Dammam limestone and the Kuwait Group. The Dammam limestone aquifer is considered as confined to semi-confined. The main source of aquifer recharge is the direct precipitation on the intake area, the Dammam Dome in Saudi Arabia, in which the water percolates down dip towards the discharge areas. The actual amount of flow to the intake area of the aquifer is unknown. Hence further studies to assess the groundwater fluctuations will be incomplete. However, according to Senay (1981), the amount of groundwater flow is estimated to be about 2×10^4 m^3/day through the Kuwait Group and 5×10^4 to 7×10^4 m^3/day through the Dammam limestone aquifer beneath the border with Saudi Arabia. According to Al-Rashed (1993), the estimated average quantity of groundwater flow in 1976 for the Kuwait Group aquifer was 3.1×10^5 m^3/day and became 1.4×10^5 m^3/day in 1988. For the Dammam limestone aquifer the groundwater flow was estimated as 3.1×10^5 m^3/day in 1972 and 1.8×10^5 m^3/day in 1988. Thus, the quantity of groundwater flow decreases annually in the Kuwait Group and the Dammam limestone aquifers by 1.4×10^4 m^3/day and 0.8×10^4 m^3/day respectively. The calculated amount of groundwater flow in a radial direction to the pumping center of Al-Sulaibiya field is approximately 1.4×10^4 m^3/day. Such small quantities of lateral replenishment and storage indicate the view that significant leakage from adjacent formations must be taking place (Al-Ruwaih, 1981). The amount of groundwater flow to the Dammam limestone aquifer of Umm-Gudair field along the border with Saudi Arabia was estimated to be 1.0×10^4 m^3/day, which is far below the average daily production of 6.0×10^4 m^3/day of the field. Therefore, a serious decline in the water level would result.

Table 1

Source aquifer and Fresh/Brackish Groundwater production in different fields in the state of Kuwait.

Operating Field	Aquifer	No. of wells	The productive capacity (m^3)	Daily prod. Av. 1998 (m^3)	Average T.D.S. (mg/l)	Uses
1962	Dibdibba	16	16	0.2	300-2000	Northern area & Army bases
1965	Dibdibba	9	7	0.06	300-2000	Northern area & Army bases
1945	Dammam	9	56	27	3500-4500	Supply for Kuwait Oil Company
1954	Dammam	107	68	58	4000-7000	Irrigation water
1972	Kuwait Group and Dammam	12	32-36	17	3000-4000	Irrigation water and domestic needs and mixing
1975	Kuwait Group and Dammam	15	36-46	24	3000	Irrigation water and domestic needs and mixing
1975	Dammam	31	82-91	49	3000	Irrigation water and domestic needs and mixing
1979-1980	Dammam	24	55-64	30	3000-4000	Irrigation water and domestic needs and mixing
1979-1980	Kuwait Group and Dammam	30	68-77.3	39	3500-5000	Irrigation water and domestic needs and mixing
1986	Kuwait Group and Dammam	41	114.1	76	3500-4000	Irrigation water and domestic needs and mixing
1990	Kuwait Group and Dammam	26	68.2	68	3300-5300	Irrigation water and domestic needs and mixing
1987	Dammam	90	23	16	5000-6500	Irrigation water and domestic needs and mixing
Late 1960's	Dibdibba	933		35	3000-10,000	Shallow wells for irrigation of Farms (Hand dug wells) & Pipy
Late 1960's	Kuwait Group	963		31	3000-10,000	Shallow wells for irrigation of Farms (Hand dug wells) & Pipy

Records of annual production from Al-Sulaibiya field since 1957 show an annual increase in the amount of groundwater abstracted due to the increased demand of brackish water for domestic as well as irrigation purposes (Fig.7A). The relative stabilization in seasonal demand during the 1970's is the consequence of additional well fields. Presently, the maximum seasonal abstraction per year is of the order of 27×10^6 m^3/day. The annual production from the Al-Shagaya Field-D is about 3.0×10^4 m^3/day as shown in Fig.7B. And after 16 years of production, the water level in Field-D declined by more than 46 m (Al-Haddad, 1992). The decline of potentiometric head in Field-D is due to several factors such as the discharge rate, schedule of production, pumping period and hydrological properties. The production of groundwater from Umm-Gudair field is shown in Figure 7C. Table 1 shows groundwater production from the Kuwait Group and the Dammam limestone aquifers for all fields. Fresh groundwater produced only from Al-Rawdhatain and Umm Al-Aish fields is being used for drinking purposes.

Generally, it is obvious that the abstraction from the different water wells increases annually, which brings commensurate increases in the length of the critical period and by this process the aquifer becomes progressively less resilient under mining conditions. Wherever this level is set, there will be a corresponding risk of failure which must be designed into the management strategy.

Water Level Fluctuation of the Aquifers

Groundwater levels in the Kuwait Group and Dammam limestone aquifers are measured in almost every observation well in the study area.

Al-Sulaibiya Field : The water level fluctuation of the Kuwait Group and Dammam limestone aquifers indicates a direct influence of production as presented in Figure 8. The calculated average of the water level changes was found to be 1.5 m per annum over a period of 15 years, (during 1975-1990). The predicted continuous lowering of the piezometric level especially in the eastern part of the field ranges between -91 m to -116 m during the period 1990 - 2000 (Al-Ruwaih, 1996).

Al-Shagaya Field : Al-Shagaya Field-A was put in use in 1973. Groundwater is extracted from the storage in the Kuwait Group and the Dammam limestone aquifers. The transmissivity value ranges from 72 to 200 m^2/day, with an average storage coefficient of 2.0 x 10^{-4} (Al - Hajji, 1976). Figure 9A shows the fluctuation of the water level of the upper and lower Kuwait Group and the Dammam limestone aquifers.

In Al-Shagaya Field-B, the Kuwait Group aquifer reveals an average transmissivity of 300 m^2/day, while the Dammam limestone aquifer exhibit a range of transmissivity from 33 to 2600 m^2/day. The storage coefficient is 1×10^{-3} and 2×10^{-4} for the Kuwait Group and the Dammam limestone aquifers respectively. The effect of production is noticeable on the fluctuation of piezometric levels of the lower Kuwait Group and Dammam limestone aquifers, suggesting that the two aquifers are connected hydraulically as shown in Fig.9B.

In Field-D, the water levels in the upper and lower Kuwait Group show a slight fluctuation with time. The piezometric level of the Dammam limestone aquifer declined more than 30 m during the period 1981 to 1989. The rising in water level in the year 1989 is due to the change in the production rate between Al-Shagaya fields (Fig.9C). It is clear that the fluctuation of water level is due to the change in pumping rates. The water level fluctuation tends to follow a seasonal pattern in which the water level rises relatively in the winter and it decreases relatively in summer. The seasonal fluctuation of the water level is about ± 10 m.

Umm-Gudair Field: The Umm-Gudair Field production started in 1986 with 40,000 m^3/day and increased to 124,000 m^3/day in 1997 (Fig.10). The drawdown value of the Kuwait Group aquifer is 5.81 m for the production of 114 m^3/day in 1993. And it is expected to be 8.96 m when the production increases to 182 m^3/day in 2012. However, as most of the groundwater is produced from the Dammam limestone aquifer, the drawdown values are 16.5 m and 26.4 m for the years 1993 and 2012 respectively, when the production increases from 114 m^3/day to 182 m^3/day. The Kuwait Group aquifer has an average transmissivity of 209 m^2/day, average effective permeability of 2.16×10^{-12} m^2 and a storage coefficient of about 3.17 x 10^{-4}. While the average transmissivity and effective permeability of the Dammam limestone aquifer are 581 m^2/day and 2.8 $x10^{-12}$ m^2 respectively. The average storage coefficient of the Dammam limestone aquifer is $5.8x10^{-4}$ (Abu-Hijleh,1988).

In **Al-Abdali** area the water level decline of about 9 - 10 m and the deterioration in groundwater quality by about 4000 - 5000 mg/l of T.D.S. took place from the year 1963 to 1987. Mukhopadhyay et.al (1994) stated that at the present production rate, the groundwater resources of Kuwait are being mined, beside the underflow from Saudi Arabia. Moreover, the Kuwait Group and the Dammam limestone aquifers may be dewatered at some locations.

Production and Consumption of Water

Desalination water: In view of the scant natural fresh water resources, Kuwait, since founded, had to look for other sources to secure potable water requirements. The saline water desalination has become a science to produce large amount of fresh water economically. The Reverse Osmosis method which is being used in Kuwait for water desalination is of the condition that it does not require too much energy. The huge quantitative evolution which over the last three decades has raised production by sixty-four folds would not without fail have been for fresh water, the mainstay of life. The installed capacity of distillation plants has been gradually increasing since 1957. In 1997 the total production of 6 distillation plants has increased to 3.0 $x10^8$ m^3/day. It is clear from the consumption figures that the mean per capita consumption has risen from 22 m^3 in 1960 to 181 m^3 in 1997. This per capita figure is considered as one of the highest known parameter in the world. The above mentioned values reflect the huge progress achieved by the country regarded by all standards as the yardstick of prosperity and development being comparable to per capita average consumption in advanced countries.

Fresh Groundwater: Limited quantities of fresh groundwater were discovered at Al-Rawdhatain and Umm Al-Aish fields, where the estimated natural reserve of both fields is about 1.8 $x10^8$ m^3. The production of fresh groundwater during 1962-1990 is generally decreased due to its limited sources where it is being kept as a strategic reserve. In addition, the field production has been ceased during 1990-1991 due to Iraqi invasion. The usual rate of production capacity of fresh groundwater is above $4.5x10^3$ m^3/day which when necessary, could be raised to $11.4x10^3$ m^3/day for a period of 10-15 days at the maximum of twice a year in order to preserve the quality of water (MEW,1998). To avoid exhaustion to the natural reserve water, daily production was limited to $2.3x10^3$ m^3/day.

Brackish Groundwater: Brackish groundwater exists in the Kuwait Group aquifer and the Dammam limestone aquifer stretching east of Arabian Peninsula and slightly sloping towards the Arabian Gulf. The utilization of brackish water started in 1953 on a small scale basis and for limited purposes. However, in 1960 it embarked on a large scale project to provide consumers with the brackish water through a separate pipe network. The present total installed output capacity of these water fields is around $5.5x10^5$ m^3/day. An amount of 10-12% of brackish groundwater is used for blending with distilled water, in addition to irrigation, landscaping and house-hold purposes. Moreover, there are some wells in agricultural areas of Al-Wafra and Al-Abdali which are being used for agricultural purposes. The amount of production of fresh, brackish groundwater and distilled water is plotted in Figure 11.

Distilled water consumption in Kuwait totalled 3.0 $x10^6$ m^3 in 1957. The average per capita consumption of distilled and brackish groundwater was increased greatly from 1957 to 1997. Since 1992, the total consumption of fresh groundwater has been increasing gradually and the per capita consumption of fresh groundwater was also increased during 1960 - 1997. In 1962, the brackish groundwater consumption in Kuwait totalled 7 $x10^6$ m^3, and reached 109 $x10^6$ m^3 in 1997. The gross consumption includes the net consumption plus brackish groundwater used for blending. Figure 12 shows the per capita consumption of the distilled and brackish groundwater during 1957 -1997 with population.

Although groundwater mining was carried out in Kuwait in the early stages of groundwater extractions, the future supply of groundwater has not been verified against the natural groundwater potentialities in Kuwait. The future brackish groundwater demand in the year 2005 will be 4.2 times the current production and will reach a maximum of 4.0 $x10^8$ m^3/year (Master Plan of Kuwait, 1983). The other component of forecast deals with the increase of water demand due to landscaping. The estimate was based on summer and winter application rates of 5 $\times 10^{-3}$ and 9 $\times 10^{-4}$ m^3/m^2/day for regional parks and of 2.5×10^{-2} and 1×10^{-2} m^3/day for other cultivated areas. Table 2 contains the other areas of prospective production fields for brackish groundwater in Kuwait.

Table 2.
The prospective production fields for brackish groundwater in the State of Kuwait.

Field	Formation	Total production (m^3/day)	Average T.D.S. (mg/l)
North and N.W.Shagaya	Kuwait Group and Dammam limestone	159	3500 - 5000
Al-Atraf	Kuwait Group	91	4500 - 6500
N.W. of Umm-Gudair	Kuwait Group and Dammam limestone	45	3500 - 5000
N.E. of Umm-Gudair	Dammam limestone	68	4500 - 6000

Conclusion

The main groundwater resources in the State of Kuwait are the groundwater located in the Kuwait Group and the Dammam limestone aquifers. Groundwater was flowing naturally in both aquifers from SW to NE without major distortions to the lines until the excessive abstraction took place. The amount of rainfall in Kuwait is not expected to make a significant contribution to recharging the aquifers. Water levels in both aquifers are highly affected by the pumping rate from each well. Groundwater is extracted under mining conditions resulting in a rapid decline of water levels and the deterioration of groundwater quality. The predicted lowering of the piezometric level, in the eastern part of the Al-Sulaibiya field ranges between -91 to -116 m during the period from 1990 to 2000 due to heavy exploitation. The prediction of the aquifer performances of the Umm-Gudair field indicated that the groundwater production rates are much higher than the regional groundwater flow.

The total production of fresh groundwater and distilled water has been increased by 247 x 10^6 m^3, from the year 1965 to 1997. In addition, the total consumption was increased by 249 x10^6 m^3 during this period. So, the total consumption should be reduced by 2.0 x 10^6 m^3 . The total production of brackish groundwater increased by 73 x10^6 m^3 during the period 1965-1997, while the total consumption increased by 91 x10^6 m^3 during the period 1965 to 1997. The increase in cultivated areas, clustering of a large number of wells in small areas and the excessive groundwater pumping for irrigation in these areas have resulted in unacceptable impacts on the groundwater level decline and deterioration of water quality. Improvement of the groundwater management and the adoption of effective measures for lowering the irrigation water usage resulted in conserving the long-term productivity and quality of aquifer systems in the State of Kuwait.

List of Figures

Fig. 9C Fluctuation of water levels both in the Kuwait Group and Dammam limestone aquifers along with monthly production from Al-Shagaya Field-D during 1981 - 1990.

Fig.10 A Plot of the average piezometric levle of the Kuwait Group and Dammam limestone aquifers (UG-OW.4) and annual field production of Umm-Gudair Field during 1981 - 1996.

Fig.11 The production of water in Kuwait.

Fig.12 Per capita consumption of distilled water and brackish groundwater.

References

Abu-Hijleh, A.S., 1988: Hydrological and hydrochemical study of Umm- Gudair groundwater area, southeast Kuwait. M.Sc. Thesis, Kuwait University, pp. 221.(Un published).

Al-Haddad, A.J., 1992: Groundwater resources evaluation of Field-D, Al-Shagaya area, M.Sc. Thesis, Kuwait University, Kuwait, 130 p.(Un published).

Al-Hajji, Y.Y., 1976: A quantitative hydrogeological study of Field-A, South Kuwait, M.Sc. Thesis, Ohio University (Un published).

Al-Rashed, M.F., 1993: Hydrogeology of Shagaya Fields C and E, Southeast Kuwait. Ph.D. Dessrtation, University College of London, pp.406 (Un published).

Al-Ruwaih, F.M., 1981: Hydrology of Al-Sulibiya well Field, Southwest Kuwait. Journal of Gulf and Arabian Peninsula studies, Vol.2, p. 62 - 79.

Al-Ruwaih, F.M., 1996: Hydrogeology and groundwater modelling of the carbonate aquifer of Al-Sulibiya, Kuwait. Kuwiat Journal of Science and Enginnering, Vol. 23, p. 89-103.

Master Plan of Kuwait, 1983 : Ministry of Electricity and Water, Unpublished Report.

Ministry of Electricity and Water (MEW), 1998: Statistical year book, State of Kuwait.

Mukhopadhyay, A., Al-Sulaimi, J. and Barrat, J. M., 1994: Numerical modelling of resources management options in Kuwait. Groundwater, 32 (6) : 917 - 928.

Owen, R.M.S. and Nasr, S.N. 1958: Stratigraphy of Kuwait Basra Area.In Habitat of Oil : American Association of Petroleum Geologists bulletin 42: 1252-78.

Senay, Y., 1981: Geohydrology. Geology and Groundwater Hydrology of the State of Kuwait, Ministry of Electricity and Water, Kuwait. p. 57 - 75. Unpublished Report.

8

Water Retention Characteristics of a Calcareous Soil from Iran: An Ecologically Significant Property

Sayyed Ahang Kowsar

Fars Research Center for Natural Resources and Animal Husbandry, Iran

Abstract

Soil porosity in the rooting zone provides the best plant accessible water storage reservoir in the deserts. The available water capacity is the most important soil property in the floodwater irrigated farming (FIF). As the highly calcareous soils cover most of the alluvial fans suitable for FIF in Iran, characterization of their water relationships is essential for the successful implementation of the desertification control projects. The near total failure of 2 year old black locust (*Robinia pseudoacacia* L.) trees planted on a deep, silty - clay A - horizon, and the significant success of the very species grown at the same site on the same soil underlain with a loam C - horizon containing up to 66% $CaCO_3$ necessitated this study. The water characteristic curves of the two soils revealed that although the calcareous horizon behaves like a clayey soil in the high water potential range, it imitates sand at the opposite end of the curve. Particle size distribution studies demonstrated that the $CaCO_3$ content of the sand, silt and clay fractions were 60.16, 71.70, and 64.64%, respectively. Therefore, since the clay - sized particles determine the soil water content in the low potential range, as the percentage of layer silicates reduced to 9.49% in the samples whose $CaCO_3$ content had been removed, this placed the "loam" soil into a "sand" category. This "sandy soil" releases 35% more plant-available water than its counterpart, thus it supplies the trees with more water. The XRD patterns revealed the presence of expanding clay minerals in the C-horizon and their relative lack in the A - horizon. However, , either the insignificant amount of such minerals, and/or the coating of fine aggregates with $CaCO_3$, prevents the soil retaining much water at low potentials. This ecologically significant property of calcareous soils may encourage plant survival in the desertic environments.

Introduction

Tree planting has been recognized as a very useful technique in rehabilitation of the drastically disturbed land. It is generally accepted that those soil and site properties which determine the plant available, or extractable, water (Ritchie, 1983) have the greatest influence on survival and growth of trees, particularly in the arid - and semi - arid zones. Therefore, to paraphrase Mabbutt (1987), water management is the exact equivalent of desertification control (DC). As the rooting zone supplies the trees with air, nutrients and water, and the nutrient translocation to the root surface takes place in liquid water, therefore, soil porosity, and its inherent characteristic, pore - size distribution, control the extractable water that determines vegetation existence in the deserts.

Floodwater spreading is a DC technique used in Iran from time immemorial for many purposes, particularly for floodwater irrigated farming (FIF), and the artificial recharge of groundwater (ARG). As shelterbelts and windbreaks are the integral parts of the DC practices, and they should precede farm crop introduction by a few years, which takes the suspended load to form a relatively deep soil, the soil - plant - water relationships for the adaptable species should be known. Moreover, a thorough understanding of these relationships is essential for optimization of water utilization when FIF is implemented in the broad expanses of our deserts. As calcareous soils cover more than two thirds of the land of Iran (Dewan and Famouri, 1964), and they occur extensively in the Near East Region under arid and semi - arid conditions (Kadry, 1973), they assume a significant position in such studies.

The near complete failure of 2 years old black locust (*Robinia pseudoacacia* L.) trees planted on a deep, silty - clay brown A - horizon ("brown soil"), and the significant success of the very species grown at the same site on the same soil underlain by a loam grey C - horizon ("grey soil") containing up to 66% $CaCO_3$, necessitated this research. Of the different hypotheses advanced for this malady those related to pests and diseases were discarded due to isolation of the dead trees in clusters. Therefore, soil related causes might have been responsible for this phenomenon.

