Water Benchmarks of CWANA project

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Characteristics of Benchmark Research Agroecosystems in WANA: Rainfed, Irrigated, and Marginal Drylands

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ICARDA

International Center for Agricultural Research in the Dry Areas

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Foreword

Water scarcity is a growing concern in West Asia and North Africa (WANA), threatening economic development and stability in many parts of the region. Rapidly growing demand for water in other sectors is causing a re-allocation from agriculture, which currently accounts for over 75% of total water consumption. There are no new sources of water since river systems suitable for large-scale irrigation have already been developed. Groundwater sources are over-exploited, while other renewable sources are either costly or environmentally not friendly.

A large proportion of the region's agricultural production is based on dryland farming systems, which are dependent on low and extremely variable rainfall. The challenge is to enhance productivity by improving on-farm water-use efficiency and supplementing rainfall through water harvesting or better utilization of renewable water sources. However, conventional water management practices, applied under normal water supply conditions, are not suitable under conditions of water scarcity. In the WANA region, there is a need for special management, to maximize the returns from each unit of water available for agriculture.

Technologies are available for improved management of scarce water resources; but adoption is poor because farmers feel these technologies are not feasible. Low adoption is due to several technical, socioeconomic and policy constraints, and, most importantly, the lack of community participation in the development of the technologies.

The Water Benchmarks Project in CWANA is based on community participation in research, development, testing, and adaptation of improved water management options at the farm level. The project focuses on the best opportunities and potential for immediate impact on agricultural productivity, resource conservation and livelihoods in areas where water is most scarce.

Benchmark sites were established in three distinct agroecological areas: steppe (*badia*), rainfed, and irrigated sites. Water use is studied at different levels: household, community, watershed, and policy. A multidisciplinary approach is used, to understand the current situation and develop and test water use efficient technologies under farm conditions.

This report was written in close cooperation with national agricultural research systems (NARS) at the benchmark sites. The six background papers provide valuable information on socioeconomics, natural resources and national development strategies in each benchmark country, and identify gaps that need to be addressed in the future. The synthesis paper will help understand the intricacies of the water benchmarks of CWANA, selecting and characterizing benchmark sites, and establishing baseline databases.

Acknowledgments

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Chapter 1

Integrated Research Benchmarking

1.1 Integrated Research Benchmark Sites: ICARDA's Approach to Technology Development and Dissemination

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Background

ICARDA and its partners in the National Agricultural Research Systems (NARS) have fully committed themselves to tackle the challenges of dry-area agriculture through research and capacity building. These challenges include converging trends of:

- Scarce and variable water resources.
- Increasing desertification and loss of biodiversity.
- Increasing out-migration of adult males, resulting in the loss of traditional farming systems and greater reliance on women as heads of households.
- High population growth rate and pockets of poverty.
- Increasing dependence of countries on food imports.
- Poor access to international markets as a result of trade policies and subsidies.
- Increasing degradation and pollution of soil and water resources.

Conventional research approaches are not well equipped to address poverty and sustainability, because the often single-disciplinary, single-scale focus fails to deal with the complexity of natural resource management, human behavior, and policy issues. Furthermore, the demand for research is increasing, while budgets and resources are declining. More efficient ways must be adopted to conduct research and outscale the results.

To deal with the multi-faceted problems of rural poverty, ICARDA has joined other CGIAR centers in developing an integrated natural resource management (INRM) approach. To contribute to the CGIAR goals on poverty, food security, and resource sustainability, INRM strategies must be easily transferable to and applicable at other sites. In turn, this requires selection of representative sites that resemble the broader agroecological zone of interest and represent the major agricultural, environmental, and human elements. These sites were subject to research benchmarking by ICARDA and NARS partners. The benchmark sites are used to develop, test, adapt, and evaluate improved genetic and natural resources management practices and technologies under "real life" conditions, not in research stations. INRM involves multiple stakeholders: farmers, research and extension agencies, and policy makers work together to address the:

- Gap between research and development.
- Non-linear social processes of rural development.
- Development of better monitoring and evaluation methods.
- Representation of a range of biophysical and socioeconomic conditions.

Malano and Burton (2001) defined benchmarking as a systematic process for securing continual improvement through comparison with relevant and achievable internal or external norms and standards. Essentially, it involves learning, sharing information, and adopting best practices. They described six stages of the benchmarking process: identification and planning, data collection, analysis, integration, action, and monitoring and evaluation.

Selection of Benchmark Sites

The choice of a benchmark site is always a compromise between being truly representative of all the major problems and trends; and logistical considerations such as accessibility, availability of partners, similarity of edapho-climatic factors, representativeness of the predominant production systems, policy considerations, etc. In all cases, however, we study the potential of scaling out the results at national, regional, and international levels. This analysis is done using GIS-based agroecological characterization, similarity analysis, and simulation modeling.

A first approach for testing representativeness and possible out-scaling of best-bet options is to quantify climatic similarity. The value of a climatic parameter or index at one location (the 'match' location) is compared with other ('target') locations using simple distance functions for monthly temperature and precipitation between match and target locations (De Pauw, 2003). Socioeconomic conditions are approximated by assessing similarity in land use or land cover as a proxy for farming systems.

A more comprehensive approach to out-scaling is to classify areas into agroecological zones (AEZ). An internal study by the ICARDA GIS Unit indicates that the Central and West Asia and North Africa (CWANA) and the northern Mediterranean regions can be subdivided into 677 agroecological zones, using climate, land use/land cover, terrain, and soils as the differentiating criteria. Out-scaling from the benchmark site to 'similar' environments is then simply a matter of 'rounding up' the AEZs inside the benchmark site and locating the areas (in CWANA or other dryland areas) where the same AEZs exist. This approach has the advantage of incorporating the most relevant biophysical factors for land management but is in a way more restrictive than the approach based on similarity mapping. This is because it is based on 'homogeneity' rather than 'similarity' and, therefore, the biophysical environments will match in fewer areas.

Ideally, out-scaling requires knowledge about both the biophysical and socioeconomic environments. Another major bottleneck is the characterization and mapping of farming systems as an entry point to livelihood systems. A first attempt at mapping farming systems at the global level (Dixon *et al*., 2000) is spatially too tentative for use at the regional scale. Now that the biophysical environments are well characterized and mapped in CWANA, ICARDA is trying to identify and map major typologies of farming systems and their relationship to livelihood systems.

Developing baseline data on livelihoods

One objective of benchmarking is to improve the relevance of research and ultimately improve rural livelihoods and the environment. This requires an in-depth understanding of rural livelihoods in terms of assets (human, natural, physical, social, and financial), using the sustainable livelihood framework. Establishment of baseline data on the livelihoods of rural households provides the means to assess the impact of research on poverty and environment. ICARDA has developed a framework for such analysis as part of the benchmark model (La Rovere *et al*., 2006). The livelihood analysis is now being carried out as an integral component of the benchmark model in different agroecological and resource endowment conditions, to draw lessons for dry-area development worldwide.

Transferring the results (out-scaling)

Theoretically, research findings and technologies developed and tested at a given benchmark site should apply to the entire

AEZ as well as similar AEZs in other regions and countries (i.e., target sites). The identification of distinct AEZs and subsequent selection of benchmarks within each zone eliminates the need to conduct research at multiple sites. This saves cost, labor, and time while increasing the likelihood of successful adoption. Benchmark sites and their research teams serve as a hub for capacity building and technology development and transfer. Exchange of farmers and researchers helps transfer improved technologies and policy recommendations to the wider dry areas.

ICARDA's Major Integrated Benchmark Sites

The water benchmark sites of WANA

Perhaps ICARDA's best known benchmark project on water management is the Water Benchmarks of West Asia and North Africa (WANA). This project explicitly defines benchmark sites for water management research across WANA and works with communities and NARS partners to develop, test and adapt improved water management options at the farm, irrigation scheme, and watershed levels. Taking into consideration the different agro-ecologies and levels of water scarcity in the region, benchmark sites were established in Jordan, Morocco, and Egypt to represent the marginal drylands with range-livestock system, the rainfed environment, and the conventional fully irrigated environment, respectively.

The benchmark sites represent the majority of the conditions in the three agro-ecologies, but some conditions and issues related to the natural resources, environment and/or socioeconomics in the region cannot be fully represented by the benchmark sites; they need to be addressed at other locations. Examples of such issues include policies, institutions, and socioeconomics. Therefore, specific research associated with these conditions and issues is conducted at satellite sites. Most important, satellite sites offer immediate validation for any new practices and technologies identified at the corresponding benchmark sites. Research results and experiences are exchanged between the benchmark and satellite sites. The satellite sites also provide an avenue for the transfer of technologies from the benchmark sites and enhance the regional dimension of the project.

Three major benchmarks were developed based on the agroecological zoning of WANA: the steppe, rainfed, and irrigated areas.

The steppe (badia)[1] benchmark

The steppe (*badia*) represents the drier environments of WANA, excluding the desert areas. These marginal areas are home to a substantial proportion of the region's rural and poorest populations. Water is the over-riding constraint; the low and highly variable rainfall is often inadequate for economic crop production. Rainfall distribution is highly erratic both within and between years; and occurs mostly in sporadic, intense and unpredictable storms, usually on crusting soils with low infiltration rates, thus resulting in surface runoff and uncontrolled rill and gully water flow. Thus, much of the limited rainfall is lost directly through either evaporation from the soil surface or run-off, which, if not intercepted collects in *wadis* or pans. As a result the greater part of the precipitation is lost to the atmosphere through evaporation. The land is degraded by erosion and the vegetation, except in areas where rainwater collects, is depleted and subjected to severe water stress.

There is a need for interventions to halt or reverse land degradation and improve the productivity and livelihoods of rural communities in these vast areas.

1. Badia is the marginal rangeland located in dry environments, with annual rainfall of 100-250 mm.

Development investment in the steppe has been low compared to the number of households that depend on it, because of the limited resources and perceived lack of returns. Moreover, given the vulnerability and fragility of the natural resources, and in the absence of suitable development plans, national policies have tended to minimize intervention and disturbance to the existing system. Consequently, productivity remains low, degradation continues, and rural populations seek alternative income-earning opportunities elsewhere. Increasing migration from these areas creates additional economic and social pressures in urban areas, and can cause the collapse of traditional systems of land, water and vegetation management.

The challenge here is to enhance productivity and halt land degradation through improved management of natural resources, especially water. Water harvesting can increase water availability for plants through controlled concentration of runoff into target areas. It also controls soil erosion, reduces the impact of drought, and increases rainwater productivity.

The Muhareb watershed in the Jordan steppe is representative of the vast drier rangeland environments in WANA. Overgrazing and ensuing land degradation have prompted communities to integrate rainwater harvesting techniques into the dominant range-livestock system. The concept and process for site selection are fully described in *Badia Water Benchmark Site Selection and Characterization* published by ICARDA. The satellite sites for the steppe environments are located in Saudi Arabia and Libya. At both sites, the main objective is the introduction and adoption of water harvesting techniques appropriate to the physical and socioeconomic environment.

The rainfed benchmark

Most of the agricultural areas of WANA are rainfed and a large proportion of the region's agriculture is based on dryland farming. While irrigated areas may produce far higher yields and marketable surpluses, the overall value of dryland production is greater than its market value due to social and other indirect benefits associated with these systems. Rainfed production is dependent on rainfall and, therefore, productivity is low and unstable – and further affected by frequent droughts and continuing land degradation. Research has focused on how to improve water availability to crops in rainfed areas. Given the limited ability to utilize new sources of water in the region, a major challenge is to sustainably enhance productivity by improving the efficiency of on-farm use of the limited water available.

Research at ICARDA and other regional and national research institutes has led to the development of appropriate technologies and management options for increased water-use efficiency: crop and soil management practices, improved germplasm, and on-farm water management options. One option that could provide large productivity gains is the use of supplemental irrigation in rainfed crops if water is available for irrigation.

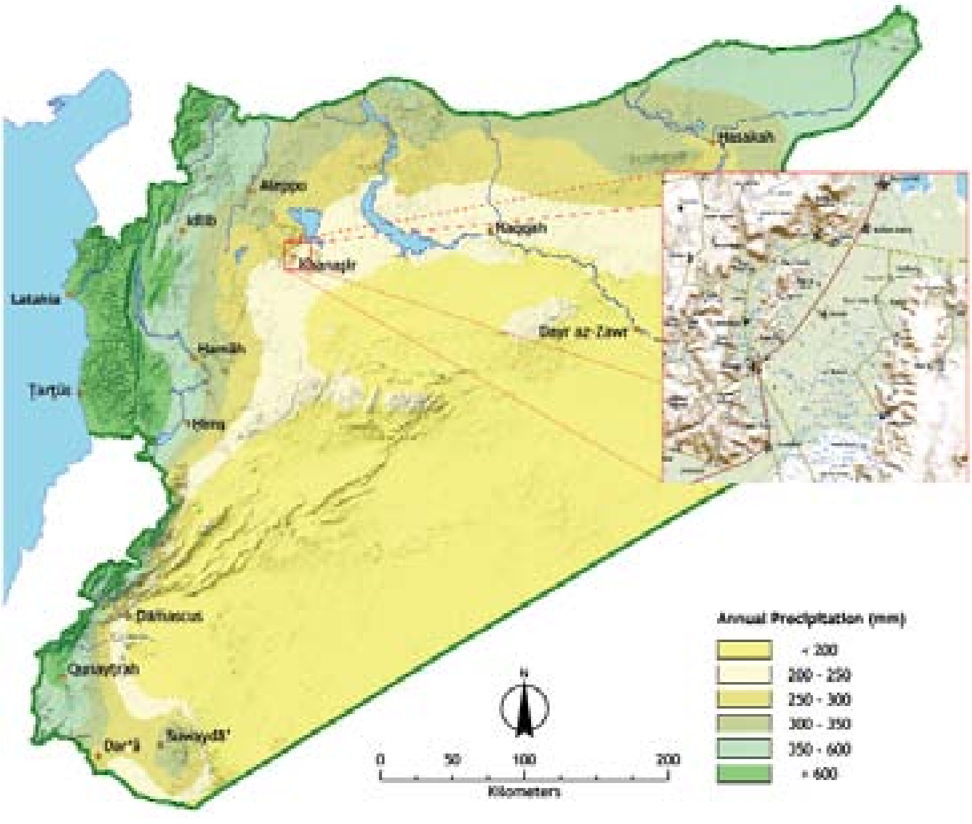
The Tadla basin in Morocco represents the rainfed agricultural systems in semi-arid regions with limited water resources. The water benchmark site was selected to optimize the use of limited surface and groundwater resources conjunctively with rainwater in supplemental irrigation systems. The benchmark site tries to improve water productivity at the field, farm, and basin levels. Satellite sites in rainfed environments are located in Algeria, Tunisia, and Syria, where socioeconomic conditions vary. Algeria represents the contribution of treated wastewater use in supplemental irrigation. In Tunisia, a model for optimal conjunctive use of rainwater and scarce water resources in supplemental irrigation is being developed. In Syria, the objective of the work is to measure the impact of supplemental irrigation on water resource sustainability and livelihoods in wheat production systems.

The irrigation benchmark

Fully irrigated areas in WANA are associated with the availability of surface water (e.g. rivers) and renewable groundwater resources. These irrigated areas provide most of the food in this region because irrigation permits more intensive agriculture. Recently, the demands of expanding populations have increased the pressure to increase output from these systems, threatening their sustainability. Lower quality water is being widely used without proper management, causing salinity and deterioration of the environment. The irrigated areas will continue to be vital in providing food security. To meet the increasing demands for food, many countries in the region are expanding their irrigated areas. However, with decreasing water resources for agriculture, the only water available for new lands is water that can be saved from irrigating old lands. Saving water in irrigated areas is a top priority almost everywhere in the world, but it is of particular importance in the dry areas where water scarcity is extreme and increasing.

There are two components of water saving in irrigated agriculture: (i) reducing water losses at the farm level by improving irrigation efficiencies, (ii) increasing water productivity at the farm, field, and basin levels.

The Nile valley is the largest intensively irrigated area in the region. Egypt is expanding its irrigated areas while its water resources are not increasing. This excessive pressure and changing land use is a threat to sustainability. Benchmark irrigation communities were selected within the fertile lands of the delta, the new lands, and saline areas in Egypt. The benchmark site was selected to study, at the community level, how to sustain high water productivity under the three situations. Each sub-site

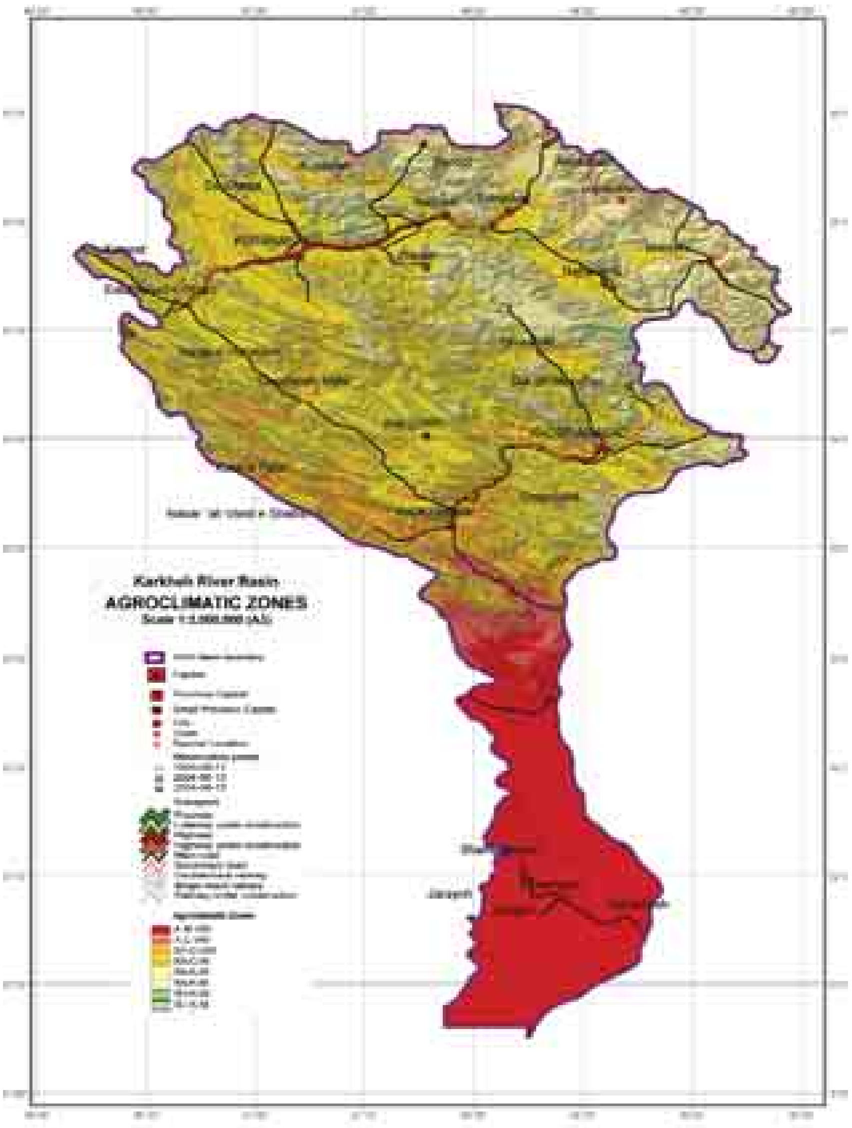


Map 1.1.1. Khanasser vally site in Syria

was selected along a canal with varying upstream-downstream socioeconomic and biophysical conditions. The water user associations' policy links are important components of this site. The satellite sites to address different policy and socioeconomic conditions are located in Iraq and Sudan, which represent the two other major irrigated areas in the region. Research at both sites aims to assess the actual water productivity and determine the sources of inefficiency in these environments.