The objective of the study reported here was to find the reason(s) for the success of the locust trees grown on a soil with a silty - clay A - horizon underlain by a loam C - horizon containing up to 66% $CaCO_3$, and the near complete failure of the same trees grown in the same place on the very soil but without the highly calcareous subsoil.

Materials and Methods

The study was conducted on a southeasterly facing hillside at the Qootchak Experiment Station, 15km NE of Tehran at an elevation of 1950m. The soil, tentatively classified as a Mollic Calciorthid, was a silty clay underlain by a highly calcareous loam (Fig.1). Average annual precipitation is 385 mm (1971-1978).

Terraces, 1.3m in width, were constructed at 1.5m vertical intervals on a 30% slope resulting in a runoff - to - runon area ratio of 2.2. Medium curing asphalt solution (MC_2) was sprayed at the rate of 1 Lm^{-2} onto the soil surface between the terraces in the summer of 1971. One year old, open - rooted seedlings of black locust were planted in 50 by 50 - cm pits dug in the terraces at a spacing of 3m (666 stems ha^{-1}) in March 1972. More details of the site and performance of the trees grown in this water harvesting experiment may be found elsewhere (Kowsar et al., 1978; Kowsar, 1982).

Four pits were dug at random in each of the living and dead locust clusters to the lower limit of root exploration which was 50cm for the dead and 120cm for the living trees. One soil sample was collected from the 0-50cm of each pit in the dead tree stand. These samples were mixed and a 1 kg sample was prepared. Four samples were collected from the 30cm increments in the living tree stand. The samples from each pit were mixed and four 1 kg samples were prepared and shipped to Oregon State University Soil Testing Laboratory for analyses. In addition to the routine works done at the laboratory (Tables 1 and 2), the following analyses were implemented on the samples.

Four 10g samples of the "grey soil" which had been dried at 105 °C for 24-h and passed through a 2mm sieve were prepared. A 1*M* NaOAc (pH 5.0) buffer was used to remove $CaCO_3$ (Gee and Bauder, 1986); however, as this proved very time consuming the treatment was discontinued. Calcium carbonate of a fresh set of samples was removed using 6*N* HCl while keeping the pH of the solution above 3.5. The addition of 6*N* HCl was discontinued as soon as the reaction terminated. The systems were centrifuged and the supernatant liquids were discarded. Iron oxides were subsequently removed by the Na - DCB method (Mehra and

Jackson, 1960). The supernatant liquids were again discarded. Organic matter was removed using H_2O_2 (30%). Particles were fractionated into sand, silt and clay - size separates by the pipet method (Gee and Bauder, 1986). The separates were dried at 105°C for 24-h and weighed.

Water characteristic curves for the two soils were obtained using the pressure plate and pressure membrane apparatuses (Klute, 1986). Clay samples for mineralogical analysis for the "brown soil" and "grey soil" with and without $CaCO_3$ removal, were prepared according to the procedures outlined by Whittig and Allardice (1986). Slides of both Mg^{2+} and K^+ - saturated fractions were prepared by the paste method of Theissen and Harward (1962).

The XRD patterns were obtained using copper K - alpha radiation and a Norelco X-ray diffractometer equipped with a focusing monochromator and a scintillation detector. All samples were analyzed between 2 and 37° 2 thetaθ which covers the range for basal reflection of phyllosilicates and most of minerals found in soils.

Results and Discussion

Table 3 presents the $CaCO_3$ content of the "grey soil" and its ratio in the different size fractions. It is observed that $CaCO_3$ is distributed almost evenly in the sand, silt and clay separates. As the whole soil contains 26.83% clay, and 64.64% of the $<2 um$ fraction is $CaCO_3$, therefore:

$$26.83 \times 64.64 = 17.34$$

percent is calcium carbonate. Thus, phyllosilicates and other minerals make:

$$26.83 - 17.34 = 9.49$$

percent of the whole soil. While the original particle size distribution classifies the soil as a "loam", the newly calculated clay - size fraction puts it in the "sand" category. This becomes more clear if one examines the water characteristic curves for the two distinct soils (Fig. 2). While the two soils hold almost equal volumes of water at - 0.05 bars, they differ considerably at - 15 bars. The amount of extractable water between these two limits for the "brown" and "grey" soils were 20 and 27%, respectively. Therefore, assuming identical bulk densities, the calcareous subsoil releases:

$$\frac{27-20}{20} = 0.35$$

more "available water" to the plants relative to the "brown soil". This has come about not only because of the presence of $CaCO_3$ in the clay - size fractions, but the probable coating of fine aggregate by calcium carbonate, thus decreasing their strong affinity for water (Massoud, 1973). This substantiates the work of Luebs (1983) who reported that Hanford very fine sandy loam and Porterville clay held 18.3 and 15.0 cm of plant - available soil water in a 120 cm profile, respectively.

The XRD patterns of the $<2um$ fractions of the two soils are presented in Fig. 3. The prominent peaks for the "brown soil" belong to chlorite or chloritic intergrades, mica, kaolinite, quartz and calcium carbonate (Fig 3 - I). The diffuse nature of the peaks in the low degree 2θtheta prevents concise identification of clay minerals in that region. The lack of expansion and collapse with the prescribed treatments refutes the presence of appreciable quantities of smectites. The prominent peaks for the "cleaned" "grey soil" indicate the presence of a chloritic intergrade, mica, kaolinite, quartz and probably gibbsite. The presence of a peak at 1.659 nm with Mg^{+2} as well as K^{+} saturation at 54% R.H. which does not expand with ethylene glycol but expands to 1.765 nm with glycerol is intriguing (Fig 3.II). This maybe a newly discovered Ca - smectite. More details are found elsewhere (Kowsar, 1977).

That the "brown soil" holds about 15% of water by weight at - 15 bars is understandable because it contains 43.16% clay - size fractions. However, apparently the 1.75% $CaCO_3$ in the whole profile does not contribute much to the water relationships of this soil.

Conclusions

As plants integrate the environmental conditions the presence of certain species in Nature reveals the site characteristics that have made it suitable for them. Black locust, an exotic tree species, could not take root in a Mollic Calciorthid in the arid environment of NE Tehran. Although it survived the summer of 1972, when we had 108mm of rain during the April - August period, it failed in the summer of 1973. It rained only 3.8mm in May of that year. There was absolutely no rain for the next 5 months. It was during this drought that the calcareous subsoil proved its potential in supplying water to black locust trees.

Although high concentration of $CaCO_3$ in soil causes some imbalance in plant nutrition, as water is the most limiting factor for the survival of every living thing in dry environments, and the clay - size $CaCO_3$ releases most of the water held in low potentials, this points to the need of looking deeper into the subject.

Drought avoidance (tolerance, resistance, endurance), and any other term that characterizes water demand of certain species of palnts, cannot fully define the intended property if the water relationships of a soil on which they are growing is not specified. Soil - plant - atmosphere is a continuum that cannot practically be divided into separate entities. The soil, being the most valuable natural resource, is not only the growth medium, but the supplier of measured amounts of water for rainless periods in the deserts. Paying more attention to this pillar of life is searching for a survival mechanism in the coming millenium.

References

Dewan, M.L., and J. Famouri. 1964. The soils of Iran. FAO, Rome. 319p.

Gee, G.W., and J.W.Bauder. 1986. Particle - size analysis. p. 383-411. *In* A.Klute(ed.) Methods of soil analysis. Part I. 2nd ed. Agron. Monogr.9. ASA and SSSA, Madison, WI.

Kadry, L.T. 1973. Distribution of calcareous soils in the Near East Region, their reclamation and land use measures and achievements. p. 17-27. *In* Calcareous soils. Soils Bulletin 21, FAO, Rome.

Klute, A. 1986. Water retention: Laboratory methods. p. 635-662. *In* A.Klute (ed.) Methods of soil analysis. Part I. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

Kowsar, A. 1977. Soil surface application of asphalt in afforestation in semi-arid zones of Iran. Ph.D. diss. Oregon State Univ., Corvallis.

Kowsar, A., E. Vaziri, P.Mehdizadeh, and L.Boersma. 1978. Water harvesting for afforestation :II. Survival and growth of trees. Soil Sci. Soc. Am. J. 42: 650-657.

Kowsar, A. 1982. Water harvesting for afforestation: III. Dependence of tree growth on amount and distribution of precipitation. Soil Sci. Soc. Am. J. 46: 802-807.

Luebs, R.E. 1983. Water conservation: Pacific Southwest p.125-136. *In* H.E.Dregne and W.O.Willis (eds.) Dryland agriculture. Agron. Monogr. 23. ASA, CSSA, SSSA, Madison, WI.

Massoud, F.I. 1973. Some physical properties of highly calcareous soils and the related management practices. p.73-94. *In* Calcareous soils. Soils Bulletin 21, FAO, Rome.

Mabbutt, J.A. 1987. Implementation of the Plan of Action to Combat Desertification: Progress since UNCOD. Land Use Policy 4:371-388.

Mehra, O.P., and M.L.Jackson. 1960. Iron oxide removal from soils and clays by a dithionite - citrate system buffered with sodium bicarbonate. Clays Clay Miner. 7:317-327.

Ritchie, J.T. 1983. Climate and soil water. p.1-23. *In* L.S.Murphy et al. (ed.) Moving up the yield curve: Advances and obstacles. ASA Sepc. Publ. 39. ASA, Madison, WI.

Theissen, A.A., and M.E.Harward. 1962. A paste method for preparation of slides for clay mineral identification by X-ray diffraction. Soil Sci. Soc. Am. Proc. 26: 90-91.

Whittig, L.D., and W.R.Allardice. 1986. X-ray diffraction techniques. p. 331-362. *In* A.Klute (ed.) Methods of soil analysis. Part I. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

Table 1

Particle size distribution of the soil of the experimental site

Horizon	**A**	**C**
Depth (cm)	**0-30**	**30-**
Color(moist)	**10 YR 3.5/3** dark-brown	5Y 7/2.5 light-gray
percent larger than 2 mm (stones)	20.00	31.00
particle size distribution of material smaller tnan 2 mm		
very coarse sand (2-1)	4.68	3.67
coarse sand (1-0.5)	2.77	5.37
medium sand (0.5-0.25)	1.84	5.41
fine sand (0.25-0.1)	2.95	9.18
very fine sand (0.1-0.05)	4.94	7.74
total sand (2-0.05)	17.18	31.37
coarse silt (0.05-0.02)	13.38	8.56
fine silt (0.02-0.002)	26.28	33.24
total silt (0.05-0.002)	39.66	41.80
total clay (<0.002)	43.16	26.83
Textural class	clay - silty clay	loam

Table 2

Chemical analyses of the soil of the experimental site

Horizon	**A**	**C**
pH (water)	8.0	8.5
P, ppm	22	5
K, ppm	444	32
Ca, meq/100g	34	38
Mg, meq/100g	2.7	1.2
Na, meq/100g	0.13	0.10
B, ppm	0.52	0.34
C.E.C., meq/100g	25.3	9.4
$CaCO_3$, %	1.75	64.64
Organic matter, %	1.9	0.27
Total N, %	0.09	0.03
Zn, ppm	0.58	0.29
Fe ppm	110	1.3
Cu ppm	4.5	8.9
Mn ppm	7.3	1.7
SO_4 , meq/100g	9.5	17.1

Table 3

Weight of soil separates without and with $CaCO_3$ in grams and percentage of $CaCO_3$ in the soil and each fraction.

Sample No.	Sand	Silt	Clay	Total weight
1	1.2294	1.4431	0.5208	3.1933
2	1.2249	0.8550	1.3222	3.4021
3	0.5266	1.0242	0.7536	2.3044
4	2.0300	1.4016	1.1975	4.6291
Average without $CaCO_3$	1.2517	1.1809	0.9485	3.3822
Average with $CaCO_3$	3.1420	4.1730	2.6830	10.0000
$CaCO_3$, weight	1.8903	2.9921	1.7345	6.6178
$CaCO_3$, %	60.16	71.70	64.64	66.17

9

Participative management of the water resources in agriculture: Case of In Belbel and Matriouen in the Algerian Sahara

Abderrahmane Benkhalifa and Iwao Kobori

Algierss University and United Nations University

Introduction

The two oases In Belbel and Matriouen are located in the center of Algerian Sahara is under extreme arid conditions. These two small villages are subject of a regular follow-up led by Professor Iwao Kobori since 1960. Successive visits of the professor and his Japanese colleagues allowed the publication of several scientific and technical documents (Kobori, 1969 and Kobori, 1982). Having met professor Kobori in 1992, we adhered to this work to give him a multidisciplinary dimension within the framework of a project entitled ' Evolution of the oases following the introduction of technologies'. The unit of Search on the Arid Regions (URZA) is the interlocutor in Algeria. A first common mission was carried out in January 1993. A review article was written in order to consolidate this work and to propose the development of a monograph concerning the case of study of In Belbel. Exchanges took place during years 1994, 1995, and 1996. Unfortunately the conditions had not made it possible to intensify the field work during this period. Nevertheless, the contact was maintained until 1999 when it became possible to us to visit these two oases. Thus, we moved until In Belbel and Matriouen (April 29 to May 8, 1999). This so short time is it, allowed us to appreciate the evolution which took place since 1993 to update the follow-up concerning the inventory of fixtures (village and palm plantation) and to count new acquisitions in these two oases. We present here our impréssions concerning the evolution of the two oases. The stress is laid on the influence of new acquisitions on the way of life of the population. Certain details relating to the stock management (water and grounds) will clarify our matter. The new hydrous resources used clearly favoured the sedentarisation of people in both village. Will this sedentarisation decrease the such pressure on the medium in this area? By widening the inventory of the resources to the animal and vegetable species used or met, we will approach the impact of the way of life of the population on the natural ecosystem in this area.

The oasis of In Belbel

The first impression felt at the time of our arrival at In Belbel this year is the enthusiasm of the population. Probably because of the season of the spring which is the favourable moment for all activities in an extremely arid area where the winter is very cold, the sand storms are frequent and heats of summer are very excessive. Except these aspects, the joy of smiling clearly indicate the improvement of the living conditions in this very insulated oasis.

The visitor is struck above all by a new masonry painted in red and white and placed very high on Tadmaït Plateau; it is the new water tower which was completed December 1998. The network of AEP will be installed in the months to come. The capacity of the water tower is 250 m3. There is also another larger masonry on the small plate enters In Belbel and the co-operative of Chahid Bouâmama. It is about the power station of which work of building site and of installation of the equipment are completed and soon the electrical supply network will change once again the two villages of In Belbel and that of Matriounne.

The village was widened by the construction of new houses of which the number largely increased compared to 1993. The landscape of the village takes style by respecting the alignment of constructions. Several small streets have been established, which gives to In Belbel the aspect of a small city. Construction does not hide the aspect again materials (cement bricks, and beams concreted). Certain houses even exceeded the ground floor. There are already two houses at least which have two floors. The house of the hosts known as ' Dar Zaouya' is always in its place, nevertheless, it increased of a new part and an internal court. Sometimes in certain spaces jet a tap to be useful out of drinking water, at precise hours, the houses which surround it. The standard number of cars is remarkable and there exists currently more than twenty personal vehicles. The village of In Belbel is not difficult any more to join. With the installation of the infermery, the new seat of the marital status and the post office, there is not only more work on the spot but a facility of the management which saves to the inhabitants displacements until Aoulef.

For this period of the year people leave home at all hours. The children go to the school, youngest go to the coranic school. Men and women go to gardens each morning and afternoon. What means more occupation and more work. The aspect of gardens testifies to an intense agricultural activity. Each morning girls and young boys lead herds (ten ewe and goats) towards the East and go up in the wadi of In Belbel. The evening each herd returns by itself to its cattle shed.

We were agreeably surprised by the availability of water definitely more abundant compared to the year 1993. Indeed, a new drilling (the second in In Belbel) was equipped with a motor-driven pump which functions containing gazoil while waiting for the electric installation. Operation at a rate of twice per day is used initially to fill the old drinking water feed basin and then for the irrigation of gardens. The quantity of water is not only additional with the low flow of single will foggara with In Belbel, but definitely higher than that it.
That allowed the extension of gardens which, apparently, doubled of surface compared to 1993. The water of drilling (0.8 mS/cm2) is salted than that of will foggara (3 mS/cm^2 — see in Appendix 1, the values of

electric conductivity). The effect of less salted water is visible through the greenery of the palm trees which become increasingly vigorous. The aspect of the new palm plantation is more greenish compared to the old one. Its surface increased following the extension of the gardens downstream. New gardens were set up, which widened this oasis more and made it attractive vis-a-vis with the dark landscape of the rocks of Tadmaït and that of the clear sand of the wadi of In Belbel. Recently, the palm plantation is delineated by a distant wall containing stones and clay, ten meters high and hundred meters downstream from the gardens. Decided by the free choice of the population, work of this cloture was completed within the framework of the social net (supported by the government) to offer a minimum of work to the young people. The extension does not relate to only plantation of palm trees, but also the practice of other cultures. Put aside the sporadic introduction of the false saffron, we did not notice new cultures compared to those inventoried in 1993. On the other hand the produced quantities are definitely higher and certain farmers are trusted to be able to market it on more primarily of vegetable towards Aoulef. There too it is thanks to the possibility of transport offered by the owners of vehicles on the spot. The income appears favorable and encouraged certain lucky farmers to get greenhouses and to learn practices of protected cultures. One cultivates under greenhouse, primarily, tomatos, sweet peppers and cucumber. More astonish is that these three cultures are practised under the same greenhouse at the same time. Artificial fertilisers or weedkillers are not used. Only the organic manure is used. The greenhouses called ' barraka' or ' barrakates' are not numerous (four or five only) but their owners are satisfied with this new experiment. This equipment is not available in the area and those which have them, they bought them from the owners of new perimeters in Aoulef or In Salah. One of the owners, having half of one of its greenhouse (25 X 8m), informed us about the costs of 15 000 DA the greenhouse and 15 000 for the plastic. Its income is between 60.000 and 70 000 DA. With his wages of schoolmaster, returned is seemed to him interesting to pay the load of his garden whose production ensures a good part of his family consumption.

As regards breeding, each house has a small warehouse primarily gathering goats, ewe or sheep. The visited warehouses contain each one to ten heads. In addition to sheep and caprine, there are breeding of local hens and sometimes of pigeons. At In Belbel people don't keep dogs. The breeding of dromedaries clearly decreased, and reduced probably the sale of these animals which made it possible to people to buy cars. Nomadism is to the maximum and there is nothing any more but the family ' Bahoura's still remains in the rivers of the plateau of Tademaït. We met only one nomad from In Belbel which year by year, according to the rainfall, leads herd of a hundred goats ' harrague' through the wadis in the area. The nonrainy years and during the summer the herd is sold. Only, a minimum of heads is maintained. It is because of goats that one built the wall surrounding palm plantation to put it at the shelter. The feeding of the domestic animals is assured primarily by the fodder plants which push the rainy years in the beds of wadis. The ' Drin' (Arestida pungens) and 'Hbaliya' (Heliotropium undulatum or Morettia canescens Boiss.) are the two principal fodder resources used in In Belbel. The second fodder species is collected in the area at a distance of 40 to 50 km. It is transported by vans and cars and costs 4000 DA. The colocainthe (Citrulus colocynthis) constitutes another additional contribution. The seeds are recovered and used to fatten goats in particular. This tradition exists primarily at the touareg, and we had the occasion to see its frequent practice among inhabitants of Ideles (Hoggar). People who still have dromedaries bring back on their premises during the summer the chamelles ones having the small ones born to protect them and to milk their mother.