Khanasser Valley integrated site

Khanasser Valley in Syria (Map 1.1.1), was selected by ICARDA as an integrated research site to address problems typical of marginal dryland environments in Central and West Asia and North Africa (CWANA). These problems include diverse



Map 1.1.2. Karkheh river basin site in Iran

and dynamic livelihoods, natural resources degradation, poverty, erratic and low rainfall, and limited water resources. Research at this site highlighted the importance of combining (i) a rapid assessment of farmers' livelihoods and the capacity of the natural resource base, (ii) testing of technologies that generate impact even in the short term, (iii) long-term strategic research and monitoring. Several technologies were tested and improved with the farming communities and in cooperation with selected NARS partners – participatory barley breeding, cumin management, vetch varieties and management, phosphogypsum use, *Atriplex*-barley alley-cropping, water harvesting and saving technologies for olive trees, and improved feeding for sheep fattening systems. A further study assessed the potential of establishing small low-cost dams to improve the water supply, as current pumping rates exceed the annual groundwater recharge potential (Thomas *et al.,* 2006). Policy recommendations for the sustainable agricultural development of marginal dry areas were developed and discussed through a series of stakeholder and policy meetings.

Karkheh river basin benchmark site

Other integrated benchmark research sites have been established within the Challenge Program on Water and Food in the Karkheh River Basin in Iran (Map 1.1.2). Honam and Merek, two watersheds in the upper catchments, represent the prevailing rainfed crop, range, and forest environments with different water resources for supplemental irrigation. Two sites have been identified in the downstream irrigated environment, one representing farm communities with access to fresh water for irrigation from the irrigation network and wells, and the other with different levels of salinity and waterlogging. The benchmark site attempts to maximize water productivity at all scales from plant to basin, improve livelihood resilience of the communities, and ensure environmental sustainability by increasing productivity of the river basin.

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Chapter 2

The Steppe (Badia) Agroecosystem

2.1 Characteristics of the Steppe in WANA with an Emphasis on Jordan

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Introduction

The world's arid and semi-arid zones cover around 50 million km^2, which is 35% of the earth's land surface (Livingstone, 1985). The steppe *(badia)* is the arid and semi-arid zone of the Middle East. It receives low rainfall and is occupied by the Bedouin. It covers large parts of the region: around 80% of Jordan, 75% of Iraq, 90% of Saudi Arabia, and 55% of Syria (Alwelaie, 1985; Sankari, 1993). In this region, the steppe *(badia)* consists of two major areas, the steppe and the desert, based on rainfall and vegetation patterns. The steppe is considered to be the potential area for the provision of animal feed. It usually receives 100–200 mm average annual rainfall and provides good vegetation for grazing, whereas the desert receives less than 100 mm, and has limited grazing resources.

The steppe areas in the Arab countries are estimated at 510 million ha: 51 million ha (10%) in the Mashreq region (Iraq, Syria, Lebanon, Palestine and Jordan); 111 million ha (22%) in the Maghreb region (Mauritania, Morocco, Algeria, Tunisia and Libya); 146 million ha (29%) in the Arabian Peninsula region (Saudi Arabia, Kuwait, Qatar, Bahrain, UAE, Oman, and Yemen), and 201 million ha (39%) in the central region (Egypt, Sudan, Somalia and Djibouti).

The steppe is home to a substantial proportion of the region's rural and poorest populations, and shortage of water is a major constraint. Rainfall is low, highly erratic both within and between years, and inadequate for economic crop production. It falls on crusting soils with low infiltration rates, resulting in surface runoff and uncontrolled rill and gully water flow. Thus, much of the limited rainfall is lost either through direct evaporation from the soil surface or through run-off, which if not intercepted, collects in *wadis* or pans where it eventually evaporates. The result is land degradation caused by erosion, poor vegetation cover, and severe water stress.
The steppe includes substantial proportions of rangeland – uncultivated low-rainfall areas that are grazed by livestock. Because human activities are limited, these areas are sources of natural biodiversity (Abu-Zanat, 2001; Abu-Zanat et al., 1993; Ash-Shorbagy, 1993). Plant cover in the rangelands helps reduce water run-off and soil erosion, allows water and air to penetrate deeply into the soil, provides food and refuge for wild animals and domestic livestock, and acts as a buffer between the desert and the rural and urban areas.

The steppe has significant economic importance. For example, the Syrian steppe can provide feed to around ten million sheep for about 6-7 months of the year, while the Sudan rangelands can provide feed for 85 million sheep during the year (Assaad, 1993; Rahma, 1993). The Jordan steppe is capable of producing sufficient feed for around 800,000 sheep for the whole year (Al-Junaidi, 1996).

This report presents an assessment of the physical, agricultural, and socioeconomic characteristics of the steppe, with special attention on the rangelands.

Characteristics of the Steppe

The steppes in WANA countries have certain common characteristics. The following section provides information about the Jordan steppe, with supplementary information on Saudi Arabia, Syria, and Tunisia.

The Jordan steppe

The Jordan steppe is representative of the vast drier environments in WANA. Droughts and ensuing water shortages during the last decade have led to several initiatives to explore the possibility of using these marginal dry areas. The steppe covers approximately 72,000 km^2, which is 81% of Jordan's land area (Fig. 2.1.1).

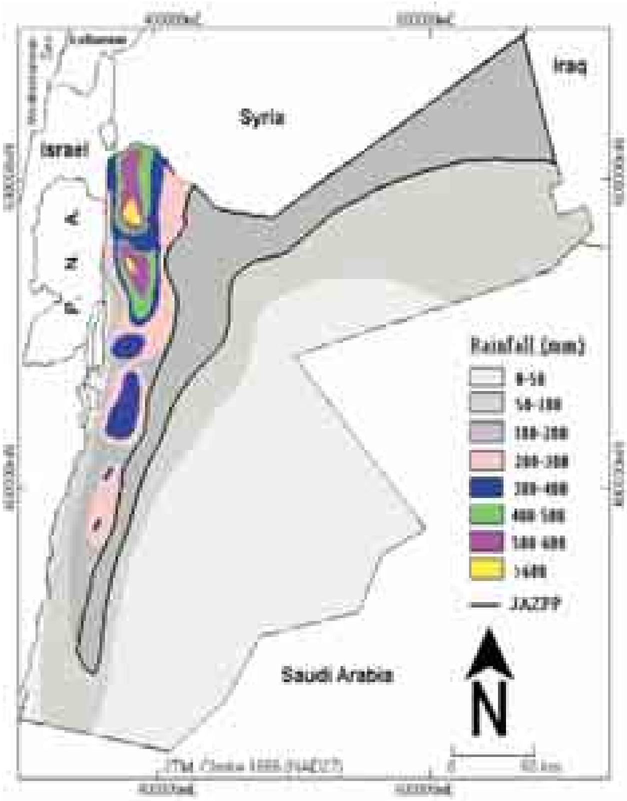

Figure 2.1.1. Rainfall isohyets in Jordan

The region is sub-divided into three geographical areas:
Northern steppe, 35% (25,930 km^2) of the total steppe.
Middle steppe, 13% of the total steppe.
Southern steppe, 51% of the total steppe.

The maximum annual rainfall is 200 mm and it is erratic. Air temperature fluctuates widely from a daily mean minimum of 10°C to a mean maximum of 24.5°C, giving a mean daily temperature of 17.5°C. Occasionally, the absolute minimum and maximum temperatures may reach –5 and 46°C, respectively (Allison *et al*., 1998).

The Jordan steppe holds numerous natural resources, including mineral deposits, surface and groundwater, renewable natural rangeland, and cultivated land suitable for agriculture and livestock production. Rangeland is the largest resource; potential pasture land covers a large proportion of the steppe, although the vegetation cover is not dense and surface water mostly absent. Barley is the main field crop in dryland farming. Irrigated forage, vegetables, and fruit orchards are located in the steppe. Around 70% of Jordan's livestock is produced in the steppe, including sheep, goats, cattle, camels, and poultry.

Population

Human population in the steppe (desert areas) is about 185,000 (roughly 98,000 men and 87,000 women), of whom 11% are nomadic and 89% transhumant herders. Average family size is 6.87 for nomadic herders and 7.27 for the transhumant population (Nesheiwat, 1995). The population is distributed among 16 major tribes as shown in Table 2.1.1 (FAO, 1994).

More than 85% of the steppe population is accommodated in areas with well established basic infrastructure such as roads, water, electricity, and telephones. More than 88% of the population has access roads and more than 72% have post offices equipped with telecommunication systems.

Nesheiwat (1995) identified 170 communities in the steppe: 71 in the north, 48 in the middle, and 51 in the south of Jordan. Table 2.1.2 summarizes regional variations in population and livestock ownership.

Socio-economic conditions and trends

It is difficult to classify the rangeland users into groups, partly due to their heterogeneous nature and lack of data. The most comprehensive socioeconomic survey of rangeland users (IFAD, 1995) was based on interviews with owners of at least 50 animals and excludes flocks of less than 30. The reason is that smaller flocks have less impact on rangelands and the income of these families does not generally depend on livestock. The main results of the survey are as follows:

- There has been a major breakdown in traditional migration patterns in favor of opportunistic search for pasture.
- The traditional land tenure system has broken down, and in practice rangeland is available to those who can exploit it.
- Monetization of sheep production is leading to a stratification of herd ownership. Large-scale herd owners (>1000) can take advantage of scale economies and survive the removal of feed subsidies, whereas medium owners lack the resources to manage their herds without getting into debt.
- Very large herd owners in the steppe no longer use the rangeland as a source of feed, but as space to raise animals. There is little economic motivation to conserve the rangelands because feed supplements are provided for all but two months of the year when the natural vegetation can sustain the flock.
- Users of the rangelands do not take responsibility to maintain them. Despite poor rainfall, rangelands are cultivated with barley and other cereals.
- Radical de-stocking is not feasible; encouraging herd owners to switch to year-round feeding is recommended. This would have to be accompanied by a change in the nutrition of ruminants to compensate for the loss of roughage and minerals usually obtained from the range.