Here at In Belbel, water of foggara is used in the same usual way which consists in sharing the water flow in several passages, using comb hones. The negligible part of the flow of each owner is recovered in a basin ' majen' which, once filled, is useful for irrigation of cultivated pieces. Today, farmers use water by drilling. Sharing of this water is organized according to a new device which draws these sources in the traditional system of distribution. Pumped water is subdivided using the valves to be channeled, through PVC pipes, towards the feed basin of water of the irrigation canals to plantations. The principal ' pipe line' pours water in a basin (1x1m) with a depth of more than one meter. Water runs through a distribution using holes of a large PVC pipe (with a diameter from 10 to 12 cm approximately), which gives, in theory, same flow in each distribution. Each new channel carries out water towards a new basin to ensure a new distribution using small PVC pipes (5 or 6cm diameter). Finally, each owner takes with free choice the flow given by one or two holes according to his desire. The payment of a monthly contribution, proportional to the number of taken pipes is fixed at two hundred dinars. It is useful for the purchase of the gazoil and the system maintenance of pumping (motor-driven pump). This new control or management of water is decided by the free choice of the population. Drilling gives a medium flow from 17 to 20 l/s. Currently, the water flow pumped and used for the feeding of the village or the irrigation of palm plantation, is not measured. Only the starting period of the motor-driven pump counts. This duration is conditioned by the rate of consumption of gazoil. Half an hour up to one hour of pumping is practised twice per day. The free choice of the volume of water shows the quantity of water available which for the moment is limited only by consumption in gazoil. It is true that people obstruct themselves by no means as for the payment of the monthly contribution of

200 DA! Here in In Belbel it is the only cost as regards regular expenditure. But the wisdom of the village lets think in durable term of management. The extension of gardens is relatively moderate, because people do not want to increase their gardens which would be catastrophic one day if the system of pumping breaks down for a long duration. This system with the difference of that of will foggara has a 'weaker sustainability' and must be used with prudence. In addition, if people are delivered to forced work than requires the maintenance of foggara, they will become less autonomous and plustôt dependent on the interview technique services of the drilling equipment.

The Oasis of Matriouen

The stay of this time enabled us to spend more time than usually in Matriouen to be able to include it in this study. The village of Matriouen is the only close village near In Belbel. With a few kilometers only, this oasis maintains links with In Belbel since a long time Sid Lhadj Mohammed Salah, the founder of the village of In Belbel had remained some years before going to found and to settle in In Belbel. The site of Matriouen is thus certainly older than that of In Belbel. Moreover, there are engravings testifying the human activity for a very long time and there remain still prestige of the old ksar established in the foot-mount of right cliff of the Matriouen Wadi. According to the local legend the name of Matriouen means ' Matrah Ouin' which wants to say ' One cannot see it', because of its situation hidden in the dark rocks.

In this ksar, several houses are new and introduction of new building materials knows the same fate as with In Belbel. The oasis, visited in 1993, remained, almost, the same one since this date. Of a surface from 4 to 5 ha it is irrigated by water of will foggara which is salted. Will foggara in Matriouen made a flow of 31 ' haba zerigue', that of In Belbel measures 50 ' haba'. There is another small will foggara of 2 ' haba' which is used for to irrigate an insulated garden. The hydrous deficits are composed by the use of water of drilling, which is equipped with motor-driven pump. The system of irrigation is the same one practised with In Belbel. On the other hand, drilling Matriouen gives more salted water and during the first 20 minutes of pumping this water is very salted (7,7 ms/cm2). It improves thereafter, but remains more salted (2,2 ms/cm2) that that delivered by drillings in In Belbel. This drilling probably passes by a saliferous layer. Fortunately, new drillings carried out recently to irrigate the new perimeters are softer.

There exists in Matriouen several perimeters recently improved. Their irrigation is ensured by pumping of water starting from small wells or starting from the second drilling. There are two large perimeters in this zone. First is managed by a co-operative known as 'Si Lhaouas and having a surface of 6 ha realized out of the 50 envisaged. It was operational since 1988. The second was created in 1997 and is managed by two groups having two plantations coast at coast of 4 ha each one. Their management is rather family even if formalities the organization took the shape of co-operative. The first exploitation belongs to the family Ouled Ben Tayeb of which one of the shareholders, the elder brother, occupies the post of schoolmaster. Second is honoured by the name Houari Boumediène is managed by a second group. In these co-operatives, we were, agreeably, surprised to see a planned system of production and aiming at the profitability of investissment. The agricultural produce is intended for Aoulef and In Salah. There are new practices which prove that modern knowledge and adoption of new techniques. The breezes wind initially containing several species delivered by the services of forests to Adrar. Casuarina is the principal species, but sometimes there are other occasional plants of false pepper (Schimus sp., Acacia cyanophylla and we noticed, even, a foot of Pinus halipensis). To reinforce these alive hedges, of dry palms are also used and sometimes a line of reed (Arendo sp.). But, it seems to us that reed will pose problem in time as invading plant and who require more water in irrigation. The date palms and sometimes other fruit trees (vine, fig trees, and citrus) are very spaced and aligned well. The technique of adopted irrigation is drop by drop using perforated pipes PVC. There are no simple perforations which seems to us to exaggerate bus too large and the poured flow quickly gives a water fleet which can cause even asphyxiation of seedlings. The intercalated cultures are food if not there are vegetable cultures protected under greenhouses or in full surface. We give in appendix 2 quantification of the productions under two greenhouses of (8x50m) for 1998/1999.

Aside from beets, these cultures do not support salinity. Even if water of irrigation is not salted too much, excess of successive irrigation and intense evaporation progressively accumulate salts in the ground. It is thus of primary importance to pay attention to this salinisation which reduces production gradually. The second danger of these cultures are the bad grasses introduced by the means of non-certified seeds and untreated organic manures. Manure is used, but weedkillers are not practised yet.

As regards palm tree, it is introduced here from other close area. Offshoots are bought from In Salah, Aoughrout and we met introduction even of Reggane. These introductions especially from the areas infested by the bayoud (Aoulef, In Salah or Reggane) will not leave this distant palm plantation safe from this disease. We alerted interested parties to get their offshoots only from healthy zones like Aoughrout. The planted cultivars are primarily TINNASER, TGAZZA, HMIRA, and TAQERBUCHT of Aoughrout and AGAZ which is introduced from In

Salah. Only one cultivar, MES' UDYA, are introduced from Reggane.

The program of the social net was used here in Matriouen to carry out an original work. That consists of the establishment of a dam concreted to retain water like a stopping at the time of believed of Matriouen Wadi. The retention of this water could enrich substrate by the gardens and thus increase the level of water stored and drained by foggara, if not in the wells. The work of more than 20 meters of concrete seems well to be built. But it was subject of no study nor plan of realization by technicians. We will see his capacity at time of next believed in the future. This initiative leaves young people having an educational level (represented in particular by Mohamed Ben Tayeb, schoolmaster) to reflect to build similar works elsewhere to take part in protection of fauna and regional flora. This sensitizing deserves to be encouraged, and it seemed interesting to discuss creation of association for example. The transmission of some document (cards and articles photocopied) could help to make better mature the ideas and bring together more people. The participation by initiation in work of inventory of fauna and flora will be able to constitute a good initiative of sensitizing and popularization as regards environmental protection.

In Matriouen as with In Belbel, there is not any more nomad put aside only one family from which old parents and young children are still apart from the village and have a herd of 70-8O goats and 3 dromedaries only. 7 to 8 dromedaries have been lost in the desert for soon 10 years. We collected same information as regards inventory of vegetable and animal species. With regard to the acacias, people testify that there are more old trees towards Mguiden, which seems to us logical because located on the Northern slope of the plateau of Tadmaït.

Discussion

The two villages of in Belbel and Matriouen, are very insulated and yet made choice siblés for introduction of solar equipment in the Sahara. This area is documented very little and aside from work leads by professor Kobori, the only reference which made sign at these two villages dates from the beginning of the century (Voinot, 1909). Our approach, at the same time descriptive and analytical, makes it possible to evaluate the impact of the activities (agriculture and breeding) on natural ecosystem in this area. The original in these two villages of In Belbel and Matriouen lies in two exemplary facts of éco-development and participative management. The first symbolizes new marriage or mixing of water of foggara with that of drilling. It is about a true succession of events which deserves a reflexion and especially a regular follow-up to document the scenario of a governmental support and adoption of new techniques with prudence on behalf of the local population. This testifies noted them study carried out and published by UNESCO (Pallas, 1972) as regards management of underground water in the Sahara. Simulation provided that whole of foggaras should be gradually replaced by drillings. With the arrival of electric power it is possible that this manner of seeing things is modified. Will pumping using this energy is favorable for the population? In continuation, how much will be the applied prices? For the moment, owners have the idea to consume what they will be able to pay as regards electric power. The difficulty which will remain will be that maintenance of pumping. What will occur if an emerged pump would break down? Here is the sharp one of our subject of the follow-up of the oasis ecosystem and its evolution following technological introductions. The second fact is that of the participative management of the funds of the social net. In spite of their proximity, the two villages of In Belbel and Matriouen keep, each one, its specificity as for management of the funds of this support. The latter (not estimated) were managed perfectly locally and in a different way. With In Belbel the funds were used to carry out the entourage of the palm plantation. In Matriouen these funds were consumed to carry out the dam which is used to retain the water of the wadi after each rising.

The technical services (hydraulics and agriculture) do not come on the spot to help the farmers technically. These services are implied only in the realization of great works (drilling, the water tower...). Many things remain to be made as regards popularization of the agricultural techniques to save water and to avoid problems of salinity. The water of foggara even if it is more salted it remains less abundant. That of drilling, more abundant is relatively softer, but with excesses of irrigation the risk of salinisation of the grounds. This situation is analyzed in other regions, notably in Mexico. Takeuchi (1989) shows that risk of salinisation constitutes a limiting factor of the cultures, which obliges to adopt tolerant species. Here in In Belbel and Matriouen, the barley and the beet are more to target.

The inventory of fauna and flora in this area of the plateau of Tadmaït emphasizes a list of about thirty animal species, and nearly a hundred cultivated or spontaneous vegetable species. Among animal species some like the eagles (observed in reproduction in the heights of the rocks of the plateau) or gazelles are of a scarcity such as currently caused protection measures. Most vegetable species are sources of traditional therapeutic medicine. The existing species are identified by their local names, which is not sufficient according to bibliographical sources; the corresponding scientific names is sometimes different and requires specialized practical identifications. This problem was raised in our preceding tests (Bounaga and Al, 1990). These species, man included/understood, live in an extremely arid medium and the rules of managements applied are of a great utility to preserve these fragile sites on the one hand and to draw from the exemplary lessons for other contexts.

The passage from a single source of water ' the foggara' to the use of deep water by drillings allows intesified agricultural fields and to widen the villages. In spite of regular follow-up of the evolution of these two oases, a new plan of state remains to be made. It appears essential to study the impact of the sedentarisation on the natural environment and scientifically to observe evolution of new very particular ecosystem of the plateau of Tademaït.

References

Bounaga N, Benkhalifa A., & J Carbonnier, 1990 - III. Inventory of the principal food species produced for the truck farming. Bull. Amélior. Prod. Vég. Arid Medium, 5: 93-134.

Brac of Stone quarry R.A. & A. Benkhalifa, 1989 - Identification of the cultivars of date palms (Phoenix will dactylifera L.) Algerian south-west. Palnt Genetic Resources Newsletter, 78/79: 13-20.

Brac of the Stone quarry R.A. & A. Benkhalifa, 1991 - Progression of Fusariose of the palm tree-date palm in Algeria. Dryness, 2: 119-128.

Kobori I, 1969. The system of irrigation of the central Sahara Tidikelt. Bulletin of département of Geography, Univ. of Tokyo.1: 1-32.

Kobori I and Benkhalifa A. the oasis of In Belbel into full transfer. *Scientific and perspective assets for a durable development of the* arid regions, Jerba Tunisia, December 5-7, 1996.

Pallas P., 1972. Water resources of the septentrional Sahara. Nature and Resources, UNESCO, vol. III, N° 3, 10-18.

Takeuchi Y. 1989. Carryforwards of 1989 Meeting Soil Sci & Seedling Nutrition Association of Kansai, 47-54. (in japanese)

Voinot L, 1909. Tidikelt, Study on the geography, History, Manners of the country. Editions Jacques Gandini. 155p.

Appendix 1.

Salinity of water of the oases in Algeria compared with other localities

Site	EC. (mS/cm)
Hassi Fhel (Drilling)	0.92
El-Méniâa (Fogare Belbachir)	0.10
El-Méniâa (Puit URZA)	1.30
El-Méniâa (development Hadjaj)	0.34
Timimoun (AEP)	2.2
Timimoun (Foggara Amghier)	2.3
Aoulef (AEP)	3.5
Aoulef (Development Boukana)	5.6
Aoulef (Development Kelli)	2.6
Aoulef (Development Ferdjani)	2.8
Timokten (news will foggara)	2.5
In Belbel Foggara	3.0
In Belbel Forage	0.8
In Belbel Puits	3.8
Cooperative If Lhaouasse	0.7
Matriouen Foggara	3.3
Matriouen Forage	1 7.8 - 2.4
Akabli (Foggara)	2.9
Akabli (Drilling)	2.7
Tit (Forage artesien)	1.7
Beni Abbès (Puit URZA)	1.1
Beni Abbès (AEP)	0.7
Beni Abbès (Foggara URZA)	1.0 – 1.7
*Guerrero Negro (Mexico)	1.39
*Tottori (Japan)	0.06
*Sea water	448

(*) Reprinted from : Tekeuchi (1989)

Appendix 2.

The results indicate the production quantities of some vegetables planted under two green houses (8x50 m2) in Matriouen. Total The of calculated returned in DA concerns 1999.

Vegetables	Quantity (qx) kg	Price (DA)	Returned (DA)
Sweet Pepper	12	70	94,000.00
Pimento / Capsicum	7	80	56,000.00
Tomato	7	25	17,500.00
Cucumber	5	30	15,000.00
Salad / Lettuces	8	30	24,000.00
Marrow / Zucchini	8	30	24,000.00
Beet	5	30	15,000.00
Carrot	6	25	21,000.00
Total			266,500.00

10

Wastewater Reuse in Water Planning and Management in Arid Area of Tunisia

Rachid Boukchina, Noureddine Nasr and Habib Jeder

Institute of Arid Lands

Background

One of the most important natural resources for socio-economic development in arid and semi-arid areas is water. More than 75 % of Tunisia is under arid and semi-arid condition. These areas are facing two major obstacles to its continued development: a growing scarcity of water resources and degradation of soil productivity.

Water resources of arid area of Tunisia are characterized by low water quality, over exploitation of fossil resources and a high risk of coastal ground water salinisation due to sea water intrusion. The average annual precipitation ranges between 50 and 220 mm/year, with 80 % of the total area receiving less than 120 mm/year. Precipitation exceeding 180 mm/year principally occurs in mountain areas, where only a small portion percolates to become groundwater.

The need for providing good water quality for irrigation is urgent to meet the increasing demand of food. Simultaneously, the same water is needed to satisfy the other economic activities (domestic, industrial, tourism). Under such conditions low water quality from wastewater treatment plants should be used to alleviate high water quality demand. However, protecting public health environment and soil degradation are the main concerns associated with wastewater reuse. The challenge is to reuse treated wastewater for crop production in a highly skill manner to minimize the risks.

Potential Volume of Wastewater for Reuse in Arid Areas

During the last few years the sewerage network in the largest cities located in arid area of Tunisia has been expanding rapidly. Municipal wastewater disposal has become a pressing environmental problem mainly in coastal cities. At present the National Sewerage and Sanitation Agency (ONAS) operates 5 wastewater plant treatment and by the end of year 2006, the number of plant treatment will reach 12 plants. Treatment processes are mainly activated sludge. The last treatment plant put into operation is Gabes treatment plant with a capacity of 17 000 m3/day of wastewater, serving an estimated population of 110 000 and treated effluent discharged to sea with an DBO5 less than 30 mg/l.

In arid area of Tunisia, local experience on reuse of treated wastewater is still limited to golf course or hotel gardens irrigation. However, the present policy in Tunisia restricts the utilization of treated effluent to forestry, fodder crops, industrial crops and tree-fruits. It should be noted that Tunisian legislation prohibits the use of treated wastewater to irrigate crops to be eaten uncooked. For fodder crops irrigation must stop two weeks before cutting and fruit picking no fruit should be picked from the ground. Irrigation systems using wastewater must operate under low pressure and avoid dispersal of the spray irrigation by wind into the populated areas.

Table 1
Treated wastewater standards for reuse in irrigation

Parameter	Maximum concentration
PH	6.5 - 8.5
Electric conductivity (dS/m)	7
Chemical oxygen demand	90
Biochemical oxygen demand	30
Suspended matters	30
Chloride	2000
Halogenated hydrocarbons	0.001
Cadmium	0.01
Copper	0.5
Iron	5
Manganese	0.5
Mercury	0.001
Nickel	0.2
Lead	1
Zinc	5
Intestinal nemathodes	< 1/1

Overall Objective

Both opportunities and problems exist in using treated wastewater in irrigation. Problems related to wastewater reuse are generally local. Locality of problems is not only due to quality of effluent or the standards adapted, but also due to climate, soil types, choice of crops, agricultural and land use practices and farmers and public attitudes. As treated wastewater volume is increasing in arid area of Tunisia and the local experiences in wastewater reuse are limited, the Institute of Arid Lands (IRA) and the International Center of Environmental Technology (CTET) with financial support of the Initiative for Collaboration to Control Natural resource Degradation (Desertification) of Arid Lands in the Middle East initiated study to demonstrate the technical and social feasibility of wastewater reuse for agricultural purposes. Effort is made to develop a pilot project suitable for large scale application and can be easily applied to other parts of arid area of Tunisia or of the Mediterranean basin. Also, a special attention will be paid to the social awareness with private sector and NGO.

The study includes the following objectives:

1. to utilize treated wastewater in irrigation under controled conditions which ensure minimum heath risks to human and environment;
2. to identify economic crop varieties that present the optimum mix of income and public safety;
3. to determine design criteria for semi-tertiary treatment (sand bed) based upon local conditions and experience;
4. to study public acceptance attitudes of wastewater reuse for agricultural purposes in arid area of Tunisia.

Expected Outputs

1. Demonstrating the advanced water management to reuse treated wastewater in secondary level for additional appropriate agricultural production without related health and environmental problems;
2. Demonstrating the best semi-tertiary level treatment method to be adapted in arid area using the local available experience at feasible costs;
3. Revising legislation which may need to allow a broader choice of crops where treatment quality is higher, by taking into account the regulation, technology, environment and economics.

Research and Development Activities on Wastewater Reuse

To achieve the overall objective presented above an experimental farm (2 ha) adjacent to the treatment plant of Gabes is utilized to carry out the experiment activities. Effort is made to determine crop varieties best adapted to irrigation with treated effluent, changes in physical and chemical properties of soil, fertilizer value of water and suitability of irrigation methods.

In 1997, annual fodder crops (barley, oat and sorghum) perennial fodder crops (alfalfa and atriplex) and industrial crops (henne and tobacco) were planted and irrigated with treated wastewater using surface irrigation method. Data were collected during the growing season by taking samples of wastewater, plant leaves, soils and groundwater. Some chemical, physical and microbiological analyses were made. Crop yields (T/ha, % MS) were also evaluated. In the same time wastewater was reused to produce forest, fruit and ornamental trees and shrubs in nursery. More than 2200 trees were produced and distributed with the collaboration of NGO ATUMED to schools and different local agencies. Even thought the number of distributed project trees is very limited compared with the number of trees produced annually in the region and used to control desertification, the objective was to demonstrate to the target population an alternative of treated wastewater reuse in irrigation without using fresh water.

In 1998, research was conducted in the same location with some modifications. Two irrigation methods - surface and subsurface drainage/irrigation - for alfalfa were used in order to assess the effect of irrigation method on microbiological quality of crop. Data were collected during the growing season by taking samples of wastewater, plant, soils and groundwater. Some chemical, physical and biological analyses were made. However, the effect of irrigation method on microbiological quality of crop does not evaluated due to shortage of laboratory equipment. Research was extended to study public acceptance attitudes of wastewater reuse for agricultural purposes. The use of treated wastewater to demonstrate producing of forest fruit and ornamental trees and shrubs in nursery was continued. More than 3000 trees were produced and distributed with the collaboration of NGO ATUMED to schools and different local agencies. In this year, the Ministry of

Agriculture has completed the construction of DISSA scheme project. Effluent from Gabes plant will be transported by pipeline over 9 km to a new agriculture area where it is proposed to develop gradually a total of 400 ha under various crops by the year 2005.