Table 2.1.1. Distribution of Bedouin tribes in Jordan

Northern Bedouins	Middle Bedouins	Southern Bedouins
Beni Hassan	Beni Sakr	Hweitat
Beni Khalid	K'abna	Sidien
Sierhan	Saleita	Hajaya
Jesa	Sherarat	Mannaien
Sardiyaj Tafih	Beni Ataye	
Jmiahn		

Source: FAO, 1994

Table 2.1.2. Population distribution in the Jordan steppe

Region	Total	%	No. of communities	Average community size	% of herd-owning families	% nomads
North	64,521	34.9	71	909	38	3.3
Middle	40,051	21.7	48	834	32	3.6
South	80,314	43.4	51	1575	66	4.8
Total	184,886	100	170	1088	48	11.0

Source: Nesheiwat, 1995

Relationship between poverty and environmental degradation

There is a positive correlation between poverty and environmental degradation. The poorer herders cannot afford to buy imported feed and, therefore, try to utilize as much forage from the rangeland as possible. Poverty seems to be an effect as well as a cause of rangeland degradation – as available natural forage decreases each year, farmers are forced to buy more feed concentrates for their flocks. Therefore, they sell some of their flock and grow barley on the degraded land, hoping there will be sufficient rainfall to harvest a crop. Although the chances of a good harvest are low in most rangeland areas, farmers still take the risk to reduce expenditure on feed. The result is increased debt for the farmer (because of the investment in planting) and further degradation of the rangeland.

Physical characteristics

The following sections summarize the physical characteristics of the Jordan steppe, based on information from Allison et al. (1998), Al-Sirhan (1998), and IFAD(1993, 1997).

Climate

Jordan can be divided into four climatic zones:

- Jordan Valley and Southern Ghor: a narrow strip of land measuring 660 km2. It is about 400 m below sea level and stretches from the Tiberius lake in the north to the Gulf of Aqaba in the south.
- Highlands: a mountainous area adjacent to the Jordan Valley, which varies from 600 m to 1500 m above sea level.
- Eastern hills: an area to the east of the highlands, known for its relatively plain lands, with a gradual eastward slope.
- Eastern steppe: an area known for its dry climate.

The rainfall season is from October to May. Mean rainfall ranges from about 300 mm to less than 500 mm per year. The highest rainfall occurs on the highlands in a narrow belt lying east of the Dead Sea and extending north to the Syrian border. From the highlands and extending eastwards, the climate becomes increasingly arid.

Temperature and evaporation are high; the annual open-water surface evaporation is about 1600 mm for highland areas, increasing to about 2500 mm in the eastern desert. Evapotranspiration in barley is 300-500 mm per cropping season; there is usually severe soil moisture deficit in rangelands planted with barley, resulting in frequent crop failure or very low yields.

The steppe occupies around 91% of Jordan's land area (Table 2.1.3). About 12.4% (1.1 million ha) of the steppe receives 100-200 mm of rainfall annually and can be rehabilitated with agriculture practices that will help capture rainwater. The desert steppe has limited potential for agriculture except for wadis and flat beds where floodwater collects and can be used.

Table 2.1.3. Rainfall distribution in Jordan

Rainfall (mm/year)	Area (km^2)	% of total area
< 50	55,700	63.2
50-100	13,851	15.0
100-200	11,391	12.4
200-300	3948	4.3
300-400	1788	1.9
400-500	1253	1.3
>500	979	1.0

Soils

The soils in Jordan are typical of those in the dry Mediterranean climates. There are two soil moisture regimes, aridic and xeric. Aridic soils do not receive sufficient soil moisture for effective leaching.

Therefore, calcium often accumulates as a subsurface horizon and vegetative cover is usually sparse or absent. Xeric soils occur at higher altitudes than aridic soils; dense stands of Artemesia spp. often indicate the presence of xeric soils.
In southern Jordan, unconsolidated sand occurs in valleys formed from an extensive, dissected sandstone plateau. Highland soils lie east of the Dead Sea, where they continue northward as a narrow strip to the Syrian border. Although erosion prevents the accumulation of soil on the sloping lands, deep fertile deposits may occur in narrow valleys. Gully erosion is common where thin upland soils promote and concentrate runoff, which then flows as intermittent torrents onto valley lands. Swenne (1995) classified the rangeland soils in Jordan as presented in Table 2.1.4.

Soil erosion is increasing as mechanization and poor land management combine to expose large surfaces to rainfall, runoff, and wind. The current trend of privatizing land ownership and the laws that encourage tilling of lands unsuitable for agriculture are increasingly destroying Jordan's soil resources. These practices can cause severe yield loss; and even a complete loss of productive capacity in 20 years time. Although addition of fertilizers can partly compensate the loss in fertility, no measure can compensate the loss of moisture-holding capacity, which is associated with the loss of soil depth.

Wind erosion is high in Jordan's eastern lands. The wind is capable of detaching and moving soil 50-70% of the time and is calm only 20-30% of the time. Damage to soil due to wind erosion can be very high in long, level and uninterrupted surfaces. The combined effects of wind and water erosion can be devastating and need to be mediated through sound agricultural practices.

Water

Annual precipitation is approximately 8500 m3, 85-92% of which is lost through evaporation, 5-11% through infiltration, and 2-4% through surface runoff. The mean evapotranspiration rate of the received rainfall is 75% in the mountainous and 98% in the desert areas.

The drainage systems are subdivided into 15 major regions (Appendix Table 1). Other than basin delineation, little is known about the characteristics of each region. The factors that influence runoff and flood, including catchment size and shape, wadi channel patterns, and the nature of sediments within the wadis, are unknown.

The topography is gently undulating or flat. The basin divides are ambiguous and complicate the task of identifying contributing drainages. Intermittent storage, seepage, and evaporation losses in such areas can be high, with basins greater than 300 km2 often having runoff coefficients of 3-4%. Discharges are laden with sediments when they occur, and small impoundments may require special inlet controls to reduce the sediments.

Table 2.1.4. Classification of rangeland soils in Jordan

Region	Physiography	Dominant soil type
North-eastern plateau	Nearly level	Calciorthids
North-eastern basalt	Basalt hammada	Calciorthids
Eastern plateau	Sloping to undulating	Gypsiorthids
Jafr basin	Gently sloping	Calciorthids
Southern sandstone plateau	Dissected sandstone plateau	Torripsamments
Northern lava flows	Flat to gently sloping	Calciorthids
Highland plateau	Undulating to rolling	Calciorthids

Source: Swenne, 1995

Impoundments for supplying water to livestock should be developed as part of a comprehensive management plan, as the landform is suitable for efficient reservoir design only in areas adjacent to the highlands. The flat topography in the east permits structures only in the channel bed, with little hydraulic head available for the design of conveyances. Reservoirs are generally shallow with high evaporation rates, and the spillway requirements leave little height for dam embankment. Development of surface supplies requires a case-by-case feasibility study and an environmental impact assessment. Part of such assessment is an analysis of the damage to rangeland by the structure, its reservoir, quarry and construction camp, and the concentration of livestock around the reservoir. In most cases animal water requirements are better met by tapping groundwater.

Much of Jordan's exploited groundwater is from deep aquifers; large amounts are obtained from shallow unconfined sources only in Azraq (north). The groundwater abstractions in the east of Safawi (northeast) are low and no aquifer decline is evident. While boreholes in the eastern desert may penetrate up to 900 m of overburden, piezometric rise will bring water to about 150 m of the surface.

Groundwater exploitation in southern Jordan has made large-scale irrigation of vegetables, cereals, and other crops possible. The aquifer is about 1200 m thick with annual abstractions of about 60 m^3.The current plan is to supply potable water to Amman from the aquifer.

Vegetation

Most rangelands in Jordan have low-density vegetation with ephemeral annual plants typical of a Mediterranean climate with hot dry summers and cool wet winters. However, the central-eastern steppe and eastern steppe are an exception; they reflect the zone's semi-continental climate. Juneidi and Abu-Zanat (1993) summarized the features of the broad vegetation zones as follows.

Vegetation Zone 1: Located in the northeast, covers 67% of Jordan's land surface, ranges from 600 to 800 m above sea level. It contains *Anavsis articulate* (shrub), *Retama raetum* (shrub), Zilla spinosa (shrub), *Artemisia herba-alba* (shrub), and *Stipa* spp (annual and perennial grasses).

Vegetation Zone 2: Located in the southeast, covers 9% of the land surface, 800-1000 m above sea level. It contains *Aristida* spp. (perennial grasses), *Calligonum comosum* (shrub), Haloxylon persicum (shrub), *Haloxylon salicornicum* (shrub), and *Artemisa judica* (shrub).

Vegetation Zone 3: Constitutes the eastern escarpment of the Jordan Valley and covers 1% of Jordan's total land area. It is mountainous and ranges from 300 to 950 m above sea level. The common species include *Acacia tortilis* (shrub/tree), *Panicum turgidum* (grass), *Artemisia herba-alba* (shrub) and *Retama raetum* (shrub).

Vegetation Zone 4: Located in the southwest, covers 5% of Jordan, and is 300 m below sea level. The most common species include *Aristida* spp. (perennial grasses), *Retama raetum* (shrub), *Retama duriaei* (shrub), *Calligonum comosum* (shrub), *Zella spinosa* (shrub), *Haloxylon salicornicum* (shrub), and *Acacia tortilis* (shrub/tree).

Vegetation Zone 5: Located in central Jordan, it covers 7% of Jordan, and comprises extensive level to gently rolling plateaus with altitudes of 700-1200 m. The vegetation includes *Dactylis glomerata* (grass), *Phalaris tuberosa* (grass), *Hordeum bulbosum* (grass), *Poa bulbosa* (grass), *Poa sinacia* (grass), *Stipa lagascae* (grass), *Artemisia herba-alba* (shrub), and *Anabsis aphylla* (shrub).

Vegetation Zone 6: Located in the northeast, 650-800 m altitude, covers 4% of the total land surface. The landscape is level and covered with basalt Hamada. The vegetation includes *Artimesia herba-alba* (shrub), *Salsola rigida* (shrub), *Haloxylon articulatum* (shrub), *Poa sinicis* (grass), and *Achillea fragrantissima* (shrub).

Cope and El-Eisawi (1998) surveyed the steppe flora through the steppe research and development program, and found 322 species belonging to 46 vascular plant families. They considered their list exhaustive.

Rangeland types and areas

Statistics on land use in Jordan are incomplete and often contradictory. Data on the different classes of land use and their corresponding areas are presented in Table 2.1.5.

The rangeland area in Jordan varies from about 85% to 97% of the total area of the country. Assessments can be based either on land use (rangeland is the land actually being used for extensive grazing) or average rainfall (e.g., rangelands receive less than 200 mm, based on a 50-year average) (Table 2.1.6). Other factors that cause variation in the estimates are the progressive reduction of rangelands through the expansion of agriculture and building development, and the different remote sensing systems and seasons. The situation is further compounded by plowing rangeland in low-rainfall areas to: (i) grow grain barley if the season is exceptionally favorable, (ii) provide green forage, and (iii) entitle the occupier to permanent rights to the land.

Table 2.1.5. Land use in Jordan

Purpose	Area (ha)	% of total
Rangeland	8,644,816	96.9
Horticultural crops	119,594	1.34
Cereal and forage crops	84,445	0.95
Forest	71,745	0.80

Source: IFAD, 1993

Table 2.1.6. Rainfall in different rangeland areas

Rangeland	Rainfall (mm)	Area ('000 ha)	% of total
Highlands	>200	200	2.5
Steppe	100–200	1000	11.5
Steppe (*badia*)	<100	7100	82
Total		8300	100

Source: IFAD, 1996

The net effect of the expansion of cropland is that grazing is becoming more restricted to the poorer lands. Productive rangeland with high-quality natural forage is being replaced with low-quality agricultural land that produces poor quality crop residues.

Present contribution from rangelands

There is currently no balance between the livestock and available rangeland resources. Therefore, any intervention effort must address the issue of balance. This imbalance is manifested in the:

- Rapidly degrading rangeland, which in some areas is irreversible.
- Increasing number of livestock.
- Decline in the productivity of livestock.
- Decline in the welfare of the poorer rangeland users.

Table 2.1.7. Main sources of livestock feed

Feed source	Area (million ha)	% of area	% of dry matter supply
Steppe (badia)	7.10	82	18
Steppe	1.00	12	7
Highlands and forests	0.24	3	8
Forage crops	0.14	2	3
Crop residues	0.16	2	11
Local grain and bran	–	–	4
Imported grain and bran	–	–	49
Total	8.48	100	100

Source: MoA Seminar September 1996

Rangeland reserves and productivity

Rangeland improvement through the establishment of reserves has been undertaken in Jordan since the late 1940s. There are 35 rangeland grazing reserves on about 84,000 ha, which accounts for only 1% of the total rangeland area. However, these reserves were established in areas with more fertile soils, and their productivity increases when grazing is controlled (Table 2.1.8).

The Ministry of Agriculture (MoA) manages about 30% of the reserves, while the Jordan Cooperative Corporation (JCC), previously Jordan Cooperative Organization, manages the rest. The reserves are usually open to local grazers once or twice a year for a nominal fee of 3 cents per day per head of grazing small ruminant, for a short period. Reserves that are under the control of JCC, where the local community has some degree of management control, appear to be the better regulated. For future rangeland rehabilitation and development programs, there is a need to consider the impact of reserves and apply the lessons learned from range reservation to the open range.

Jordan's rangelands have been overgrazed for many years. Apart from the long-term effect of range degradation, the immediate effect of overgrazing is the excessive removal of vegetative herbs and shrubs. There is reduced seeding and fewer prospects for regeneration, resulting in the loss of biomass, which in turn reduces range capacity for vegetative production in the following year. The species composition and quality will also change.

The productivity of individual plants, the total rangeland yield, and the carrying capacity of rangelands are progressively declining. The advanced stage of degradation and the pressure on rangelands will not allow re-establishment of pseudo-climax stages of the vegetation in the short- or medium-term. Therefore, range rehabilitation should involve the restoration of plant biomass to the optimum level. Once this is achieved, grazing should be controlled to increase and preserve annual biomass production. This will reduce pressure on rangeland plants and gradually restore the 'capital base'.

Property rights in rangeland areas

The property rights and production strategies developed by tribal communities in response to high environmental variability are very important. What users can or cannot do will affect the allocation and use of resources, because resource conservation and management are directly linked to the benefits of rights holders. The production strategies are individual and community responses to demographic, environmental, economic and politic pressures affecting their production system and livelihood.

There are three types of rangeland resources rights in Jordan – individual, tribal, and state –each of which offers different opportunities and constraints for access to and use of resources. Livestock production in the rangelands is based on feed resources obtained from individual crop fields, tribal pastures, state lands (forests, range and range reserves), and land and feed markets. Secured tenure rights are related to registered use rights granted by the state (miri) and private property rights (mulk). Holders of these freehold property rights have full control over their land resources.

Table 2.1.8. Annual forage production from open and protected rangelands (kg of dry matter/ha) in normal years

Rangeland type	Rainfall	Open rangeland	Reserved rangeland
Steppe (badia)	<100 mm	40	150
Steppe	100-200 mm	100	450

Source: Jordan Ministry of Agriculture

Miri rights are the dominant land rights in the low-rainfall areas. A study conducted by the Jordanian property rights team in collaboration with ICARDA and IFPRI, found that *miri* rights accounted for 91.7% and *mulk* rights 8.3% of all agricultural land in 14 villages. The predominance of *miri* rights is a result of the government's policy to settle traditionally nomadic and transhumant communities. There was a progressive decrease in the average size of landholdings from north to south. The highest average size of *miri* plots (11.2 ha) was reported in the north, while the highest average size of *mulk* plots was in the middle region. The south had the lowest *miri* and *mulk* plot sizes.

Secured access rights are agricultural use rights or grazing rights granted to community members on collective land, pasture, and water resources. The role of tribal authorities in regulating access and use of these resources was crucial in the past. Three main factors negatively affected the management of common tribal pastures: (i) sedentarization policies of pastoral communities, (ii) the possibility for community members to informally appropriate pasturelands through development, (iii) state claims over tribal pastures. Sedentarization and land appropriation affect the size of the tribal pasturelands and alienate the best lands located in areas with better rainfall, while state claims reduce the effectiveness of tribal institutions to control and manage tribal pastures.

Pastoral communities informally claim common tribal rights and enjoy free access to natural resources located in their pasturelands. They have the same rights of access and use regardless of the number of animals each person holds. However, community claims are only on settled areas of the rangelands, while the state asserts ownership of unsettled areas regardless of customary tribal claims (Nesheiwat, 1995). State claims over rangelands have changed the traditional welfare system, causing a breakdown in the mechanisms for resource allocation and transforming secured access rights into secured tenure rights. Consequently, customary management rules can often not be enforced.

State appropriation does not prevent local communities from accessing their traditional pastures, but favors open access to rangeland resources and expansion of barley cultivation. Tribal leaders and community members argued that it was against Islamic tradition to prevent anyone from accessing pastures and water. However, failure to recognize the superiority of legal and institutional rights over their customary rights has prevented them from controlling access to resources. State appropriation therefore impedes their ability to set rules for access to their pastures.

Livestock

Livestock holdings are decreasing. Since August 1996, when government removed feed subsidies, many farmers have sold some of their animals to buy feed, while others who had additional sources of livelihood disposed of their entire flocks. More livestock owners now have other sources of income. This led to a 25% reduction in livestock holdings between 1996 and 2000 (Table 2.1.9), and a decrease in the price of animals.

A survey by IFAD (1995) found that 97% of respondents owned very small sheep flocks, which they maintained domestically (Table 2.1.10). Flock size distribution was

Table 2.1.9. Livestock holdings in Jordan, 1991-2000

Year	Sheep	Goats	Total
1991	2524	881	3405
1992	2524	881	3405
1993	2878	1115	3993
1994	2211	786	2979
1995	2182	821	3003
1996	2375	784	3159
1997	2144	782	2926
1998	1935	624	2559
1999	1581	615	2196
2000	1933	419	2352

Source: Jordan Agriculture Strategy, 2002

Table 2.1.10. Relationship between sheep flock size and average rainfall

Average rainfall (mm)	Average flock size
National	297
<100	467
100-200	241
>200	182

Source: IFAD 1995.

inversely proportional to the average annual rainfall. The Research and Development Program (BRDP, 1996) reported a median holding of 250 in the *badia* steppe. A minimum flock size of 100 was considered adequate to maintain a family that has no supplementary source of livelihood. However, the minimum viable flock size today is greater than 500, because of the absence of feed subsidies.

National Institutions and Projects Working on Badia Improvement in Jordan

Ministry of Agriculture: Institutional responsibility for rangelands lies with the Ministry of Agriculture. Prior to the mid-1980s there was a Department of Steppe (badia) Development, which is now the Directorate of Rangeland. The Directorate's mandate is to develop (government) range reserves.

Institutions: Many organizations, agencies, departments, and NGOs are involved in different aspects of rangeland rehabilitation and development. Some of them collaborate with each other while others pursue separate agendas. The institutions include:

- Directorate of Rangelands
- Department of Forestry – Soil and Land Use Division
- Department of Agriculture Economics and Policy – Monitoring and Evaluation Division
- Department of Livestock Production
- Veterinary Department
- National Centre for Agricultural Research and Technology Transfer
- Ministry of Planning – Department of Statistics
- General Corporation for Environmental Protection
- Department of Lands and Surveys
- Jordan Cooperative Corporation
- Royal Jordanian Geographic Centre
- Higher Council for Science and Technology – Badia Research and Development Program
- Royal Society for the Conservation of Nature
- Queen Alia Fund
- Noor Al-Hussain Fund
- University of Jordan
- ICARDA
- Canadian International Development Agency (CIDA).