In 1999, research activities focus on irrigation method and on semi-tertiary treatment under arid area condition. Three irrigation methods - surface and subsurface drainage/irrigation and subsurface - for alfalfa to minimize microbiological contamination and water efficiency. Data were collected during the growing season by taking samples of wastewater, plant, soils and groundwater. Some chemical, physical and biological analyses were made. Unfortunately, of the second year, the effect of irrigation method on microbiological quality of crop does not evaluated. Research on sand filtration system is started at column scale. A group of 24 young farmers was selected for DISSA agricultural area and have followed training programme on wastewater reuse technic. The project team was involved in this training programme. Also, it was planned that when Tataouine city treatment plant will be in operation the treated flow of 3 000 m3/day will be available for irrigation. An area of 100 ha and adjacent to the treatment plant is proposed.

Conclusion

Since research activities have been started recently, only a few preliminary observations can be made. The chemical quality of treated wastewater from Gabes city plant does not pose problems on the uses of the water for irrigation. However the microbiological quality of effluent allows a restrictive reuse. Collected data show the positive effects of wastewater reuse for fodder and industrial crops production. However, there is a need for multidisciplinary long term research which investigates the optimum conditions for irrigation with treated wastewater in terms of the environment, public health and agricultural productivity. Also, additional financial support is needed to achieve the other objectives mentioned earlier.

Acknowledgments

This work is financially supported by the Multilateral Working Group on the Environment - Middle east Peace Process: Initiative For Collaboration to Control Natural Resource Degradation (Desertification) of Arid Lands in the Middle East.

11

New Techniques for the Control and Valorisation of the Runoff Water in Arid Regions

Bellachhed Chahbani

Institute of Arid Lands

Abstract

In arid regions, runoff water represents an important renewable water resource. In the arid parts of Tunisia, several techniques of water harvesting are used for the control and evaluation such us smalls dams (Jessours and Mgouds) and traditional storage tanks (Fesguias, Majels) These techniques have the following problems:

1. The used of unadapted calculation methods to determine the values of hydraulic parameters of dams, terraces and the watersheds,
2. The loss, by evaporation, of the retained runoff water and supplemented irrigation water, pumped from the traditional tanks.
3. The drawing, transportation and distribution of the stored tank water.
4. The low utilisation of the storage potentialities of the traditional tanks, particulary during the rainy years.
5. The evacuation of the overflow water during the floods through spillways.

To resolve these problems, research have produced the following results:

a. Calculation of new formulae to determinate the values of the mean parameters of dams, terraces and watersheds.
b. Construction of a compute model with elementary hydrological of a watershed.
c. Presentation of methods for dimensioning storage tanks according to the irregularity of rains, and their use for semi-irrigated crops in green houses or for supplemental irrigation of fruit trees.
d. Derivation of appropriate techniques to optimise the use and conservation of water retained in dams and storage tanks.
e. The replacement of the existing spillways by tubes systems to avoid destruction of the spillways and dams during normal and exceptional overflow events.
f. The gravity technique of drawing, transport and distribution of water stored in tanks.

Introduction: Problems and Objectives of the Study

Water and soil are the basic elements of dry-farming agriculture. The importance of those two elements is more appreciated in hot and dry regions. In these regions soil and water are scarce, therefore farmers and officials should know how to optimise their use and conservation.

The total water resources in Tunisia are estimated at 4530 x 10^6 m^3/year. The surface water resources (runoff water) represent 59% (2690 x 10^6 m^3/year), with the other 41% (1840x 10^6 m^3/year) from groundwater resources. These amounts show the importance of the runoff water in national water resources. More important is the renewability of the surface water resources. The surface water resources are not distributed evenly in space and time. In northern part of Tunisia (30% of the country surface) which has a semi-arid climate with more than 300 mm rainfall, the resources are more important than in centre and south regions which have arid climates with rainfall less than 300 mm. Rainfall is very variable with annual rainfall below average, a greater occurrence than above average.

This occurs due to the occasion intense storms. The characteristics of these intenses storms one important because they form torrential runoff.

The rains intensity can reach rates of 200 mm/h during 5 minutes; 150mm/h during 15 minutes; 100mm/hour during 30 minutes and 70mm/hour during 60 minutes. Those high intensities can happen at least once in ten years.

In the arid regions of south and central Tunisia, there are several traditional and modern practices (or techniques) used for dry farming crop agriculture and for water and soil conservation. Although they are technically and economic effective during the normal years, these techniques are not sufficient to avoid the following:

1. negative effects of runoff during exceptional torrential rains such as soil erosion, dams destruction, human infrastructures destruction, floods etc...

2. negative effects of drought during the dry years such as death of trees, low crop, productivity scarcity of potable water.

3. loss by evaporation of dams retention water.

In addition to the above problems, the techniques do not allow the use and conservation of the full potential at the rain water of the exceptional storms on to avoid the negative effects of the dry years.

The aim of this paper is to present the problems of several water harvesting techniques in central and southern Tunisia, and the results of 15 years applied research by the Arid Regions Institute. These results provide some of solutions to the above problems.

The problems of the different water harvesting techniques in central and southern of Tunisia

The problems of the techniques (modern and traditional) based on the retention of runoff (new thalwegs and slopes)

In the Tunisian arid regions, the techniques (traditional and modern techniques) based on the retention of the thalwegs and slopes runoff water, represent more than 90% of the existent agricultural small hydraulic infrastructure. These techniques have many problems. The mean problems which have been studied are:

- The unadapted calculation methods used to determinate the values of hydraulic parameters of the dam, the terrace and the watershed
- The loss by evaporation of the retained run off water
- The evacuation of the overflow water during the floods, through the spillways.

The first problem (the unadapted calculation methods used to determinate the values of hydraulic parameters of the dam, the terrace and the watershed) is a result of the used empirical formulas. For the traditional management the farmers do not fallow any formula for the dimensioning of the different parts of the Jessours(Catchment area, terrace, dam).For the modern techniques, the technicians of the agriculture ministry use formulas elaborated by Bugeat, Saccardy.The two authors of these formulas worked on small dams dimensioning in semi-arid regions or North Tunisia and Algeria. Both formulas Bugeat formula($H=2,2+8P;D=H/P$) and Saccardy formula($H=P(260\_10)^{1/3}$; $P=H/D$) are based only on the slope(p),the altitude(H) and the distance(D)differences between dam two successive dams. other important parameters are ignored(Watershed surface, dam height, retention capacity, maximum runoff, etc.). That is why, during the exceptional rain storms(1969, 1979, 1996), the dams are destroyed.

The loss by evaporation of the retained runoff water, is a result of the sedimentation of the transported erosion particles contained in the runoff water. This sedimentation involves the formation of several superposed strata covering the soil surface supporting the retained water. The last strata contains specially silt and clay(90% clay 10% silt). This clay stops the infiltration of the retained water in the soil of the terrace. This water is lost by evaporation.

The spillways of the traditional and modern techniques are discontinuities in the dams. Sometimes those discontinuities are consolidated with stones (cemented or not). During the exceptional runoff, in both cases (protected or not), the spillways are very sensible to the water flowing between the soil part and the consolidated part. The flow affects the stability of the protection structure and prepares its falling down. After that falling down, the overflow water attacks the wall of the spillway. When there is no consolidation, this wall is directly attacked by the over flow water. Sometimes The destruction of the dam through the spillway is a result of the head erosion due to the overflow fall.

The problems of the water storage tanks (Fesguias and Majels)

The first problem is the difficulties of drawing, transport and distribution of the water stored in the tanks. The traditional techniques of drawing, transport and distribution of the stored water, is based on human and/or animal power. To draw the water the people use a can or a bucket(5-10l)and a rope. They use also the traditional "Dalou" made of rubber or leather. Jars and jerry-cans carried by man or animals, are used for the transport and distribution. With such techniques irrigation with stored reservoir's water is a hard task. Therefore irrigation is done only during the first two or five years after the installation of the trees. The drawing and transport need a labour time equal to 375 hours (250 hours for transport and 125 hours for drawing) for 30 cubic meters. This was estimated for a slope of 30% and a transport distance of 150 m. Considering 8 hours working time per day, this labor time represents about 47 days and costs 282 TD (TD : one Tunisian dinar is about one US dollar).

The second problem is the technique used in the complementary irrigation(the basin irrigation). This technique is not a good method to valorise the water stored in the tanks. A great part of the irrigation water is lost by evaporation from the subsurface soil horizons.

The third problem is the very low use of the water storage potentialities. The tanks used for complemental irrigation have several sizes and shapes. According to the low needs of the stored water for irrigation during the autumn, winter and sometimes the beginning of spring(low evapotranspiration, dormancy of the trees) a great part of the runoff water coming from the tanks' catchment area, is not stored. Usually the tanks are filled maximum twice during all kinds off years(DY,NY,HY,VHY). The volumes of the potential water resources of the tanks are very important. If each time the tanks are filled, the half of the stored water is instantaneously used for irrigation(using water saving techniques), it is possible to increase the agricultural production of the traditional hydraulic units(jessours, mgouds, tabias). The potential water resources produced by the catchment area but not stored in the tanks during normal year, humid year and very humid year are very important(table-1).

Table 1

Potential water resources produced by the catchment area but not stored in the tanks

Individual Catchment area Surface /m^2	*1)*stored water resources during normal year/m^3 (NY, Kr= 46mm)	*2)*Non stored potential water resources during normal year/m^3 (NY, Kr= 46mm)	Total *1+2*	*3)*stored water resources during humid year/m^3 (HY, Kr= 208mm)	*4)*Non stored potential water resources during humid year (HY, Kr= 208mm)	Total *3+4*	*5)*stored water resources during very humid year/m^3 (VHY,Kr= 322mm)	*6)*Non stored potential water resources during very humid year (VHY, Kr= 322mm)	Total *5+6*
1000	20 m^3	26 m^3	46 m^3	20 m^3	188 m^3	208 m^3	20 m^3	302 m^3	322 m^3
2 000	40 m^3	52 m^3	92 m^3	40 m^3	376 m^3	416 m^3	40 m^3	604 m^3	644 m^3
3 000	60 m^3	78 m^3	138 m^3	60 m^3	564 m^3	624 m^3	60 m^3	906 m^3	966 m^3
4 000	80 m^3	104 m^3	184 m^3	80 m^3	752 m^3	832 m^3	80 m^3	1208 m^3	1288 m^3
5 000	100 m^3	130 m^3	230 m^3	100 m^3	940 m^3	1040 m^3	100 m^3	1510 m^3	1610 m^3
6 000	120 m^3	156 m^3	276 m^3	120 m^3	1128 m^3	1248 m^3	120 m^3	1812 m^3	1932 m^3
7 000	140 m^3	182 m^3	322 m^3	140 m^3	1316 m^3	1456 m^3	140 m^3	2214 m^3	2254 m^3
8 000	160 m^3	208 m^3	368 m^3	160 m^3	1504 m^3	1664 m^3	160 m^3	2416 m^3	2576 m^3
9 000	180 m^3	234 m m^3	414 m^3	180 m^3	1698 m^3	1872 m^3	180 m^3	2718 m^3	2898 m^3
10 000	200 m^3	260 m^3	460 m^3	200 m^3	1880 m^3	2020 m^3	200 m^3	3020 m^3	3220 m^3

DY=dry year NY=normal year HY=humid year VHY=very humid year Kr=annual runoff coefficient

The results of the applied research in water and soil conservation in the arid regions of centre and south of Tunisia.

Those results in fact are the solutions for the problems mentioned above.

New formulas to determinate the values of the mean parameters of the dams, the terraces and their watershed(fig.1)

The parameters used in different complementary formulas are:

- retention area length, agronomic and edaphic criteria.
- maximum retention height, maximum daily runoff, slope,
- Watershed surface, maximum retention capacity,
- size of the sides of the dam.

Computed model including several data on the different parameters of the elementary hydrological units of a river watershed(fig.2)

Each dam, of the runoff retention Water techniques, and its terrace and watershed represents an elementary hydrological unit(E.H.U). Each river watershed(big hydrological unit) is a "puzzle" constituted of the different elementary hydrological units. The model is based on:

- the relationship between the different elements(E.H.U) of the "puzzle",
- the different formulas we have elaborated and exposed above.

The model has been used to study about 2500 hydraulic units of Oued Demmer watershed(20 Km^2)in South Tunisia. Using this computed model, we have studied the hydrological behaviour of each unit for different values of runoff. The model could be used also to prepare the arrangement of watersheds with retention dams.

Technique of dam's retention water injection in the deep soil horizons (Chahbani.b. 1996,1997).

The technique has two components:

- the underground water infiltration system,
- the water drainage system.

The underground water infiltration system has as specific function to favour the infiltration of the drained dam's retention water in the deep roots horizons. To attend that goal two methods have been tested. The first method is based on a "stones pocket" built in the bottom of a trench. This "pocket is buried 80cm below the terrace soil surface. The second method uses punched plastic tube covered with artificial sponge and installed in the bottom of a trench. The top side of that plastic tube is protected (against the filling in with soil materials)with a plastic film.

To drain the dam's retention water until the underground water infiltration system, a drainage technique has been performed. It is composed of a floating basin and a draining floater(fig.3).

This technique of dam's retention water injection in the deep soil horizons, has been applied in a farmer traditional field(Jessour) in 1994 . In 1998 during a heavy rain the dam of this field retained 300 m^3 of water. This water has been injected during two days(using the underground water infiltration and the water drainage system) in the deep soil horizons where are the roots systems of the fruit trees.

The draining is patented and has obtained the prize of the Agriculture and Technology Fair of Tunis in 1998.

Techniques of underground localised irrigation for trees.

The first technique is called « buried stones pocket » (Chahbani.B.1992,1997). In the bottom of a plant pit(1m x 1m x 1m) and alongside the corners a pocket is built with hard stones(limestone, sand stone, limecrust, etc..)(Fig.4). The stones, which measure 10cm x 7cm x 4cm, are set in three to four levels, and each level has two to three rows of stones. The pocket of stones is then covered on three sides with plastic film, whose role is to avoid the introduction of soil in the stones pocket when it is buried. In the middle of a side, a plastic tube(diameter 3 to 7cm and 80cm length) with a "T" shape is fixed vertically with stones. This plastic tube, of which 10cm should be above the topographic level, will serve for irrigation purposes. After the installation of the "stones pocket" the pit is filled with a mixture of extracted soil and fertilisers.

The « buried stones pocket » could be also installed for existed trees. In this case it is built in the bottom of a trench around the tree. This trench is minimum 50cm far from the tree trunk. It is 60 to 70 cm deep and 50cm wide.

The "buried stones pocket" is already spread in centre and south of Tunisia with the contribution of the regional extension authorities.

The second technique is based on patented manufactured plastic distributors for underground localised irrigation. The distributor is buried near the roots zone, 50cm → 60 cm below the soil surface. The capacity of the distributor is 4 litre. It is equipped with water draining tube. When it is used in low water pressure conditions the distributor has a system of driving out the air contained inside. This allows the uniformity of the irrigation water in an underground buried distributors network.

Compared with the traditional or the modern irrigation techniques(basin, drip) those new techniques(« buried stones pocket » and « underground buried distributors ») allows the conservation of all irrigation water. That means that in each irrigation there is 30 % 70% of water saving.

Techniques of underground localised irrigation for annual crops
The stored runoff water in the reservoirs could be used also for the irrigation(complementary or continuous) of water melon, potatoes, tomatoes, etc. That is possible only if water saving techniques are used. Therefore new techniques have been conceived and tested.

The first one is called «buried straw pocket »(fig.5). It is based on a layer of 5cm straw put in the bottom of a small pit(30 cm x 30 cm x 40 cm). In the middle of this straw layer there is a hole(diameter=10cm) filled up with fertilised soil. This straw is covered with a plastic film which has a hole(diameter=10cm) in the middle. This second hole should be placed on the hole of the straw layer. An irrigation pipe system cross the plastic film and arrives till the middle of the straw layer. If the irrigation is done manually and individually, the pipe should have a big diameter(30 cm → 40 cm) and 45 cm length. If there is a drip irrigation network, a dripper in each pit is placed in the straw layer. After the installation of the irrigation system, each pit is completely filled with soil. The seeds or the young plant are then placed in the hole of the middle of the straw layer. During the irrigation the water of the pipe or of the dripper occupy all the empty areas in the « straw pocket », then it is infiltrated specially in the soil below. The plastic film cover reduce the lost of soil water by evaporation and capillary rise.

The second technique is based on patented manufactured plastic distributors for underground localised irrigation. The monitoring of the water content of the soil in containers(some are irrigated with dripper and the others are irrigated with the new underground localised irrigation distributor), shows that(table-2-):

After two months the water contents of the containers irrigated with 3 liters using distributors, is 8.8 times higher than those irrigated with 3 litres using surface irrigation and 4.4 higher than those irrigated with 3 litres using drippers.

Table-2

Evolution of the water contents of the soil irrigated with 3 litters using in the continer dripper buried and surface watering.

Date	16 Jun	21 Jun	28 Jun	05 Jul	12 Jul	19 Jul	26 Jul	2 Aug	9 Aug	16 Aug
Surface watering	2890g	1280g	940g	750g	590g	400g	330g	240g	140g	100g
Drip irrigation	2580g	1210g	930g	760g	630g	490g	440g	350g	250g	200g
Buried (diffusors)		2570g	1980g	1620g	1366g	1250g	1160g	1060g	940g	880g

The replacement of the actual used spillways by tubes system to avoid the destruction of the spillways and the dam during the normal and the exceptional overflow.

This new technique for the evacuation of the overflow water, is based on two joined tubes: one vertical and one sub-horizontal(Fig.6-). For the calculation of specific flow of the tube we use specific formula based on two parameters: the height of the vertical tube and its diameter, the instantaneous water flow which should be evacuated in a minute(Fig.7).

This new tube spillway has been tested in the mountains of south and centre of Tunisia: in the experimental station(3 spillways) and in the fields of farmers(6 spillways). The exceptional runoff of 1995, 1998, 1999, were a good test to prove and to demonstrate the efficacy of the tube spillway to evacuate and distribute the water in the traditional water harvesting techniques(Jessours and Mgouds).

The Gravity technique of drawing, transport and distribution of the reservoir's stored water(Fig.8)

The technique is based on a flexible plastic or rubber tube. One part of the tube is inside the reservoir. The extremity of this first part is fixed to a floater which insure the immersion of it's orifice. The floater enables continuously the floating of the immersed extremity of the inside part of tube. The second part of the tube is outside the reservoir. It's extremity is connected to a tap. Outside the reservoir this second part of the tube contains a connection for the priming of gravity flow(drawing and transport). This priming is done by filling up with water the part of the tube situated downward of the connection. This should be done only after closing the tap. After the filling, the connection should be closed to engage the priming by opening the tap for a while. The priming is done only one time and if there is an interruption of the gravity flow. This happens when the level of the water in the reservoir arrives below the orifice of the inside part tube.

The gravity technique of reservoir's water drawing and transport enables a gain of labour time equal to 375 hours(250 hours for transport and 125 hours for drawing) for 30 cubic meters. This was estimated for as lope of 30% and a transport distance of 150 m. Considering 8 hours working time per day, this gained labour time represents about 47 days and 282 TD(TD : one Tunisian Dinar is about one US dollar).The cost of the installation of the gravity drawing and transporting water technique is about 100TD which is equal to 30% of the gained labour time cost.
This technique is already extended in centre and south of Tunisia. In some locations, it allows a water pressure of 2 and 3 bars. In these conditions it enables the use of drip irrigation and other new techniques (buried plastic distributors for annual crops and trees).

Elaboration of a method for the dimensioning of the storage tanks (Fesguias and Majels)
Three mean parameters should be considered in the dimensioning of the storage tank:

- the catchment area surface
- the maximum storage capacity
- the maximum annual runoff during the driest year.