There are some overlaps in the functions and activities of these institutions, but the Directorate of Rangelands is responsible for preventing duplication of activities at all levels.

Other programs and projects: Many of the institutions listed have past and ongoing projects on rangelands and livestock. These include:

- Support for Participatory Land Development, a new project by the World Food Program (WFP). About 10% of the budget is to develop rangeland in the highlands.
- IFAD-funded Income Diversification Project, which focuses on small-scale livestock keepers in the highlands.
- The Badia Research and Development Program (BRDP) of the Higher Council for Science and Technology is implementing an applied research project at the Safawi Field Centre (<100 mm rainfall). Attention is on livestock research, soils and rangelands analysis, socioeconomic and anthropological research, information management, and GIS documentation.
- EU-funded Jordan Arid Zone Productivity Project (JAZPP), managed

by the University of Jordan in the 100-200 mm rainfall steppe zone. The research focus is integrated livestock production, increasing rangeland productivity, and establishing a GIS system and a natural resource database.

- ICARDA and IFAD support the Mashreq/Maghreb project on technology development and transfer in the barley/sheep zone, rangeland use and degradation, and property rights in the rangelands. The work is regionally focused, bringing a wider perspective to the prevailing issues. It is being coordinated by NCARTT and MOA.
- The Jordan Society for Desertification Control and Badia Development (JSDCBD), an NGO, is conducting research on the causes and impacts of desertification. The aim is to educate the public on the need to protect their natural environment. The government has commissioned JSDCBD to collate all existing data and reports on rangeland and prepare a national database of information.
- GTZ was involved in the Agricultural Extension and Promotion of Production Project to promote an extension policy aimed at improving the capacity and number of field extension staff.
- GTZ and WFP are supporting the Watershed Management Project in Karak Governorate, which is testing participatory approaches to planning and conservation with local communities.
- CIDA is implementing a Rangeland Management Project jointly with RSCN and MOA. One objective is to develop a sustainable rangeland management system based on the participatory approach to planning with local communities. It is located in and around the Dana Nature Reserve.
- The Queen Alia Fund (QAF) has an extensive network of well-trained staff who can use participatory methods and implement community-based projects. It has 11 main and 36 satellite centers, and a training center for training of trainers in local group formation and self-help participation.
- Noor Al-Hussein Foundation (NHF) is a national NGO that aims to identify and meet specific development needs. Although its focus is not rangeland problems, its extension staff are experienced in participatory planning methods.

The Egypt Steppe

The steppe area in Egypt that has an agricultural potential is concentrated in the northwest coast, extending about 500 km from Alexandria in the east to El-Salloum at the Libyan border in the west. It is bounded on the north by the Mediterranean Sea and on the south by the Great Sahara Desert, 50-80 km inland. However, most of the eastern part of the region (from Alexandria to Fuka) receives irrigation water from a Nile canal system, leaving the area extending some 300 km to the west as rainfed. This rainfed part of the region is the current geographic mandate of the Matrouh Resource Management Project (MRMP). The objective of the project is to intensify agricultural production in the western half of the northwest coast region, i.e. from Marsa Matrouh to the Libyan border in the west (MRMP, 1992).

Climate

The climate is arid Mediterranean, but the maritime influence of air moisture and temperature reduces the effects of drought and high radiation. The climate, however, gradually changes as one moves to the south, and merges into a Mediterranean Saharan climate about 40-50 km inland. Rainfall is only 100-150 mm per year along the coast, tends to decrease from east to west and decreases sharply inland. Average annual evaporation appears to be constant, about 1500 mm.

The air is humid, the mean annual relative humidity at noon being about 55%. Air temperature is mild, the mean annual maximum temperature is 25°C, and the mean annual minimum temperature is 15°C. The winds blow mostly from the north-west at 4-5 meters per second, with regular strong sandstorms in spring.

Water

The main source of water is the rainfall and its consequent *wadi* and sheet runoff. Runoff water is harvested with earthen, stone, and cemented dykes, while cisterns and water reservoirs are used to store water for domestic use and irrigation of tree plantations during the summer.

Groundwater suitable for agricultural and domestic use is available in relatively shallow non-artesian aquifers, which are recharged directly by rainfall and runoff infiltration. The water is obtained from galleries and some 360 wells, but productivity of the wells is low due to over-pumping.

Topography and land use

The coastal belt of alluvial soils is very narrow and irregular. A large area of gentle uniform slope extends to the Libyan plateau, south of the coastal belt. The area contains numerous *wadis* formed by runoff floods from the northward sloping plateau and eroded escarpment. There are about 216 such *wadis* with their watersheds within the targeted area of MRMP. Soil from the plateau and upper slopes of the *wadis* accumulates in the lower section, below the escarpment, forming localized areas of deep and relatively more fertile soil. There are four agroecological zones in the area.

- The narrow (about 5 km deep) coastal strip of good alluvial soils, covering an area of about 60,500 ha. Average annual rainfall varies from 100 to 170 mm, and the area is inhabited by communities that cultivate fruit trees and vegetables.
- A mixed production strip, 5-15 km inland, covering about 294,000 ha, with lower rainfall and low soil permeability. The inhabitants practice small ruminants-barley systems with horticulture in the *wadis*.
- A rangeland strip, 15-40 km inland, covering an area of about 294,000 ha, with lower rainfall (50-100 mm) than the mixed production strip. The population is semi-nomadic and the strip is largely used for small ruminant grazing, with scattered barley cultivation in land depressions.
- The open range area lies beyond 50 km inland, with an entirely nomadic population practicing only animal production, especially camels.

Soils

The Egypt steppe has limited soils suitable for agriculture; about 10% of the total area, mainly in the coastal belt, and in the transition zone up to the plateau. Generally, the soils are underlain by rock, which determines the soil depth. This rocky layer is very useful for water harvesting systems because it prevents deep percolation and loss of water stored in the soil. The five major types of soils identified are:

- Wind-blown soil, mostly range, barley, and/or orchards on limited deep soils, including the coastal and inland dunes.
- Soils of former beach plains and dune depressions, consisting of alluvial and colluvial materials. They are the most promising soils in the area and are suitable for all crops depending on the depth, except the saline portions of the soil.
- Soils of the elongated depression in the plateau, which are suitable for all crops except the saline and poorly drained parts.
- Soils of the alluvial fans and outwash plains, which are suitable for all crops depending on the depth.
- Soils of the *wadis*, which are suitable for all crops.

Vegetation

The natural vegetation consists of many species of annual plants, mostly herbs, and a few grasses and perennial plants, shrubs, sub-shrubs, and sub-trees. These represent 50% of the total flora of Egypt. The main plant associations in the coastal ridges are *Ammophila arenaria* and *Euphorbia paralias,* which form 75% of the total associations. A lesser association is *Crucianella maritime*. Uncultivated land is covered with natural perennial vegetation dominated by the association of *Thymelaea hirsute*, *Asphodelus microcarpus*, *Plantago albicans* and *Anabasis articulate*. The five predominant shrubs in the area are *Asphodelus microcarpus, Artemisia herba-alba, Thymelaea hirsute, Anabasis articulate* and *Thymus capitatus.*

Human population

The total population of the MRMP target area is around 200,000; 85% are Bedouin and the remaining are immigrants from the Nile Valley (or oasis inhabitants). This population is among the poorest and most deprived in Egypt; 70% of them depend on crop and livestock production, hence the government's commitment to improve their livelihoods. Some Bedouin live in urban areas, but the majority reside in permanent houses in dispersed rural settlements.

Land tenure

The steppe and desert lands belong to the government, but the traditional Bedouin practice was communal ownership. Individuals and households did not hold formal title to land. The government recognizes the *de facto* usufruct rights of established tribal territories. The desert Law 124 of 1958 and Law 100 of 1969 (MRMP 1992) allowed individual tribesmen to hold title over any land they cultivate, based on certain criteria. However, 88% of cultivated land in Matrouh Governorate is still held under traditional tenure without legal title. Furthermore, Law 17 of 1969 empowered the government to lease or sell state land to companies or individuals for projects considered to be in the national interest.

Individual land ownership is not practiced under the traditional system. Those who cultivate the land or habitually or traditionally use it have claims to it, but ownership is communal. The tribal territory in the target area is no longer communal or collectively cultivated by members of the tribes, except the southernmost parts of common range. Land has been allocated to individual tribesmen in such a way that each landholder knows the shape and boundaries of his share in the tribal area (the principle of *wada' el-yad*, literally meaning putting one's hand on). The land becomes the property of the person who has been using it continually and he has exclusive rights over it.

Communal grazing rights

In the Bedouin customs and tradition, communal land ownership means that the tribe and sub-tribe members have exclusive rights to graze their flocks on the area allocated to their tribe or sub-tribe. Members of other tribes are forbidden from grazing their animals there without prior permission. No traditional measures appear to be practiced within a sub-tribe territory, but grazing lands in the settled population zone are increasingly being allocated to individual families.

Water rights

Each tribe has its water sources and respects the territorial boundaries of others. Water rights and disputes are subject to tribal laws. Water trapped by small dikes and other water harvesting structures is used for agricultural production. A household in need of water for domestic purposes can use the nearest stored water regardless of whom it belongs to.

Livestock populations

Sheep, goats and camels are the main livestock using rangeland vegetations. A 1998 estimate puts their populations at 4,352,000 sheep, 3,261,000 goats, and 142,000 camels (AOAD, 1999).

Rainfed agriculture and farming systems

Only about 10% of the total area of the northwest coast zone (NWCZ) is suitable for cultivation. About 7% of the area covered by MRMP services is cultivated, 9% is fallowed, 48% is rangeland, and 36% barren land. Agriculture in most of the region depends entirely on rainfall, and cultivation relies on various forms of water harvesting. Resource (water and soil) development efforts by national authorities in the last few decades have helped transform the region from pastoral to a more sedentary agriculture. Several farming systems have evolved. However, this transformation was done without adequate technical support and has contributed to natural resource degradation (overgrazing).

Technological interventions

MRMP uses an integrated resource management approach, involving local communities, for improving rangeland, feed resources, and animal productivity. The project introduced income-generating activities such as planting of fruit trees and medicinal plants, food processing, and skills training for women. The water harvesting programs have helped improve the efficient use of both water and soil. They were implemented in three forms: (i) water storage in cisterns and concrete reservoirs, (ii) surface water distribution and spreading through earthen and stone dykes, (iii) cemented dykes across the bed of wide *wadis* to create, through sedimentation, terraces for tree plantation.

Saudi Arabian Rangelands

The *hema* system was used to control grazing of common rangelands in the Arabian Peninsula. Under the system, strict tribal principles were used to determine the extent of each tribe's reservation and the associated grazing rights and regulations. However, the system was abolished in 1953 for social and economic reasons. Since then Saudi citizens have been using the rangelands without restriction (Al-Shareef, 1998).

Because of the uncontrolled use, all the areas with suitable vegetation have been subjected to intense grazing pressures; livestock numbers have exceeded the optimum carrying capacity of the range. There were around 10 million head (Table 2.1.11) in 1992, but the number had exceeded 17 million by 1998: 10,341,000 sheep, 6,235,000 goats, and 796,000 camels (AOAD, 1999). Moreover, several dry cycles have occurred, causing an unprecedented level of deterioration. The result is that only 39% of the rangeland is now considered good to excellent (Table 2.1.12).

Table 2.1.11. Number of livestock in Saudi Arabia in 1992 (excluding cattle)

Type of animal	Traditional range	Specialized farm
Sheep	6,022,721	1,023,441
Goat	3,349,995	–
Camel	416,865	–
	9,789,581	1,023,441

Source: Ministry of Agriculture and Water, Saudi Arabia

Reserves

The Ministry of Agriculture and Water (MAW) established 35 reserves, ranging from 25 to 8700 ha, and the primary productivity and plant cover inside and outside the reserves were measured (Table 2.1.13).

Table 2.1.12. Rangeland condition and productivity in Saudi Arabia

Condition	% of total area	Total area (ha)	Average productivity (kg/DM/yr)*	Total production (DM/yr)*
Excellent	8	14,238,000	180	2,562,480
Good	31	52,545,000	120	6,305,400
Moderate	33	55,087,500	88	4,847,700
Poor	29	47,639,500	25	1,667,022
Total	100	169,510,000	–	15,382,602

Source: Ministry of Agriculture and Water, Saudi Arabia

**DM/yr = Dry matter per year*

Table 2.1.13. Average productivity, plant cover and density in some protected and open rangelands in Saudi Arabia

Year	Dry matter production (kg/ha/yr)		% plant cover		Density (plants/m^2)	
	Protected	**Open**	**Protected**	**Open**	**Protected**	**Open**
1984	26	68	1	3.9	0.07	0.46
1990	294	6.5	32	0.27	8.8	0.40

Source: Al-Shareef, 1998

Interventions

The MAW is primarily responsible for managing range resources. They have collected and analyzed basic data and rehabilitated degraded rangelands through re-seeding, adoption of specific protection measures, and improved use of rainwater. Re-seeding has resulted in a substantial increase in range productivity, ranging from 73 to 339 kg dry matter per ha per year compared to the previous average of 0-6.5 kg. Rangelands re-seeded with a mechanical seeder were better than those re-seeded manually, and seeding along contour lines was superior to pit seeding on flat plain with mild gradient.

Protection generally increased plant density and the frequency of key species. It also reduced wind erosion and runoff, indicating its effectiveness in reducing the rate of desertification.

Syrian Rangelands

The *badia* steppe land represents the driest agricultural area in Syria. It covers 10.2 million ha, and has less than 200 mm mean annual rainfall. The Syrian government has banned cultivation in this zone since late 1994, and range grazing is now the only permitted form of land use. By decree, these lands belong to the State, and there plans for massive range rehabilitation projects on millions of hectares (Nordblom *et al*., 1999).

Aridity is a common characteristic of the *badia* steppe, and it increases from west to east. Annual mean rainfall decreases from 200 to 125 mm also and is marked by a high inter- and intra-annual variability. Botanical studies suggest that the vegetation comprises mostly perennial shrubs such as *Artemisia herba-alba, Haloxylon articulatum,* and *Salsola vermiculata.* The vegetation is very poor; over 40% of the study area is sparsely vegetated, essentially with annual species. Certain eroded areas on decimated soils and calcareous crusts or gypseous slabs have no vegetation. Four different classes of vegetation were identified:

<u>Steppe dominated by halophyte species:</u> This vegetation type was the most densely vegetated, with high frequencies of peren-

nials and annuals, located in low-lying areas that receive runoff water. It contained halophytic species. The high vegetation density is due mainly to the planting of several thousand hectares of fodder species – *Atriplex,* or mainly *Artemisia.* The first range reserve was established in the late 1950s in Wadi al-Azib. Some 70,000 ha are currently under protection in Aleppo and Hama provinces.

<u>Steppe dominated by shrubs</u>: This vegetation type is characterized by the presence of perennial species, including shrub species like *Noaea mucronata, Haloxylon articulatum, Atriplex halimus, Atriplex canescens*, and *Artemisia herba-alba*, or herbaceous species like *Poa bulbosa*. There are two subtypes of vegetation cover based on the density and the soils and micro-topography influencing water availability.

<u>Degraded steppe</u>: The vegetation cover is usually temporary and essentially made up of low-density annual species. It depends greatly on the spatial distribution of rainfall. Perennial vegetation has almost completely disappeared from these very dry or highly eroded lands. They appear to have been heavily grazed or cultivated in the past but have now been abandoned.

<u>Areas with sporadic or no vegetation</u>: These areas are characterized by rocky outcrops of calcareous crust.

The steppe vegetation contributed about 70% of the total animal feed consumption in the 1960s in Aleppo province, but this fell to about 20% in the early 1990s. However, the data on which the 1960s estimate was based are not known and should be treated with caution. The estimate appears to be high for animals grazing in the steppe four to five months of the year. However, recent data indicate that the contribution of pasturelands to animal feeding is limited. Flocks feed mainly on barley grains and straw, and on concentrates made from cotton residues or sugar beet pulp (Debaine and Jaubert, 2002).

The small ruminant populations utilizing the steppe rangeland in Syria are about 15,425,000 sheep and 1,101,000 goats, in addition to 8,000 camels (AOAD, 1999).

Tunisian Rangelands

Rangelands constitute about one-third (5.5 out of 16.4 million ha) of the total land area in Tunisia and are located mainly in the central and southern regions. In recent years, rangelands in central and southern Tunisia have undergone remarkable changes following the privatization of rangelands, increasing human and livestock populations, and extension of agriculture into marginal areas. The contribution of rangelands to livestock feeding has decreased from 65% to 10%. Nomadic and semi-nomadic pastoral production systems are slowly disappearing, herd sizes are shrinking, and agro-pastoral systems are intensifying (Nefzaoui, 2000). The number of small ruminants in 1998 was about 6,544,000 sheep and 1,132,000 goats, in addition to 34,000 camels (AOAD, 1999).

Rangeland Management Systems and Institutions in Some WANA Countries

Rangeland management systems and institutions were similar in almost all the Arab countries; the *hema* system was most common. The system conserved resources and sustained their utilization all year around, but it collapsed when the State took over range management and declared rangeland areas State properties. Different political regimes developed different institutional arrangements for rangeland and *badia* steppe management. This section presents the findings of the Mashreq/Maghreb project in Jordan, Morocco, and Tunisia.

Jordan

Since 1980, the Jordanian government has been trying to organize pastoral communities into cooperatives and develop rangelands through the Jordan Cooperative Corporation (JCC). In addition, the Ministry of Agriculture is developing and managing range reserves. Under this system, specialists determine the grazing capacity and grant grazing licenses for a specified period and number of animals. New types of cooperatives have emerged in recent years, requesting the government to recognize their claims on traditional tribal pastures and subsequently engaging in the improvement of allocated areas (Roussan, 2000).

Four management options have been identified in Jordan: (i) private management, (ii) government reserves, (iii) herder-driven reserves (cooperatives), (iv) tribal management. Preliminary results of econometric analysis suggest that herder-driven cooperatives are the most efficient. Households spend 21% less on feed in the herder-driven cooperatives than the tribal managed pastures. Government reserves require 30% more feed expenditures than tribal managed pastures. These results are corroborated by data on range productivity and vegetation cover for the three management options. Feed production in the cooperative and government managed pastures exceeds that of the tribal system (which has degenerated into open access) by 124 kg/ha and 164 kg/ha, respectively. Although the differences in productivity between government reserves and herder-driven cooperatives are marginal, the latter may be more efficient in managing rangeland reserves because of the high transaction costs associated with fencing and guarding government reserves.

Morocco

A study by the Mashreq/Maghreb project (Herzenni, 2000), found that traditional institutions (*jmaas*) for managing rangelands have been disempowered in Morocco, and are no longer effective. Large areas are being appropriated and used for crop production, while the remaining rangelands are overexploited and degraded. The study covered three zones:

- The high plateau of the Eastern Atlas (or Oriental Atlas), where range cooperatives have been created according to tribal membership.
- The Middle Atlas, where traditional tribal rangeland management is reported to face severe difficulties.
- The Central High Atlas, where the tribal management system continues to play an important role in management of community pastures.

Except in the High Atlas, tribal management systems play a limited role in the management of community pastures. Many people in the Middle Atlas and Oriental Atlas, where cooperatives have been introduced, do not understand the functions of cooperatives, and there is a general tendency not to respect the rules governing the use of cooperative reserves.

Preliminary results of the econometric analysis suggest that households with access to tribal cooperatives and those with access and involvement in management of tribal pastures (*agdals* of the High Atlas) spend respectively 3.4% and 10% less on feed than households relying mainly on tribal non-improved (or unmanaged) pastures. In comparison, households using pastures under government management (Forest Services) spend 11% more on feed. These results suggest that the cooperative reserve could be an important option in the Oriental Atlas, where tribal management is eroding due to increasing sedentarization of pastoral households. Therefore, it is important to maintain the traditional management systems in the Central High Atlas, where they are being used to effectively manage access to and use of pastures. This does not mean that the Moroccan government should not intervene in the Central High Atlas, but they should improve the system without disrupting existing management institutions.