The following formulas are recommended to dimension the storage tanks. This allows the filling(one time) of the tank during the driest year.

$$Q = S_{ca} \times R_d$$

Q = maximum storage capacity of tank in litre
S_{ca} = *catchment area surface, in* m^2
R_d= *maximum annual runoff during the driest year in* mm/m^2

S_{ca} = *catchment area surface, in* m^2
Q= *maximum storage capacity of tank in litre*
R_d= *maximum annual runoff during the driest year in* mm/m^2

Conclusions

Most of the different research results and techniques presented in this paper are now in extension phases(participatory extension) in different regions of centre and south of Tunisia. According to their importance in the water harvesting and conservation in arid lands, these techniques and research results could be transferred specially to other countries in the world with arid conditions.

References

BANNOUR.H. et al (1978):Problème de l'aménagement anti-érosif d'un bassin versant de la Tunisie centrale:le cas de l'oued Elfoul.DRES,Tunis,N°530.

BONVALLOT.J.(1979):Comportement des ouvrages de petite hydraulique dans la région de Medenine(Tunisie Sud)au cours des pluies exceptionnelles de mars 1979, cahier de l'ORSTOM,séerie sciences humaines,volume XVI,N°3.

BOURGES.J.et al(1977):Etude d'un milieu représentatif du sud tunisien(type Segui):citerne Telmen.Travaux et documents de l'ORSTOM.Paris.

CHAHBANI .B,1984:Contribution à l'éude de l'érosion hydrique des loess de Matmata et de la destruction des"jessour". Bassin versant de l'oued Demmer, Béni khedache, sud tunisien. Thèse de Doctorat de 3ième cycle en géomorphologie appliquée. Université de Paris I.

CHAHBANI.B,1990:Contribution à l'étude de la destruction des ouvrages de petite hydraulique dans le sud tunisien. Revue des Régions Arides. N°1. Publication de l'Institut des Régions Arides.

CHAHBANI.B,1992:The"buried stones pocket"a new irrigation technique for trees plantations in arid regions. Proceedings of NATO Workshop: water saving techniques for plant growth(17-19 september 1990-Gent-Belgium).Kluwer Academic Publishers. Netherlands.

CHAHBANI.B,1996a:Researches on Water and Soil Conservation and Use in Aridlands of South and Center of Tunisia. Symposium of Water Resources in Arab countries. Tripoli (Lybia)-18-21 March 1996.

CHAHBANI.B,1996b:Nouvelle méthode pour le dimensionnement des ouvrages de petite hydraulique dans le centre et sud tunisiens. Revue des Régions Arides N°(1/96).Publication de l'Institut des Régions Arides. Medenine-Tunisie.

CHAHBANI.B,1997:Les acquis de recherche dans le domaine de la conservation et la valorisation optimale des eaux de ruissellement dans les régions arides du centre et sud tunisiens. Actes du seminaire international:Djerba (Tunisie)4-6 decembre 1996.

EL AMAMI.S.et al (1980):Les aménagements hydrauliques traditionnels (Meskats et Jessour) moyen de lutte contre l'érosion.Seminaire national sur l'érosion. Sidi Thabet (Tunisie)5 et 6 juin 1980.

FERSI.M. (1979):Caractéristiques hydrologiques du sud tunisien. Seminaire sur la recherche scientifique et le développement des zones arides. Tozeur (Tunisie) 26, 27 et 28 novembre 1976.Ministère de l'Agriculture,Tunis.

HAMZA.A.et al (1977):causes et modalités de l'érosion dans le bassin versant inférieur de l'oued Elhajel (Tunisie centrale). Actes du colloque sur l'érosion et transports solides dans les eaux continentales.Paris, juillet 1977,AISH,N°122.

12

A Decision Making Tool for Optimizing Water Allocation and Management in Arid Zones:
A multi-objective and compromise programming model applied in the oasean production systems of Nefzaoua (Tunisia)

Mongi Sghaier

Institut des Régions Arides de Medenine

Abstract

Nowadays, the awareness on the optimum use and management of water resources and on the sustainable development has increased at the national as well as at the international level.

Located at the north of the 30th parallel, Tunisia is influenced by the vagaries of the Mediterranean climate and the desert impacts of the Sahara. This aridity, in addition to the increase of inter-sectorial demands (quantity and quality), has given water, which is becoming increasingly scarce, a decisive and fundamental role in the economic and social development process of the country.

This paper is intended to be an aid to decision making. It endeavors to contribute to the on-going efforts to optimize the allocation and management of irrigation water. The study is about a desert oasean zone where the water resources are underground and non renewable. Besides the financial criteria, it is necessary to integrate in the definition of efficiency, criteria that help to preserve water resource that lead to reduction of water consumption and the minimization of users surplus.

To do so and taking into account the conflicting nature of objectives, a multi-objective optimization and compromise models was developed. It was shown that it is possible to envisage efficient solutions without greatly sacrificing the financial result while preserving very important quantities of water resources.

Introduction

The decision-making in agriculture is characterized by the multitude of criteria to take in consideration. However it has been supposed, for longtime, based on the hypothesis of optimization of a unique objective that is often linked to a financial or economic result criterion (value added, gross margin,...). In reality, the decision-maker is confronted with a problem of choice of the optimal decision that depends on several criteria and that replies often to the multiple objectives. The problem of decision-making becomes more complex if there are conflicts between these objectives.

The conciliation between multiple objectives has become today possible because of the development, since the seventies, of several works such as: Arrow And Raynaud (1986), Roy (1989), Vinck (1989), Van Huylenbroeck (1993), Romero et al. (1989) and Romero et al. (1987). Multicriteria methods and multiobjective and compromise programming are tools which can serve for solving this type of problem.

In Tunisia, the growing water resources scarcity, conjugated to an increase of intersectorial demands (quantitative and qualitative aspects), needs a large decision-makers concern about the necessity to rationalize the exploitation and management of these resources. The decade 1990-2000 water resources strategy considers that the planning as well as the management of water resources have become a vital necessity to insure the water security of the country (DGRE, 1990). Due to current transition of the tunisian economy to more liberalization and to market mechanisms illustrated by the structural adjustment program , the problematic of water resources shifted from a supply problematic to a demand problematic.

The diversity of agricultural production systems is one fundamental characteristic of the Tunisian agriculture (Selmi, 1991; Ben Said And Ben Zaid, 1980). This diversity becomes more evident where addressing water use efficiency in irrigated areas.

To take advantage of the opportunities given by of multiobjective and compromise programming tools, an application of these methods has been undertaken to solve non renewable water resources allocation (underground fossil water) in the oasean region of Nefzaoua located at the Saharan region of Tunisia (map n°1).

Some optimal solutions (in Pareto sense) are proposed, to decision-makers and to users. Based on hypothesis of production system diversity, this paper try to identify efficient allocation schemes which correspond to an optimal allocation of irrigated areas between identified oasean production systems.

Data and methods

It concerns, in a first time, to apprehend the diversity of production systems in the study region by their identification and their characterization. An inquiry of a representative sample of 400 farmers (14 % of all farmers) has served for establishment of a farm typology by using multidimensional analysis methods (Factorial Correspondence Analysis (AFC) and Hierarchical Classification (Labrousse,1980; Marchal, 1973) . A second inquiry of 50 representative farmers in the identified production system has been undertaken for characterization.

In a second time, methods of multiobjective programming (NISE method (Noninferior Set Estimation), Compromise Programming and method of simultaneous optimization) have been applied so as to optimize the available water resources allocation between production systems.

In fact, the multiobjective programming allows the simultaneous optimization, in Pareto senses, of several objective functions under all constraints. The NISE method which developed by COHON (Zekri, 1991), allows a rapid approximation of the whole efficient solutions, when the number of objectives is not high. This method consists in undertaking a series of iterations to reduce gradually the size of the efficiency zone on the curve of the "trade-off" which is defined as the value of the marginal sacrifice related to a criterion. It corresponds to the gain of a unit of an other criterion. In other term, it is similar to the concept of opportunity cost. The corresponding mathematical formulation is:

$$\mathbf{T}_{\mathbf{jk}} = \frac{\mathbf{F}_{\mathbf{j}}(\mathbf{x}^1) - \mathbf{F}_{\mathbf{j}}(\mathbf{x}^2)}{\mathbf{F}_{\mathbf{k}}(\mathbf{x}^1) - \mathbf{F}_{\mathbf{k}}(\mathbf{x}^2)}$$

T_{jk} : Trade-off between the jth criterion and the kth criterion

$F_j(x)$ and Fk(x) represent the two objective functions.

X_1 and X_2 two efficient solutions.(Romero and al, 1989)

The method of compromise programming aims to more specify the zone of efficiency by identifying the most optimal segment (the nearest of the ideal point). The principle is to calculate distances between the value of the objective function and the respective ideal solution. In case of maximization, the sought distance is expressed by:

$$\mathbf{d_j = \frac{Z_j^* - Z_j(x)}{Z_j^* - Z_{*j}}}$$

d_j : distance between the jth objective (X) and its ideal point

$\mathbf{Z_j^*}$: ideal solution of the jth objective

Z_{*j} : anti - ideal solution of the jth objective

When the objective function is to minimize, the distance becomes as follow :

$$\mathbf{d_j = \frac{Z_j(x) - Z_j^*}{Z_{*j} - Z_j^*}}$$

The method of simultaneous optimization of objective functions allows to optimize the three objective functions simultaneously to end which unique solution. This solution constitutes to decision-maker an approach of optimization process. In this framework, the method of approximation of the zone of efficiency, proposed by Romero and Rehman (1989), is tried. Analyses are undertaken by LINDO software (Schrage, 1986).

Study area and identified production systems

Located in the southwest of Tunisia, the region of Nefzaoua belongs administratively to the province of Kebili that cover approximately 2208340 ha. It is characterized by a saharian climate very low precipitation (less then 90 mm/year), an intense wind regime and very high evapotranspiration estimated to 1589 mm/year (FLORET and PONTANIER, 1982).

The economic activity is based on the agricultural sector notably the production of palm dates of the variety "Deglat Nour" destined largely to exportation. The 360000 ha exploitable area are divided into crops : 50000 ha and pasture :310000 ha. Exploited agricultural areas cover 190000 ha whose 160000 ha pasture). Irrigated areas (oases) cover 12196 whose 8111 ha (66,4 %) are irrigated perimeters legally recognized by public authorities and 4085 ha (33,6 %) are considered "illicit" oases not planned by the water authorities of the Ministry of the Agriculture. Water requirements of these "illicit" perimeters are pumped from underground water table (essentially the "Terminal Complex") by drillings realized by the farmers themselves. Public oases cover 7628 ha (94 % of legal perimeters and 62,5 % of total irrigated area. Green houses cover 38 ha (0,5 % of legal perimeters and 0,3 % of total of irrigated area. While the Agricultural Development Company and Dates called SODAD occupies 445 ha (5,5 % of legal perimeters (CRDA Kebili, 1994; Sodad, 1994). The average production of palm dates reach 50000 tons whose 75 % are "Deglat Nour".

The typological analysis of farmers has ended to the identification of seven production systems:

- **SP1**: great oasian farms (2855 ha (23,4 % of the whole irrigated area and 37,4 % of public irrigated area),
- **SP2** : oasian farms specialized in fruit and date palm production (Deglat Nour)(2948 ha (24,2 % of the whole irrigated area and 38,3 % of the area of public irrigated area),
- **SP3** : integrated oasian farms specialized in Deglat Nour) (895 ha is 7 % of the whole irrigated area and 11,3 % of the public irrigated area),
- **SP4** : marginal oasian farms (968 ha respectively 7,9 % and 12,7 % of the whole irrigated area and public irrigated area),
- **SP5** : farms specialized in green houses heated by geothermal water (38 ha respectively 0,3 % and 0,6 % of the whole irrigated area and public irrigated area),
- **SP6** : modern agricultural company (SODAD) (445 ha planted exclusively in "Deglat Nour" 3,6 % of the whole irrigated area),

- **SP7** : "illicit" oasian farms developed by the individual initiative of private farmers, based on the exhaustion of water resources by well (drillings) called illicit in reference to the code of waters (MIN. AGR. TUN, 1978). (4085 ha, 33,6 % of the whole irrigated area)

Description of the model

The model aims to conceive an optimal allocation scheme of irrigation water in the case of oasis, where water resources are extremely rare and exhaustible (fossil waters). The model admit that the decision maker is supposed optimizing at least three main objectives:

(i) maximizing of the gross margin
(ii) minimizing of the consumption of the water so as to reduce the waste of water.
(iii) minimizing of irrigators (users) surplus (gap between the real price of the water and the tariff supported by users) for the purpose to more involve the users to water cost recovery.

The multi-objective and compromise model takes the following form:

$$\text{Max } GM = \sum_{j=1}^{7} (Gm)_j X_j$$

$$\text{Min } WC = \sum_{j=1}^{7} (WC)_j X_j$$

$$\text{Min } \mathbf{S} = \sum_{j=1}^{7} \mathbf{s_j X_j}$$

Knowing the whole of constraints linked to water and soil resources scarcity and to socio-policy aspects. The formulation as well as the detailed numerical description of the model are given in annex.

GM= Gross Margin

(Gm)j = unit Gross Margin by hectare corresponding to the production system j.
WC: Water Consumption of all production systems in the region.
(WC)j: Water Consumption by hectare corresponding to the production system j.
S: Surplus of the irrigators of all production systems in the region.
sj: unit irrigators surplus by hectare corresponding to the production system j
Xj: area occupied by the production system j.

Results and discussions

Separated optimization of objective functions

The interest of this step is to study efficient solutions corresponding to the separated optimization of each objective functions. It allows also to obtain the Pay off table .

- **Max MB** : as shown in table 1, the gross margin reachs its maximum level (36,235 MD/year with a corresponding water consumption of 162,133 Mm3/year and a maximum surplus level of 10,716 MD/year. The combination of production systems that allows to reach this objective is formed by production systems SP2, SP3, and SP5 with respective areas of 4829, 3233 and 105 hectares. It appears a maximum utilization of available areas legally recognized (8167 ha). Production systems SP1, SP4, SP6 and SP7 do not appear in the optimal solution. Concerning water resources, this optimal solution does not imply total utilization of available water resources (174,5 Mm3/year) and allows to preserve a quantity of resource of 12,366 Mm3/year.

- **Min WC** : the optimal solution corresponds to a minimum of consumed volume of 138,022 Mm3/year but to a fall of the gross margin to the lowest level (22,767 MD/year). In these conditions, the productive combination is composed by four production systems SP2, SP3, SP4 and SP5 with respective areas of 36; 6249; 1843 and 38 ha. This case illustrates the preference to the production systems which with a less water consumption. This optimal solution allows to preserve a water amount estimated to 36,477 Mm3/year.

- **Min. S** : if the objective of irrigators surplus minimization is privileged, the optimization gives us the lowest level of surplus of 8,566 MD/year. However, the corresponding gross margin reaches only 23,034 MD/year with a consumption in water of 138,063 Mm3/year. The corresponding productive combination integrates all production systems except SP3. In the same order of idea, the systems SP1 and SP6 which were not integrated in the first optimal solutions, occupy an important position with 4266 and 445 ha respectively. The optimal solution resulting of the minimization of surplus allows to preserve an water amount of 36,437 Mm3/year.

Table 1

Results of the separated optimization of objective functions

	GM	WC	S	Occupied area (ha)								TWRNC
Obj.	MD/an	Mm3/an	MD/an	SP1	SP2	SP3	SP4	SP5	SP6	SP7	Total	Mm3/an
Max GM	36,235	162133	10716	-	4829	3233	-	105	-	-	8167	12,366
Min WC	22,768	138022	8736	-	36	6249	1843	38	-	-	8167	36,477
Min S	23,034	138063	8566	4266	1633	-	1662	105	445	56	8167	36,437

TWRNC : Total Water Resources Non Consumed
Source : our calculations

The three optimal solutions ended with a total area utilization of legally recognized perimeters. The respective water allocation model allow in general a suitable water resources exploitation with a savings of 12 Mm3/year in case of maximizing of the brute margin and 36 Mm3/year (the triple) in the two other cases. This fact illustrates the misallocation of water resources, simultaneously to maximize the gross margin, and to save a quantity of available resources. Furthermore, the opportunity cost of the irrigation water, during the high-tech period, is high and it is estimated to 0,262 DT/m3.

Multiobjective optimization:
Objectives taken two by two (Method NISE)

The second stage of approximation consists of the application of the method NISE taking into account objectives two by two.

1 - Max GM and Min WC.

2 - Max GM and Min S.

Optimal compromise solution between Max MB and Min WC

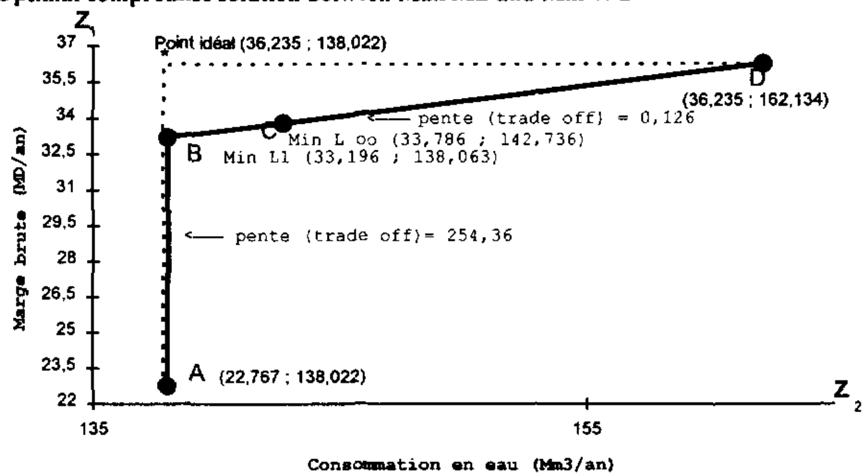


Figure 1 -Trade off curve in case of Max MB and Min WC

As shown by figure 1, the zone of efficiency situates along the curve of trade-off between points A and D. The consumption of water of an additional cubic meter reduced the gross margin of the equivalents of 254 dinars on the segment AB, while on the segment BD, this reduction has almost negligible effect on the economic result. However, the most effective zone of efficient compromise solutions (the closest from the ideal point), taking into account the two objectives simultaneously, is determined by the two limiting L1 (point B) and L∞ (point C). The zone of compromises allows to guarantee a respective gross margin situated between 33,196 and 33,786 MD/year, a consumption in water situated between 138 ,063 and 142,736 Mm3/year of water with a quantity of saved water resources situated between 31,746 and 36,437 Mm3/year. It allows to situate the consumers surplus at a level between 8,9 and 9,3 MD/year.

Optimal compromise solutions between Max GM and Min S

The figure 2 shows that the trade off curve corresponding to Max GM and Min S is situated between the point I (8,566 ; 23,339) and the point M (10,716 ; 36,235). It is characterized by 4 extreme points. The figure 2 reveals that along the segment IJ, a reduction of irrigators surplus of a dinar, would provoke a fall of approximately

37 time its value (36,8 dinars) of the gross margin and reciprocally. This report is only 2,19 time and 1,68 time respectively for segment JK and KM. This shows that rising of irrigation water tariff would have a considerable effect on the level of the gross margin if the decision maker aims to reduce the level of surplus under the bar of 8,8 MD/year (point J on the figure 2). It has no effect beyond this bar.

The most effective zone of efficient solutions corresponding to the segment JK allows on one hand to guarantee a gross margin level situated between 32,962 and 33,462 MD/year and on the other hand to reduce the consumers surplus at very low level situated between 8,843 and 9,071 MD/year.

On the other hand, the whole of efficient solutions of the compromise zone, allows a utilization of a volume of irrigation water situated between 138 and 140 Mm3 resulting thus in savings 35 Mm3/year of water.

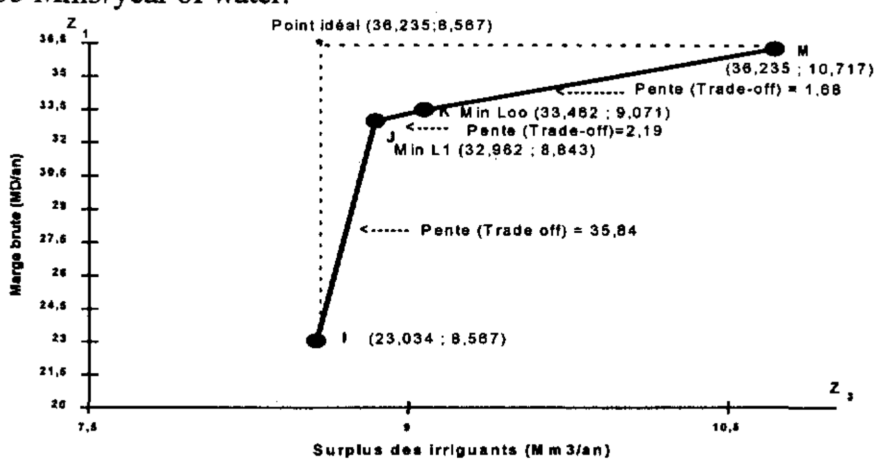


Figure 2: Trade-off curve in case of Max GM and Min S.

Approximation of the efficiency zone based on compromise zones

The analysis of the two trade off curves and respective compromise zones allows to distinguish a common compromise zone allowing on one hand, to narrow and more specify the whole of efficient solutions and, on the other hand, to take in consideration the three objectives simultaneously.

This common compromise zone has for lower limit the point B (L1) and for upper limit the point K(L∞). It allows to guarantee a total gross margin situated between 33,196 and 33,462 MD/year with consumption in irrigation water situated between 138 and 140,17 Mm3/year. The corresponding interval of surplus is situated between 8,913 and 9,071 MD/year.

Table 2 - Characteristics of the optimal compromise zone resulting of the approximation process.

Value	Objective Fonctions			Occupated area by production systems (ha)			Non consumed water (Mm3/an)			Water res. alloc.(Mm3/an)		
	Z1	Z2	Z3	X_2	X_3	X_5	Total water ress.	High demand Period	Geo-thermal water Ress.	SP2	SP3	SP5
Lower limit. B (L1)	33196	138063	8913	3044	5017	105	36437	11610	27708	76,8	57,1	2,3
Upper limit. K(Loo)	33462	140171	9071	3201	4861	105	34329	10593	27708	80,8	58,9	2,3

Z1 = MaxGM MD/an
Z2 = Min WC Mm3/an
Z3 = Min S Md/an
Source: our calculations.

As illustrated in table 2, the simultaneous optimization of the three objectives, envisages a diagram of occupation characterized by respective areas situated between 4861 and 5017 ha for the system SP3, 3044 and 3201 ha for the system SP2 and an area of 105 ha for the system SP5. This optimal situation leads to the allocative model defined by quantities situated between 77 and 81 Mm3/year, between 57 and 59 Mm3/year and 2,3 Mm3/year corresponding to system SP2, SP3 and SP5 respectively. Furthermore, these optimal solutions allow to save an annual water volume situated between 34,3 and 36,4 Mm3/year, approximately 21% of potential resources.

Sensitive Analyses of the Model

Sensitive analyses of optimal solutions have been realized for the purpose to test the optimal solution stability in case of relative variations to the hierarchization of objectives or to the two objective functions limits fixed during the simultaneous optimization. These analyses have shown a relative constancy of optimal solutions of compromises when the hierarchization of objectives varied. Indeed, if the weight of the objective Max GM is doubled there is no effects on the basis solution.

Concerning the optimal solution resulting from the simultaneous optimization of the three objectives, sensitive analyses have shown that it is impossible to find an optimal solution if lower surplus level is dropped to 8 MD/year. A level of surplus fixed to 8,7 MD/year allows, even so, to maintain the gross margin at 31,2 MD/year corresponding to a total consumption in water of 138,073 Mm3/year. This optimal solution reveals the possibility to maintain the water consumption of production systems to the lowest level, approximately 138 Mm3/year, and to drop the surplus to 8,7 MD/year without significant reduction of the gross margin. Indeed, sacrifying only 5 MD of gross margin to preserve approximately 24 Mm3/year is not a major problem. Nevertheless, the gross margin remains at a level higher than 31 MD/year (31,2 MD/year).

Conclusion

The application of multiobjective and compromise programming methods to the studied case, has revealed that it is possible to establish an allocative scheme of water resources that optimize the allocation of irrigation water between existent production systems and that can conciliate between conflict objectives notably the maximization of the economic system profitability and the minimization of water consumption and of the irrigators' surplus.

The approximation of the compromise zone of efficiency, resulting from the optimization of objectives two by two, allows to identify optimal solutions characterized by a gross margin situated between 33,196 and 33,462 MD/year. It allows to reduce the volume of consumed irrigation water and the irrigators' surplus to levels going from 138 to 140,171 Mm3/year and 8,913 to 9,071 MD/year respectively. This leads to the preservation of water resources situated between 34 and 36 Mm3/year, approximately 21 % of the potential exploitable water resources.

Referring to the studied case, it proves that modern production systems, based mainly on the production of date palm "Deglat Nour" (SP2 and SP3) and on the production cash crop irrigated by geothermal water (SP5), are retained by optimal solutions in case of optimization of the two objectives of Max GM and Min WC. When we want to integrate the objective of minimization of the consumer surplus, the system SP3 disappears in the optimal solution because of its remarkable consumption of irrigation water.

On the other hand, tests of sensitivity, undertaken on the initial formulation, have revealed a relative stability of identified optimal solutions, as one modifies weights granted to different objectives. If the legal prohibition constraint is lifted for the system SP7 (its area is then integrated by public authorities), the optimal solution does not undergo notable changes in general and the system SP7 remains little competitive. Such decision leads to the extension of the system SP3, assimilating illicit exploitations that are vowed to transform.

In definitive, this work has shown that it is possible to push the rationalization of the exploitation of water resources in agriculture beyond a simple recourse to the instrument of water pricing by using methods of multiobjective and compromise programming at microeconomic and regional levels. Indeed, this second level of optimization allows to conciliate objectives, in appearance opposed, and ends to allocative schemes which not take in account solely the objective of maximizing of the financial result of the production system but also the preservation of water resources .

However, one can notice that is exposed results are linked to the starting model hypotheses. On the other hand, through this attempt of modeling of the allocation of water resources ,one does not claim to conceive an explanatory model of the functioning of production systems. Such models require the integration of others criteria, others constraints and others objectives.

References

ARE KEBILI (1994) : Exploitation des nappes profondes à Kébili. Note interne.

ARROW K.J., RAYNAUD A. (1986) : Social choice and multicriterion decision-making, MIT Press, Cambridge.

BEN SAID M., BEN ZAID A.S. (1980) : Agriculteurs tunisiens face aux impératifs de l'intensification. Economie Rurale, n° 135,. pp 28-37.

CRDA de KÉbili (1994) : Compte rendu des activités de l'année 1993. 119 p.

DGRE (1990) : Stratégie pour le développement des ressources en eau de la Tunisie au cours de la décennie 1991-2000. 30 p. + annexes.

FLORET Ch., PONTANIER R. (1982) : L'aridité en Tunisie présaharienne, climat, sol, végétation et aménagement, ORSTOM, Paris, 544 p.

GIH (1986) : Situation des associations d'intérets collectifs dans le gouvernorat de Kebili . Rapport, 16p.

HAMDI L. (1988) : Gestion des ressources en eau. Rationalité des agriculteurs dans la consommation d 'eau d'irrigation. Cas du périmètre de Mejez El Bab - Tunisie. Mémoire de fin d'étude du cycle de spécialisation INAT.

HORCHANI A. (1994) : Gestion des ressources en eau en Tunisie.Min.Agr.Tun 10p.

MARSHAL P. (1973) : Méthodes d'analyse statistique des entreprises agricoles. INA, Paris - Grignon (5 fascicules).

ROMERO C., AMADOR F., BARCO A. (1987) : Multiple objectives in agricultural planning, a compromise programming application. Am. J. Agr. Eco., p. 79-86.

ROMERO C., REHMAN T. (1989) : Multiple criteria analysis for agricultural decisions. Elsevier. Amsterdam.

ROY B. (1989) : Main sources of inaccurate determination, uncertainty and imprecision in decision models, models and methods in multiple criteria decision, Editor RODIN E.Y, Pergamon Press, Oxford, p. 1245-1254.

SCHRAGE L. (1986) : Linear, integer and quadratic programming with LINDO. Scientific Press, USA, 89 p.

SELMI A. (1991) : Validation micro-économique et transition au marché : Les systèmes de production agricoles en Tunisie.

Seminaire sur la politique agricole tunisienne. DGPDIA (MIN. AGR.) et FAO, 11 p.
SGHAIER M. (1995) : Tarification et allocation optimale de l'eau d'irrigation dans les systèmes de production de la région oasiènne de Nefzaoua (sud de la Tunisie). Thèse de Doctorat d'Etat, Université de Gand, Belgique, 235 p.
SODAD (1994) : Rapport d'activité 1993.
VAN HUYLENBROECK G. (1993) : The conflict analysis method, braiding the gap between Electre, Promothée and Oreste, European Journal of Operational Research (82), North-Holland, p. 490-502.
VINCKE Ph. (1989) : L'aide multicritère à la décision, Editions de l'Université Libre de Bruxelles, Bruxelles, 179 p.
YU P.L (1973) : A class of solutions for group decision problems, Management science, Vol (19), p. 936-946.
ZEKRI S. (1991) : Modelos decisionales multicriterio en planificacion agraria: objectivos economicos versus objectivos ambientales, Tesis doctoral, universidad de Cordoba.
ZELENY M.O. (1974) : Linear multiobjective programming , Spinger-Verlag, Berlin.

Annexe

Mathematical formulation of the multiobjective model

$$\text{Max } GM = \sum_{j=1}^{7} (Gm)_j X_j$$

$$\text{Min } WC = \sum_{j=1}^{7} (WC)_j X_j$$

$$\text{Min } \mathbf{S} = \sum_{j=1}^{7} \mathbf{s}_j \mathbf{X}_j$$

Where :
GM= Gross Margin
(Gm)j = unit Gross Margin by hectare corresponding to the production system j.
WC: Water Consumption of all production systems in the region.
(WC)j: Water Consumption by hectare corresponding to the production system j.
S: Surplus of the irrigators of all production systems in the region.
sj: unit irrigators surplus by hectare corresponding to the production system j
Xj: area occupied by the production system j.

With the following constraints:

1) $\sum_{j=1}^{7} \mathbf{X}_j \leq 8167(\mathbf{ha})$

2) $\sum_{j=1}^{6} \mathbf{X}_j \geq 8111(\mathbf{ha})$

3) $X5 \geq 38$ (ha)

4) $X5 \leq 105$ (ha)

5) $X6 \leq 445$ (ha)

6) $X7 \leq 4085$ (ha)

7) $\sum_{j=1}^{7} (\mathbf{WC})_j \mathbf{X}_j \leq 174500$ $(1000\ m^3)$

(8) $\sum_{j=1}^{7} (\mathbf{WC})_j \mathbf{X}_j \geq 138000$ $(1000\ m^3)$

(9) $\sum_{j=1}^{7} (\mathbf{wcp})_j \mathbf{X}_j \leq 80000$ $(1000\ m^3)$

(10) $(WC)_5\ X_5 \leq 30000$ $(1000\ m^3)$

Table 1

Numerical description of the model

Système de production	X_1	X_2	X_3	X_4	X_5	X_6	X_7	Rela-*tion*	Constraint *level*
potentiel area of oasis	1	1	1	1	1	1	1	≤	8167 ha
Current area oasis	1	1	1	1	1	1	-	≥	8111 ha
Min. area of Green houses	-	-	-	-	1	-	-	≥	38 ha
Max. area of Green houses	-	-	-	-	1	-	-	≤	105 ha
SODAD area	-	-	-	-	-	1	-	≤	445 ha
Illicit area	-	-	-	-	-	-	1	≤	4085 ha
Total water consumption (1000 m3/ha/an) Max	7,2	25,239	11,744	34,115	21,825	12,662	26,966	≤	174500
Total water consumption (1000 m3/ha/an) Min	7,2	25,239	11,744	34,115	21,825	12,662	26,966	≥	138000
Total water consumption in summer (1000m3/ha/an)	4,112	12,529	6,020	22,736	0,356	6,906	19,668	≤	80000
Geothermal water consumption (1000m3/ha/an	-	-	-	-	21,825	-	-	≤	30000
Max GM (DT/ha)	2298	4842	3138	1086	25800	1710	887	Max	
Min WC (1000m3/ha/an)	7,2	25,239	11,744	34,115	21,825	12,662	26,966	Min	
Min S (DT/ha)	346	1716	705	2286	1440	684	593	Min	

Source : Our survey ; SODAD (1994) ; CRDA Kébili (1994)

13

The Affect of Geothermal Water on Quality of Tomatoes

Haddad Mansour and Boukris Meki

Institute of Arid Lands

Introduction

In Tunisia, Tomato (Lycopersicum esculentum.L), is the most important crop. It covers more than 120 000 Ha from The 150 000 Ha reserved for vegetables.

With the introduction of plastic methods, and due to the influence of the sea, tomatoes are cultiveted around the year in the tunisian coast in protected green houses. With this new process prices are more than too time higer comparead with the normol system. Production can mainly be divided as follows :

1. The in-saison field production: Tomatoes are sown in the springtime and harvested in summer. They are mainly processed and a little part is marketed as fresh tomato.

2. The off-saison production : Tomatoes are ptrotected against cold and conducted in round arched greenhouse.

They have been increased very rapidly since 1974 to reatch 1250 ha in 1984. They have been developped mainly for export but this new process didn't give satisfaction, the main factor limiting is nocturnal temperature in relation to tomato growth exigent (12 to 15°C). In the south of Tunisia, 1984, greenhouses are heated by the use of geothermal water.

The geotermal wells are mostly artesian and only in some cases pumped. The cold water is also used for irrigation purposes. Energy is distributed by corrugated polypropelentubes(Φ25) disposed on the ground surface. With this system, vegetative and generative growth were increased with earliness production for export.

In this paper we will report some one's findings research of general informations, market demande and quality aspects of tomatoes producction in the south east of Tunisia.

Quality Aspects of Tomato

Foreign markets require fruits which are evenly ripend, regular in size, healthy, clean, red , intact, firm (Anonyme,1991). All these aspects can be grouped in 2 different cases: Commercial quality and flavor.

Commercial quality

Visual aspects
Tomatoes have to be healthy, exempt from visual spots of diseases and the residue tolerance of pesticides has to be as lawer as possible than the legal tolerated limits.

The production has to be clean and intact, exempt from dust, cracks and pesticides spots, so fruits must be brush.

The fruit colour is a very important component of tomato quality. Tomatoes have to be uniformly deep red and free from ripening defects.

Firmness is a very important judgent factor determining tomato quality and maintenance of this quality during harvest, handling and storage, is regarded as the main factor that dedetermines « shelf life »(Kouki,1991).

Flavor
The major relish characteristics of tomatoes are mealliness, juiciness, aroma, sweetness and sourness. The sugar and acid contents are very important. Low sugar content results in water taste , whereas low acid content gives inspid fruits. (Janse, J. et Gielsen, C.J.M.,1991)

To have good taste, the pH of tomato juice must be inferior to 4,4 and preferentially lower than 4.1, dry matter content must be higher than 5% and EC higher than 4,5. Total acidity in tomatoes is important as a major taste component. (Sonneveld, C and Welles, G.W.H.,1988)

Materials and Methods

Observations had been conducted this year on xix farms which produce both for national and foreign markets. These farms had been encoded from 1 to 6 and general informations and more than 100 half mature fruits are collected at random in each one.

- Fruits are calibrated on seven class across (40, 47, 57, 67, 77, 82, and 87mm)
- Firmness is estimated with a penetrometer according to a negative correlation between firmness and penetration.
- Titratable Acidity with 0,1 sodium Hydroxide and directly pH metre are determinated
- Soluble solids are mesured directly using a refractometre according to a relationship between refraction indice (RI) and soluble solids.
- Production and prices were collected from the principal maerket in Tounès

A. General information

1. Cultivars

Different type of indeterminate varieties were used and sown in the begining of august 1998:

- Round tomatoes : Elena and Amel in 10.2 and 2.75 ha respectively;
- Round truss tomato : Durinta
- Long tomato, only one cultivar was used. It's called Bochra ;
- Three cherry tomatoes, still trial were cropted : DRS 119, DRS155 and DRS156

2. Technical informations

2.1 Nutritious solutions

All of them use geothermal water for irriguation, the EC value of water varied from 2,5 and 3,2 mS/m and a fertigation technique based on N, P, K and micro- elements. It was dificult to collect informations about quantity of fertilizers so we maesured EC and pH of the nutritious solutions. EC and pH of nutritious solutions in the different farm are in Table 1.

Table 1.
EC and pH of nutritious solutions in the different ferms

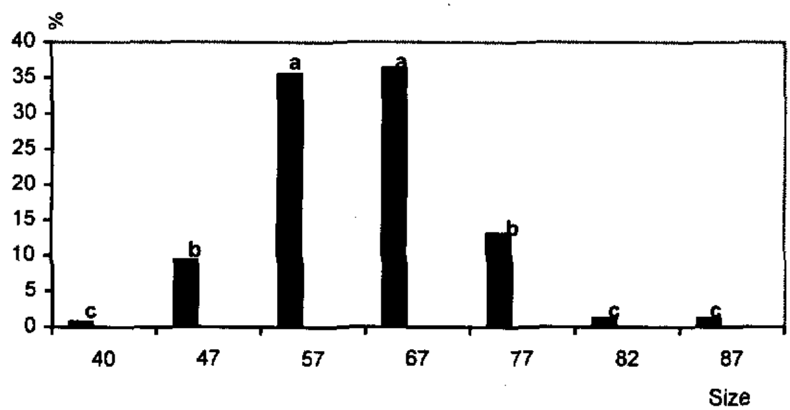
Farm	EC	Ph
1	3.95-4.98	5.5-6
2	4.86	6.34
3	4.61-5.66	4.31-7.57
4	4.87-6	5.5-7.57
5	4.78	6.97
6	4.68-5.59	6.17-7.69

This table shows that every one has got its own nutritious solution

2.2 Fruit size

More than 80% of the yield in the six farms is classed between 57 and 77mm across which can be exported. Fig1.

FIG.1 Fruit size



2.3Average yield

Cultivars are harvested together so we have collected average yield toled and % of export in the six farms, Table 2.

B. Quality aspects

12 fruits by cultivars at random were evaluated, at the harvest and after 5 and 10 days of storage for firmness. At the harvest, the juice acidity, EC and RI were also measured.

Table 2.

Average yield and % of export of tomato

Farm	Yield Kg/m2	%of export
1	13.05	18
2	8	61.75
3	9.47	65.49
4	6.2	38.2
5	12	60.94
6	8	21.81

1. Firmness: Affect of storage and average of the different values are classed in tables 3

Table 3.

Affect of storage on firmness (mm)

	At harvest		5 days after		10 days after	
	Average	σ	Average	σ	Average	σ
Elena	2.58	0.26	3.71	0.31	4.64	0.63
Amel	2.65	0.22	4.06	0.39	4.94	0.65
Durinta	2.5	0.23	3.9	0.56	5.23	0.81
Bochra	2.86	0.31	3.96	0.2	4.75	0.19

All of these cultivars are firm, but Durinta isthe best at the harvest but it lost its firmness after 10 days of storage. Also we have seen that the same cultivar had different value in ecth farms, for instance, Elena had 2,6, 2, 7 and 2,3 respectivly in the farm 1, 2 and 3. So this factor depends on the technical conditions in each farm.

2. pH and total acidity (TA)
Different value are in table 4.

Table 4.

Averages of pH and total acidity (TA) of juice

	Elena		Amel		Durinta		Bochra	
	PH	TA	pH	TA	pH	TA	pH	TA
Avg.	4.41	7.82	4.45	7.52	4.50	5.34	4.64	5.12
σ	0.09	2	0.06	1.45	0.07	0.64	0.05	0.95

Table 4 shows that Bochara has the lowest value of (TA) but pH values are comparable and ranged between 4, 41 and 4,64. This factor is affected by cultivars and growing method.

3. Soluble solids(RI)

All the cultivars are suitabale for this parameter. It is affected both by the cultivar, Table 5 and the farm (table.6). Amel and Elena are the best for this factors

Table 5.

Affect of cultivar on soluble solids of juice

	Elena	Amel	Durinta	Bochra
Average	5.98	6.02	5.13	5.75
σ	1.01	0.71	0.14	0.44

Table 6.

Affect of farm on soluble solids of juice

Farm	1	2	3	4
RI	7.13 a	5.13 b	6.02 ab	6.6

4. Electic conductivity of juice(EC)

This factor can give an idea about mineral composition of fruit, the affects of cultivar and farm are in table 7 and table 8.

Table 7.

Average EC of juice cultivars (mS/cm)

	Elena	Amel	Durinta	Bochra
Average	5.58	6.48	5.3	5.47
σ	0.42	0.50	0.53	0.40

Table 8.

Affect of farms on EC of juice of Elena and Amel(mS/cm)

	Elena	Amel
1	6.07 a	-
2	5.13 ab	-
3	5.46 ab	6.64 a
4	5.86 a	6.59 a
5		6.23 a

4. Aspect quality of cherry tomatoes

This type of tomatoes are particular so they were examined with each other. Different values are listed in the Tab 9.

Table 9.
Aspect quality of cherry tomatoes

	RI	pH	TA
DRS155	7.73ab	4.31a	8.28b
DRS119	7.00ab	4.24a	9.22b
DRS156	8.66a	4.26a	14a

Conclusion

It can be concluded from this quality evaluation of tomatoes that geothermal water has got a positive affect on quality. The taste of cherry tomatoes was appreciated significantly better compared with the other culitivaers.

Differences in yield were observed , average values were low, it must be attributed to the high EC of geothermal water.

References

Anonyme (1991) : La qualité de la tomate pour l'exportation. Les documents techniques de l'utilisation de la géothermie dans le chauffage des cultures sous serres.Problèmes de phytotéchnie et de qualité. DGPA, PNUD. Ministère de l'Agriculture.

Janse, J. et Gielsen, C.J.M.(1991) : Effects of growing temperature and EC on flower, other quality characteristics and yield of tomato. Annuel report MG. Glasshouse Crops Research Station

Kouki, K. (1991) : Influence du substrat de culture et de la fertilisation sur l'amélioration de la qualité de tomate de primeur. Thèse de 3^{cme} Cycle de l'INAT, 162p.

Sonneveld, C and Welles, G.W.H.(1988) : Yield and quality of of rockwool, grown tomatoes as affected by EC values and climatic conditions. Plant and Soil 111 : 37-42.

14

Comparison and Management of the Desertification Phenomenon in Tunisia and Sardinia

Marini A., Talbi M.**, Melis M.T.*, and Pitzalis A**

** Università di Cagliari*
***Institut des Regions Arides*

Introduction

In this paper we report the first results of the study within the actual collaboration between the Università di Cagliari (Sardinia - Italy) and the Istitute des Regions Aridés (Medenine - Tunisia). This collaboration take place from the interest of the Remote Sensing Laboratory of Cagliari (TeleGis) toward the study of the problem of desertification hazard in arid and semi-arid regions. This project has been financed by the Regione Sardegna to encourage the co-operation between developing Countries; the co-operation acts by experience and knowledge changing among researchers and the identification and application of common research methods.

The collaboration between the two Institutes regards especially the development of the common research field: "Desertification, comparison and check-up of the phenomenon in Tunisia and Sardinia" (Fig.1).

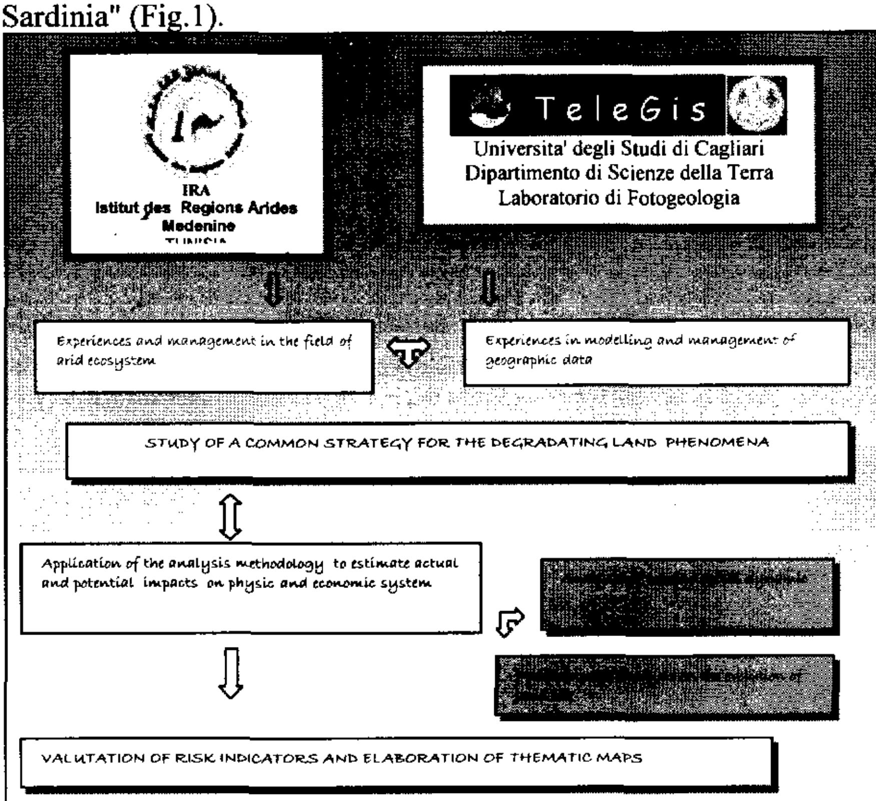


***Figure 1.** Project objectives.*

Presentation of Research

The analysis of parameters defining the degradation status of lands derives from a multi-disciplinary research. With this study we enhance the knowledge of physical indicators of the natural environment and verify, by multi-temporal analysis, the natural faculty of territory to re-establish the equilibrium conditions.The parameters considered in the multi-temporal analysis identify variations of land covering and land-use. The principal cause of environmental changing is the man. Fires, over-exploitation of lands for agriculture and grazing, and urban development affect and still cause strong mutation in environment; even if they could offer immediate economical benefit, they are going to be the main cause of impoverishment.

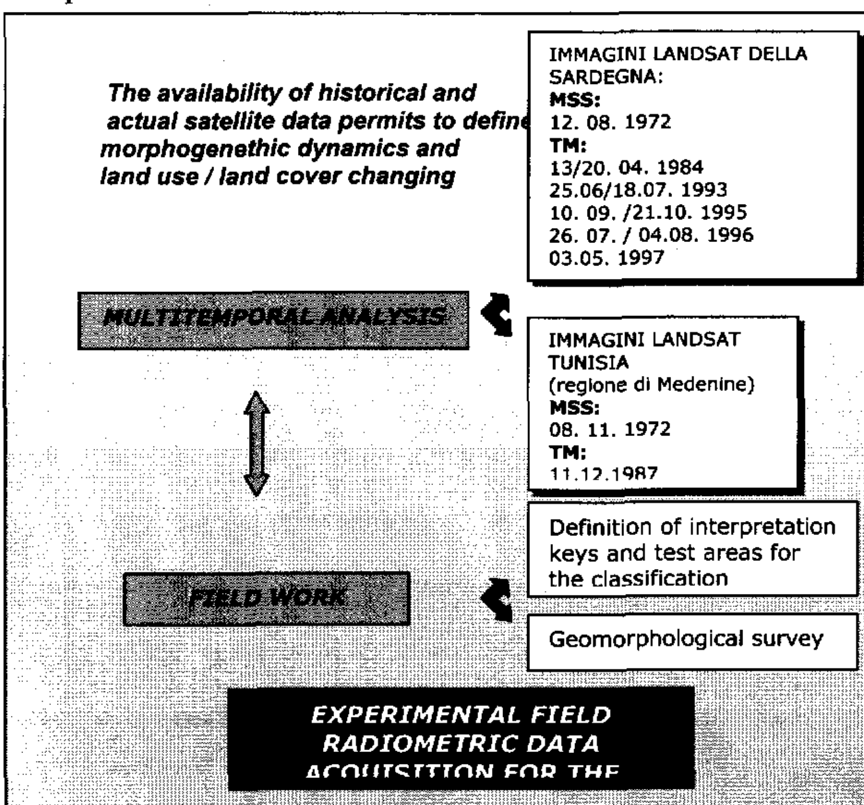


Figure 2. Research steps during the collaboration project.

The multi-temporal study from remote sensing data (Fig. 2), even if is not a new methodology, allows for the first time, the representation of Sardinia and Medenine region based on homogeneous information.

The project includes a second phase of study which utilises radiometric data acquired on land using a spectroradiometer (0.4-2.5 micron), already employed for elaboration of phenological diagrams on natural Sardinian vegetation.

Geomorphological Analysis of the Medenine Region

Remote sensing techniques were applied to mapping physiographical units on the study area. The definition of these units was made by interpreting satellite data and mapping land cover / lithological, soil classes. The principal aim of this analysis was the knowledge of this area for the definition of the degrading indicators strictly connected with geomorphological processes.

Figure 3. Satellite image representing the study area in the Medenine region.
(In white physiographic units are reported, limited by dash lines.)

Four principal units were defined as parallel belt put in NW-SE direction, as we can see on Fig. 3. The unit IV is covered by Mesozoic carbonate lithologies with altitude around 500 metres. The drainage pattern is partially controlled by faulting and jointing, but it can be defined like dendritic. The boundary with the third unit is the watershed that separate two river systems: one that flows north-eastward to the coast and the second one south-westward, towards the sand desert plain, where the system becomes an endoreich drainage. Land cover is everywhere poor and locally along the river we can find scrub and cultivated areas. Pedological and morphological characteristics don't allow the extensive agriculture; on limited areas artificial terraces were built to combat the erosion phenomenon. The grazing is the most important activity. Almost the total absence of land cover and the medium relief energy contribute to rill and sheet erosion processes. Aeolic erosion and accumulation forms were recognised during the field trip and the distribution of the sand on this area was evidenced on satellite data as spreading oriented extensions.

The third unit is classified as glacis d'accumulation: it's an gentle slope separated from the stepper upper slope by the piedmont zone and the knick along the scarp is undulated because of coalescing of adjacent alluvial fans. On this area there is a parallel drainage pattern and the linear fluvial erosion is poor. Sheet erosion and rill/gully erosion are the principal reasons of sediment transport that moves debris and soil components, while the aeolic dynamic isn't active because of orographic barrier. The glacis is composed of unconsolidated materials and soils are weakly developed; the interpretation of satellite image has evidenced the agriculture land use on the area and the multitemporale analysis that was applied on MSS 1972 and TM 1987 images may assure an increasing on cultivation practices.

A concave slope divides the third unit from the second: this area is almost flat and there are gypsum crusts. The aeolic dynamic and the lack of soil limit strongly the agricultural use of this area and the vegetation growth.

The firs unit covers the north-eastern side of the study area where there is Medenine as we can see on the Fig. 3. This is a surface weakly sloping with an intense phenomena of sheet and gully erosion and deflation as it's possible to evidence as desert pavement. These processes are causing of prohibitive condition for agricultural use and grazing is the principal activity.

Analysis of Desertification/Land Degradation in Sardinia.

The island of Sardinia is located in the central-western Mediterranean basin. It can be possible to identify two morphoclimatic zones: the first one in the southern part of the island and partially along the coast belongs to a semi-arid system; the second one, in the central island and on the medium and high altitude can be classified as humid and sub humid system.

This regional climatic differentiation regards both the mean annual rainfall entity and the mean temperature. The common factor for all the areas of Sardinia is given by the extreme irregularity of raining in a year; in particular, rainy winters follow dry summers that in some cases may extend up to late October. An other characteristic of raining in Sardinia is the cyclicity of extremely dry years whit extremely rainy ones.

These climatic aspects are the base of the strong sensitive of the land to the human modifications that often cause erosional processes and soil degradation, with losing of potential land productivity. Sardinia is, thus, a land in which the natural restoring of ecological equilibrium is extremely hard and slowed by strong climatic condition (Fig. 4).

Although, without any anthropic affecting, Sardinia would be characterised by biostasys condition and morphological stability, in which pedogenetic processes would rule in morphogenesis.

The history of desertification, or better the reduction of land productivity in Sardinia, is related to the human coming and his social-economic slow-to-swift evolution, even if the starting of greatest erosion processes may be dated from the middle of 18th century when primary forests have been destroyed. More often than not, fires and land overuse (overgrazing and further deforesting) followed that deforestation, avoiding the restoring of the natural equilibrium and increasing the erosion that causes the overcoming of the resilience limit, which marks the capacity of autoequilibrium for lands (Fig. 5).

The changing, from subsistence agriculture, in which soil resources are saved, to extensive agriculture aiming profits, in plain and slightly steep areas, rose to land overusing. Desertification causes a concatenation of situation which final result is an exponential autoincreasing of degradation processes.

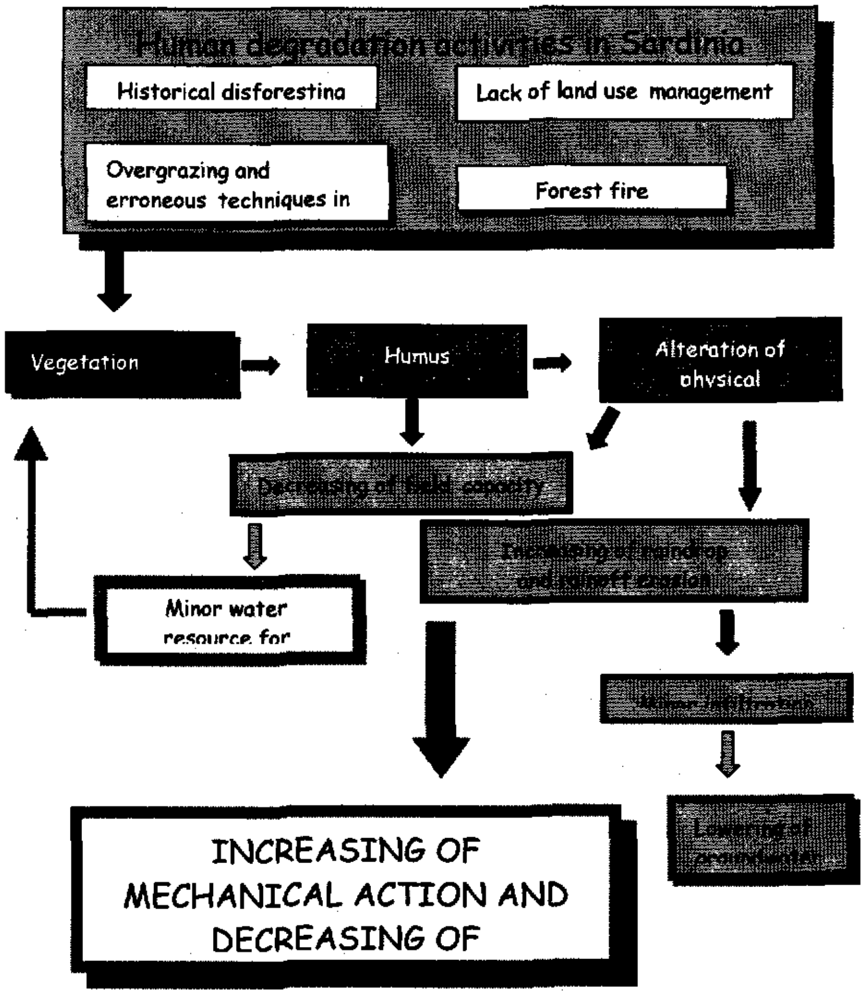


Figure 4. The problem of land degradation in Sardinia.

Figure 5. Landsat TM image (432 bands): we can see in black the burned areas

Conclusion

The environmental analysis and the comparison of morphoclimatic processes bring our research project to consider the necessity of a regional approach on land degradation and desertification problem. The next step will be the study of a quantitative model about the capacity to restore ecological equilibrium in Sardinia.

References

Hellden, U., Stern, M. (1980) - Monitoring land degradation in Southern Tunisia. A test of Landsat imagery and digital data - Lunds Universitets Naturgeografiska Institution. Rupporter och Notiser 48.

Marini, A., Melis, M.T., Pitzalis, A. (1998) - Geomorfologia e land use delle regioni di Axum e Adua (Tigray-Etiopia nord-orientale) - Atti II Conferenza nazionale ASITA, 24/27 novembre 1998. p 175-176 vol.2.

Marini, A., Melis, M.T., Pitzalis, A., Talbi M. (1999) - Analisi geomorfologica in aree predesertiche: la regione di medenine,

Tunisia meridionale. Atti III Conferenza ASITA, 9/12 1999, pp. 911-916 V. II.
UNESCO, (1980) - Case studies on desertification. Natural resources research, XVIII.

Summary Report

UNU International Workshop
Water Management in Arid Zones

18-22 October, 1999
Médenine, Tunisia

Prepared by Zafar Adeel

Summary of the Worskhop Sessions

Technical Session 1
Water Management in Arid Lands

This session focused on the general issues pertaining to water management in arid lands. The paper presentations and the subsequent discussions highlighted both technical and institutional aspects of the water management issues. In general, the following points were made:

a. In recent years, water resources issues have become a foremost item on the international and regional agenda. Increased stresses on limited global freshwater resources due to population and industrial growth are part of the reason for this increased interest.
b. In the context of arid lands, it is important to define long-term sustainability of water resources. There is also a need for integrated management of natural resources to achieve this sustainability. Long-term environmental and social impacts of water utilization schemes and quantitative cost-benefit analyses should also be a part of such integrated management schemes.
c. The integrated management schemes should ideally operate on both top-down and bottoms-up approaches. This may be achieved through an inter-disciplinary approach that explicitly involves those who could be impacted by implementation of such approaches.
d. To successfully manage the water and natural resources social, institutional, economic and technological barriers have to be overcome. Particularly, the socio-economic aspects should be dealt with through a participatory approach that engages general public and interested citizens. In this respect, it is very important to educate the public in conservation of natural resources through capacity building programmes.
e. The UN convention to combat desertification (UN CCD) provides an idealized framework for action on the pertinent issues. Sustainable use of water is obviously the key element of efforts to combat desertification, as identified in the convention.

f. There appears to be an increased level of interest by donor agencies in funding research and development programme related to water issues in the context of land degradation and desertification. The Global Environment Facility (GEF) has special focal areas designed for this purpose.

Technical Session 2
Regional Approaches to Water Management

In this session, the emphasis was placed on discussing the regional problems and solutions in dry lands. Presentations focused on many large-scale problems in Central Asia (particularly former Soviet Union), Middle East, China, Iran, and Tunisia. The general conclusions from this session were:

a. Many problems of sustainable development in arid lands are related to water-resource management. The nature and severity of these problems is often unique and distinct to the region. Therefore, it is paramount to understand the morpho-thematic causes behind desertification and land degradation in various areas.
b. Some participants emphasized the need for including hyper-arid areas in the discussion. However, this was found to be somewhat contradictory to the definition outlined in the CCD context. It may also be argued that a vast majority of the population in dry regions actually lives in semi-arid areas.
c. It is important to explicitly consider transboundary issues when dealing with problems that are regional in nature. In many cases, the extent of problems may surpass national or political borders. It is, therefore, important to devise mechanisms for collaboration between the various stakeholders on conservation and protection of local/regional watersheds.
d. The social and cultural dimension of water should not be ignored when discussing regional water-resources issues. Most importantly, water utilization is directly linked to food production and security. Thus, water has important role to play in the lives of people who live in arid lands.

Technical Session 3
Management of Groundwater Resources in Arid Lands

It was highlighted that groundwater and fossil water forms a very crucial component of the water management theme in arid lands. In arid lands, where rainfall is typically insufficient to meet the water requirement – even with the most efficient water management systems – the reliance on groundwater can be quite heavy. In this context, the following points were made:

a. In general, aquifers are gravely threatened by depletion due to over-withdrawal and water quality degradation. The declining water levels in regional aquifers can lead to increased costs in water utilization and have some potential for triggering conflict between riparian countries.
b. When dealing with groundwater for agricultural and domestic use, due consideration should be given to salinity and water quality. It was emphasized that using saline water for irrigation purposes may lead to accumulation of salts in the long run and eventual soil-quality degradation.
c. It is also important to consider seawater intrusion into freshwater aquifers in coastal areas. Over-withdrawal of freshwater from aquifers is a global problem that causes saline seawater intrusion.
d. There should be emphasis on developing technological solutions for remediating water quality problems in aquifers located in arid lands. Particularly, there is a need for developing efficient and reliable methods for aquifer recharge.

Technical Session 4
Innovative Techniques for Water Management

This session focused on innovations –in terms of both technological advances and management practices – in the arena of water management. On the whole, it was emphasized that South-South collaboration in transfer of technology is essential to the success of sustainable water management approaches. Additionally, the following themes were discussed during the session:

a. The need for developing innovative technologies for management of water and combating desertification was highlighted. It was interesting to note that in a number of research programmes efforts are being undertaken to improvise traditional water management technologies. Combining the old with the new technologies can often maximize the benefits to the user.
b. It is important to develop integrated and comprehensive monitoring and evaluation programmes to understand the nature of problems. The success of water management approaches can also be fully evaluated only if sufficient information and monitoring data are available.
c. The need for developing new and innovative economic techniques that are geared towards arid lands was also emphasized. Such economic mechanisms can greatly help in implementing sustainable water management approaches.
d. Water harvesting was presented as viable mechanism for sustainable utilization of limited water resource in regions with average rainfall of 100-300 mm.
e. Deficit irrigation was introduced as a concept whereby reducing the amount of irrigated water in early stages of plant growth can result in significant savings in water, while having minimal adverse impact on productivity.
f. It was argued that using domestic wastewater and sewage can provide an additional water resource for irrigation. Such wastewater must be pre-treated prior to application and its quality must be carefully monitored to ensure safety.
g. Use of geothermal waters was shown to be an important resource for water in arid lands. At the same time, the hot water may used as a thermal energy source for heating up greenhouses.
h. Remote-sensing through satellite imagery and its combination with Geographic Information Systems (GIS) was shown to be an effective tool for optimization of management practices.

Publication of Workshop Proceedings

During the Panel Discussion, the following modes were suggested for publication of papers from the workshop:

a. Publication of workshop proceedings as an unedited (re-formatted) volume

b. Editing all the papers prior to publication as workshop proceedings
c. Combining all the papers into an edited volume, which may be submitted to the UNU Press for publication
d. Development of an executive summary for immediate dissemination

This report serves the purposes of immediate dissemination. In the absence of volunteers to serve as editors, it was decided to publish an unedited volume, similar to the one produced for the first workshop.

Recommendations for Future Workshop

Topics for Discussion

During the Panel Discussion, several themes were suggested by the workshop participants for the next workshop under the UNU initiative. These are summarized here:

a. Biodiversity in Arid Lands
b. Comparison of Regional and Integrated Approaches
c. Coping with Environmental Stresses in Arid Lands
d. Sustainable Development in Arid Lands
e. Local and Scientific Knowledge for Conservation in Arid Lands

The final decision for the topic will be made in consultation with the Steering Committee and the host country for the next workshop.

Venue of the Workshop

In terms of a venue for the next workshop, several suggestions were made during the Panel Discussion. The offer to hold the workshop was made by participants from individual organizations/countries. The following locations were proposed:

a. China
b. Kuwait
c. Libya
d. Uzbekistan

Recommendations for Future Work

UNU Programme on "Land Degradation in Dry Areas"

As an outcome of the panel discussion, it was agreed that a collaborative research and capacity building programme should be developed. This programme will focus on water management and biodiversity conservation issues within the broader umbrella theme of land degradation. The need for such a programme was highlighted in the various technical sessions and the panel discussion during the workshop.

To fully develop the programme proposal and seek financial resources for its implementation, a Steering Committee was formed. This committee comprises UNU (Chair), IRA (Secretary), ICARDA, Iran, China and Niger. The general objectives of Steering Committee are listed here; detailed terms of reference for the committee have been developed and will be shortly available to those interested.

a. Act in an advisory role to the UNU Programme,
b. Propose collaborative activities to the network members and other interested parties,
c. Prepare and develop a comprehensive research proposal for future collaborative activities,
d. Facilitate and assist in organization of workshops under the UNU Programme, and
e. Emphasize on activities related capacity building and public awareness.

The Global Environment Facility (GEF) was identified as a potential donor for this programme. In the process of proposal development, a Concept Paper for the programme will be developed and submitted to GEF. Based on the Concept Paper, Programme Development Funds will be sought for developing a detailed proposal.

UNU Network

It was agreed the Institut des Régions Arides (IRA), Médenine will serve as the regional focal point for the UNU Programme on Land Degradation in Dry Areas. The UNU network comprises Northern

Africa, Middle East, Central Asia and China. Based on its leading role in efforts to combat desertification and land degradation in the region, IRA can serve as a strong presence in the region. It will assist in developing and maintaining a regional network of researchers and scientists through information dissemination and collaborative activities. IRA will also provide a strong linkage to the other components of the UNU network.

Workshop Programme
18 – 22 October 1999
Médenine, Tunisia

Water Management in Arid Zones

18 – 22 October, 1999 - Médenine, Tunisia

The United Nations University, Tokyo
The Institut des Régions Arides, Médenine

Workshop Programme

17 October

Arrival of Participants

18 October, Monday

8:30 – 9:00	Registration and Paper Submission
OPENING CEREMONY	
9:00 – 9:10	Welcome Remarks by Dr. Khatteli, Director General IRA
9:10 – 9:20	Speech by the Representative of the Ministry of Environment
9:20 – 9:30	Speech by Prof. Iwao Kobori, Programme Advisor UNU
9:30 – 9:40	Speech by H.E. Prof. Mohamed Ben Ahmed (State Secretary for Scientific Research and Technology)
9:40 – 10:30	Introduction of Participants
10:30 – 11:00	*Coffee Break*
11:00 – 12:30	Visit to IRA, Médenine
12:30 – 14.00	*Lunch*
14:00 – 19:00	Field Trip Matmata / Douz

(*Overnight stay at Douz*)

19 October, Tuesday

8:30 – 12:30	Continental Oasis Douz / Kébili
12:30 – 14:00	*Lunch*
14:00 – 17:00	Coastal Oasis Gabès
17:00 – 18:00	Travel Back to Médenine

20 October, Wednesday

Technical Session 1 – WATER MANAGEMENT IN ARID LANDS

Session Chair: Prof. van Ginkel, Dr. Houcine Khatteli

8:30 – 8:40	Welcome Remarks by Prof. Hans van Ginkel, Rector UNU
8:40 – 9:05	Facing the Challenge of Water Resource Sustainability in Arid Lands – The Role of Network Development and South-South Collaboration (Zafar Adeel)

9:05 – 9:30	Global Environment Facility - Opportunities for Combatting Desertification (Nora Berrahmouni)
9:30 – 9:55	Integrated and Sustainable Management of Water Resources of the Niger River Basin in the Sahel Area (Dieudonné Goudou)
9:55 – 10:30	**Discussion on Technical Session 1**
10:30 – 10:50	*Coffee Break*

Technical Session 2 – REGIONAL APPROACHES TO WATER MANAGEMENT

Session Chair: Prof. Iwao Kobori, Dr. Theib Oweis

10:50 – 11:15	Water Management Problems in the Arid Zones of the Former USSR and Russia (Genady N. Golubev)
11:15 – 11:40	Water Use and Management in Arid Zones of China (Wang Tao and Wu Wei)
11:40 – 12:05	Water Management in the Arid Zones of Pakistan: Issues and Options (Munir Ahmad) – *Not presented*
12:05 – 14:00	*Lunch*
14:00 – 14:25	Irrigation in Arid and Semi-Arid Zones of Iran: Present Status Challenges and Suggestions (Hamid Siadat)
14:25 – 14:50	The Tunisian Experience in Soil and Water Conservation (Habib Farhat)
14:50 – 15:15	Water Management in Uzbekistan – Utilization and Protection of Water Resources (Vladimir Savello)
15:15 – 15:40	ICARDA's Experience in Water Harvesting in the WANA Region (Theib Oweis)
15:40 – 16:20	**Discussion on Technical Session 2**
16:20 – 16:40	*Coffee Break*

Technical Session 3A – MANAGEMENT OF GROUNDWATER RESOURCES IN ARID LANDS

Session Chair:	Dr. Mohamed Ennabli, Prof. Ismail El-Bagoury
16:40 – 17:05	Environmental Impact Assessment and Remediation of Groundwater Mining in Northern Libya (Saad A. Alghariani)
17:05 – 17:30	Management of Water Resources Aquifers in the Northern Sahara (Ahmed Mamou)
17:30 – 17:55	Withdrawal Impacts on Piezometric and Chemical Characteristics of Ground Water in the Arid Regions of Tunisia: The Case of Zeuss-Koutine Water Table (Houcine Yahyaoui and Mohamed Ouessar)
17:55 – 18:20	Groundwater Utilization and Management in the State of Kuwait (Fawzia Mohammed Al-Ruwaih)

21 October, Thursday

Technical Session 3B – MANAGEMENT OF GROUNDWATER RESOURCES IN ARID LANDS

8:30 – 8:55	Management of Fossil Water Tables in the Arid Zones (Mohamed Ennabli)
8:55 – 9:20	Water Retention Characteristics of a Calcareous Soil from Iran: An Ecologically Significant Property (Sayyed Ahang Kowsar)
9:20 – 9:45	Evaluation of unisolated oases in Algeria and Sahara (Abderrahmane Benkhalifa and Iwao Kobori)
9:45 – 10:10	Seawater Intrusion into the Gaza Coastal Aquifer as an Example for Water and Environment Inter-Linked Actions (Shaul Sorek, V. Borisov and A. Yakirevitch) – *Not presented*
10:10 – 10:40	**Discussion on Technical Session 3**
10:40 – 11:00	*Coffee Break*

Technical Session 4 – INNOVATIVE TECHNIQUES IN WATER MANAGEMENT

Session Chair:	Dr. Genady Golubev, Dr. Ahmed Mamou
11:00 – 11:25	Wastewater Reuse in Water Planning and Management in Arid Area of Tunisia (Rachid Boukchina and Noureddine Nasr)
11:25 – 11:50	New Techniques and Methods for the Control and Valuation of the Runoff Water in Arid Regions (Chehbani Bellachheb)
11:50 – 12:15	A Decision-Making Tool for Optimizing Water Allocation and Management in the Arid Regions: A Multiobjective and Compromise Programming Model Applied in the Oasis Production Systems of Nefzaoua, Tunisia (Mongi Sghaier)
12:15 – 14:00	*Lunch*
14:00 – 14:25	Farming Systems for Efficient Water Management in Arid Zones (Ismail H. El-Bagouri)
14:25 – 14:50	Crop Water Requirement for Water Resources Management in the Arid Regions (Nétij Ben Mechlia)
14:50 – 15:15	Effects of Geothermal Water on Quality of Tomatoes Cultivated in the South of Tunisia (Mansour Haddad)
15:15 – 15:45	**Discussion on Technical Session 4**

FIELD TRIP & RECEPTION

16:00-19:00	Field Trip to Koutine / Béni Khédache
19:30-22:00	*Cultural Dinner*

22 October, Friday

Panel Discussion

Session Chair:	Dr. Houcine Khatteli, Dr. Zafar Adeel, Prof. Noureddine Akrimi
Panelists:	*All participants*
9:00 – 9:30	Recap of Technical Sessions
9:30 – 10:30	Panel Discussion on Key Findings
10:30 – 11:00	*Coffee Break*
11:00 – 12:00	Formulation of Recommendations

Closing Ceremony

12:00 – 13:00	Closing Remarks by Organizers
13:00 – 15:00	*Lunch*
15:00 –	Afternoon in Jerba / Departure

List of Participants

Dr. Zafar ADEEL
Academic Programme Officer
Environment and Sustainable Development
The United Nations University Headquarters
53-70, Jingumae 5-chome
Shibuya-ku, Tokyo 150-8925, Japan
Tel: (+81-03)3499-2811
Fax: (+81-03)3499-2828
Email: Adeel@hq.un.edu

Mr. Ashraf Omer AFANEH
P.O. Box 25 Salfit, West Bank, Palestine
Tel: 972-2-298-1495
Fax: 972-2-298-1494

Prof. Saad A. ALGHARIANI
P.O. Box 91176, Dat Al-Imad
Tripoli, Libya
Tel: 218-21-3338400
Fax: 218-21-3607154

Prof. Fawzia AL-RUWAIH
Head, Geology Dept. Kuwait University
P.O. Box 5969, Safar – 13060,
State of Kuwait
Tel: 965-4810481
Fax: 965-4816487
Email: fawzia@kuc01.kuniv.edu.kw

Dr. Abderrahmane BENKHALIFA
Unite de Recherches sur les Zones Arides (WRZA)
Universite des Sciences et de Technologie Houari Boumediene – USHB
B.P. 44 Alger Gare, Alger 16000, Algeria
Tel: 213-2-64-5670
Fax: 213-2-64-9283
Email: Benkalifa@hotmail.com

Mr. Netij BEN MECHLIA
Institut National Agronomique de Tunis (INAT)
43 Avenue Charles Nicolle

Tunis, Tunisia
Fax: 216 1 795 008

Ms. Nora BERRAHMOUNI
Sustainable Development Advisor
UNDP – Algeria
Tel: 213-2-691212 (ex:234)
Fax: 213-2-692-355
Email: Nora.Berrahmouni@undp.org

Mr. Rachid BOUKCHINA
Institut des Regions Arides (IRA)
Nahal 6051 Gabès, Tunisia
Email: Habib.jeder@ira.rnrt.tn

Mr. Bellechheb CHEHBANI
Institut des Régions Arides (IRA)
4119 – Médenine- TUNISIA
Tel: +216 5 633 005
Fax: +216 5 633 006

Mr. Goudou DIEUDONNE
President
Energy and Environment for Rural development
P.O. Box 12418, Niamey, Niger
Tel: 227-73-2313
Fax: 227-73-7511
Email: kandadji@intnet.ne or ccfn4@ccfn.ne

Mohamed ENNABLI
Director General
Institut Nation de Recherche Scientifique et
Technique (INRST)
BP 95 – Hammam Lif
Tunis, Tunisia
Fax: 216 1 430 934

Mr. Habib FARHAT
Director, Direction de Conservation
des Eaux et des sols
Ministere de l'Agriculture
30 Rue Alian Savary
1002 Tunis Belvédère, Tunisia
Tel: 216 1 287 192
Fax: 216 1 891 516

Prof. Genady N. GOLUBEV
Moscow State University
Faculty of Geography,
Dept. of World Physical Geography and Geoecology
119899 Moscow, Russian Federation
Tel: 7-095-939-3842
Fax: 7-095-932-8836
Email: ggolubev@mtu-net.ru

Mr. Mansour HADDAD
Institut des Regions Arides (IRA)
Nahal 6051 Gabès, Tunisia
Email: Habib.jeder@ira.rnrt.tn

Mr. Ali HAMDANE
Direction Denerale de Genie Rural
Ministrere de l'Agriculture
30 Rue Rue Alian Savary
Tunis, Tunisia

Mr. Mouldi KARDOUS
Institut des Régions Arides (IRA)
4119 – Médenine- TUNISIA
Tel: +216 5 633 005
Fax: +216 5 633 006

Dr. Houcine KHATTELI
Director General
Institut des Régions Arides (IRA)
4119 – Médenine- TUNISIA
Tel: +216 5 633 005

Fax: +216 5 633 006
Email : Houcine.khatteli@ira.rnrt.tn

Prof. Iwao KOBORI
Programme Advisor
Environment and Sustainable Development
The United Nations University Headquarters
53-70, Jingumae 5-chome
Shibuya-ku, Tokyo 150-8925, Japan
Tel: (+81-03)3499-2811
Fax: (+81-03)3499-2828
Email: Kobori@hq.un.edu

Prof. Sayyed Ahang KOWSAR
Senior Research Scientist
Fars Research Center for Natural Resources and Animal Husbandry
P.O. Box 71365-458, Shiraz, Iran
Tel: 98-71-52450
Fax: 98-71-705107
Email: nafissis@pearl.sums.ac.ir

Ahmed MAMMOU
Direction Generale des Ressources en Eaux
43 Rue de la Mannoubia
1008 Tunis, Tunisia
Fax: 216 1 391 549

Mr. Kamel NAGAZ
Institut des Régions Arides (IRA)
4119 – Médenine- TUNISIA
Tel: +216 5 633 005
Fax: +216 5 633 006

Noureddine NASR
Institut des Regions Arides (IRA)
Nahal 6051 Gabès, Tunisia
Email: Habib.jeder@ira.rnrt.tn

Mr. Rachid OUAHMED
UNESCO
B.P. 363 Tunis Belvedere

1002 Tunis, Tunisia
Tel: 216-1-790947
Fax: 216-1-791588

Mr. Mohamed OUESSAR
Institut des Régions Arides (IRA)
4119 – Médenine- TUNISIA
Tel: +216 5 633 005
Fax: +216 5 633 006
Email : Houcine.khatteli@ira.rnrt.tn

Dr. Theib OWEIS
International Center for Agricultural Research in the Dry Areas (ICARDA)
P.O. Box 5466, Aleppo, Syria
Tel: (963-21) 221-3433
Fax: (963-21) 221-3490
Email: icarda@cgiar.org

Abderrazak ROMDHANE
Institut des Regions Arides (IRA)
Nahal 6051 Gabès, Tunisia
Email: Habib.jeder@ira.rnrt.tn

Mr. Vladimir SAVELLO
Chief of Water and Land Resources Protection
State Committee for Nature Protection
Republic of Uzbekistan
Tel: 998-712-410-422
Fax: 998-712-413-990
Email: prognoz@ecoinf.org.uz

Mr. Mongi SGHAIER
Institut des Régions Arides (IRA)
4119 – Médenine- TUNISIA
Tel: +216 5 633 005
Fax: +216 5 633 006

Dr. Hamid SIADAT
Soil and Water Research Institute,
Jalal-al-Ahmad Avenue, Tehran, Iran

Tel: 98-21-464-0228
Fax: 98-21-63-4006
Email: swri@sinasoft.net or siadath@hotmail.com

Mr. Houcine TAAMALLAH
Institut des Régions Arides (IRA)
4119 – Médenine- TUNISIA
Tel: +216 5 633 005
Fax: +216 5 633 006

Dr. Wang TAO
Director, Institute of Desert Research
Chinese Academy of Sciences, Lanzhou, 730000
People's Republic of China
Tel: 86-931-8839197
Fax: 86-931-8883209
Email: wangtao@ns.lzb.ac.cn

Mr. Mohamed THABET
Institut des Régions Arides (IRA)
4119 – Médenine- TUNISIA
Tel: +216 5 633 005
Fax: +216 5 633 006

Mohsen ZAIRI
Institut National en Genie Rural, des Eaux et des Forets
BP 2 2080 Ariana
Tunis, Tunisia