Tunisia

Four types of management regimes were identified in Tunisia (Nefzaoui, 2000).

- The tribal system, practiced in a majority of the ranges in southern Tunisia. The ranges have not been privatized but the weakening managerial role of tribal institutions has led to crop encroachment and appropriation of the best pastoral areas by agriculturalists. State development intervention in some of these areas includes the development of roads and watering points.
- The private system, which emerged from the privatization of tribal rangelands. The Pasture and Livestock Office (OEP), a government agency, is in charge of range improvement in these areas. The main problem is land fragmentation.
- The government sponsored cooperative system, which is relatively new and involves organizing pastoral communities and devolving range management to local communities. The World Food Program (WFP) cooperatives have not been successful because of the limited role played by cooperative members.
- The co-management system, practiced on the residual tribal pastures that have not been privatized in central Tunisia. Under this system, the community cedes control of overgrazed pastures to the Forest Services for improvement, The Forest Services charges grazing fees. The community may reclaim its rights once improvement costs have been fully recovered. The main problems with this option are strong state intervention and weak local participation.

An econometric analysis was conducted to evaluate the effects of range management options on total household feed expenditures. The preliminary results show that, compared with the tribal system, co-managed and privately managed reserves reduce household feed expenditures by 33% and 9%, respectively, while cooperative reserves increase household feed expenditures by 62%. These results reflect the changes occurring in rural Tunisia. The performance of the co-managed reserves depends on the management quality of the Forest Services and the ability of community members to pay for grazing or cutting forage. Co-management could be the best option for providing additional feed resources while also improving the resource base. However, these are only preliminary results and need further confirmation.

All the site studies, regardless of the type of management option, are experiencing similar problems: animal and human population pressures, scarcity of grazing resources, and weak participation of communities in the management of their common resources. In addition, there are differences between central and southern Tunisia because of the extent to which privatization policies have been implemented. In central Tunisia, where the privatization process is very advanced, major problems include unequal access to grazing resources, over-exploitation, and introduction of inappropriate technologies. The main problems in southern Tunisia, where tribal systems prevail, are poorly defined property rights and consequent land encroachments, and resource degradation.

Potential for Rangeland Improvement

Evidence suggests that previous work, which has concentrated on the establishment of range reserves, has had little demonstrable effect on improving rangeland conditions or providing a model for wider replication. Rangeland users do not see government controlled and managed grazing reserves as a solution to their problems. A top-down approach to planning and implementing rangeland development and livestock improvement in arid and semi-arid regions has failed to deliver the expected outputs. There is wide recognition today of the need to give local communities responsibility for the land on which they live and obtain a livelihood, and to give them control over common natural resources. Development efforts will be more successful if the intended beneficiaries are involved in making decisions that affect their livelihood. Genuine participation generates greater interest, thus producing greater impact and enhancing sustainability.

The problems of rangeland degradation are not technical, they relate to property rights, social organizations, and the behavior of rangeland users. The question is how best we can engage rangeland users constructively to improve their own economic well-being, in the context of environmental sustainability and biodiversity protection.

The Mashreq/Maghreb project conducted a study (Masri, 1997) to develop a proposal on participatory approach to rangeland development in Jordan. It presented ideas on how to implement a rangeland improvement project with the involvement of resource users, the conditions to be met, and actions to be taken by the government to ensure the success of such project. The proposal listed sites, communities, and activities to be covered in the project. It highlighted land tenure and the absence of land user associations as issues to be addressed.

There is a need for intervention in these extensive areas in order to halt or reverse land degradation and improve the productivity and livelihoods of rural communities. Due to limited resources and perceived lack of returns, investments in development in the steppe have been low in relation to the number of households that depend on it. Moreover, given the vulnerability and fragility of the natural resources, and in the absence of suitable development plans, national policies have being tailored towards minimizing intervention and disturbance to the existing system. Consequently, productivity remains low, degradation continues, and rural populations seek alternative income-earning opportunities elsewhere. Increasing migration from these areas creates additional economic and social pressures in urban areas, and can cause the collapse of traditional systems of land, water, and vegetation management, leading to further degradation of the steppe. The challenge here is to enhance productivity and halt land degradation in these areas through improved management of the natural resources, particularly the most limiting resource, water.

Technological solutions have been developed and tested in some WANA countries and found to be effective in the sustainable improvement of rangeland productivity and feed resources in dry areas. However, adoption of these technologies by land users and herders has been very low. This is because range rehabilitation and improvement is not a technical issue alone, it needs to also address policy and institutional issues in a holistic approach as indicated in the previous sections. Some of the promising technologies are summarized in the following section.

Water harvesting provides a means for making water more available to the plants. Through controlled concentration of runoff in target areas, it increases water availability to plants, controls soil erosion, reduces the impact of drought, and increases rainwater productivity. Various systems of water harvesting have been developed and used for centuries throughout the WANA region: *jessour* and *meskat* in Tunisia, *tabia* in Libya, *cisterns* in north Egypt, *hafaer* in Jordan, Syria and Sudan. Unfavorable socioeconomic conditions in recent decades have led to a decline in the maintenance and use of many of these systems, but as water scarcity in the dry areas increases, attention has focused on efforts to revive the use of these systems.

Examples of the successful use of new water harvesting systems include small basin micro-catchments that have supported almond trees for over 17 years in the Mwaqqar area of Jordan, where mean annual rainfall is 125 mm. The system has proved sustainable during several years of drought. In the same area, small and low-cost farm reservoirs used to store and release runoff water several times over the season provided enough water to support agricultural development.
Livestock (sheep and goats) is the principal economic output, and provides a large proportion of household income in the steppe. The establishment of fodder shrubs can provide a valuable feed source for rangeland-based livestock. In the Mehasseh area of the Syrian steppe, with average annual rainfall of 120 mm, the survival rate is less than 10% for rainfed shrubs but over 90% for those grown in micro-catchments. Shrub survival rate can be improved by 70-90% with the introduction of water harvesting technology (semi-circular bunds). In Mehasseh, shrubs were planted during a normal rainfall year, which was followed by three consecutive drought years.

In north-west Egypt, with average annual rainfall of 130 mm, small water harvesting basins with 200 m^2 catchments support olive trees. Harvesting rainwater from greenhouse roofs can provide about 50% of the water required by vegetables grown in the greenhouse.

These and many other examples show that it is possible to substantially increase the productivity of rainwater in the drier environments with appropriate water harvesting techniques. At the larger scale, remote sensing combined with ground information in a GIS framework has been used to identify suitable areas and appropriate methods for water harvesting. About 30-50% of the rainfall in these environments can be captured and utilized through water harvesting, thus improving rainwater use efficiency.

Successful and sustainable integration of water harvesting techniques within existing agricultural systems in the dry areas is not easy. Socioeconomic, technical, and policy factors must all be considered.

Experience in the Mashreq/Maghreb project indicates that working at community level accelerates the transfer of technology, because communities have an interest in solving their problems. Moreover, involving farmers in planning and implementation and integrating them into the researchers' and extension agents' group, facilitated dialog and identification of appropriate options.

Constraints to Rangeland Improvement, and Potential Solutions

Climate

The climatic constraints to livestock production in arid and semi-arid environments are enormous. These include irregular rainfall patterns that result in inadequate and unpredictable supply of forage and water. Shortage of water is a major problem that also limits opportunities for development and, therefore, hampers the change process.

Land tenure

The most important factor hindering the sustainable improvement of rangelands is land tenure. The absence of effective land users' rights and rules and the passive attitude of users to this problem is a major constraint to change. Most intervention efforts in rangeland management will most likely fail if this problem is not effectively resolved.

Economic factors

The BRDP reports that the minimum profit for a model Bedouin family is about 1500 JD per year. When the government was providing feed subsidy, this implied a minimum flock size of 100 sheep. With the removal of the subsidy, the profit per ewe has declined from about 14 JD to 3 JD, assuming the levels of grain feeding remains unchanged. However, there are immense opportunities to increase productivity and profit through technological improvement. The subsidy on feeds was a hindrance to the evolution and development of optimal rangeland use and a major contributing factor to degradation. Removal of the subsidy may lead to the re-establishment of a better balance between forage output and livestock populations. However, this will be possible only if other factors, such as transport subsidies, free access to watering facilities, price controls, and the distribution of benefits from livestock are reviewed.

Support services

Extension and veterinary services and training for farmers are generally weak in Jordan. There appears to be virtually no government extension service at the livestock owner's level, although some NGOs provide isolated services within their projects. There is an urgent need to train farmers in health care, nutrition and feeding, natural resources management, and animal management.

Constraints due to attitudes

Range users believe that rangeland management is the responsibility of the government; therefore, they are waiting for external interventions for a change. Intervention programs must encourage range users to take responsibility for managing these resources.

Constraints to technology adoption

Several technical issues need to be addressed, such as direct seeding of shrubs versus transplanting, selection of adapted native species for rangeland, and grazing management. However, other issues also hinder technology adoption by farmers and rangeland users. These include:

- Low priority for livestock extension.
- Rapid and sudden policy changes in some countries, which discourages livestock owners from investing in technologies that could improve animal productivity. These include policy changes on import-export and the movement of flocks across borders.
- Marketing problems, especially for milk produced in remote areas.
- Lack of credit facilities for limited investment in new technologies in some countries.
- Feed subsidies, which discourage farmers and sheep owners from adopting new technologies because feed is available to them at a price lower than the cost of its production.
- Problems of property rights in catchment areas and legal disputes on the utilization of water, especially in *wadis,* which run through a long strip of land (head and tail land owners).
- Inadequate characterization of soil profiles and the associated physical properties.
- Limited applicability of the results because of they are site-specific.
- Community approach to water collection and utilization, which may require special policy and other arrangements by government institutions.

Suggestions for improvement

The following recommendations may help alleviate the technical, policy and socioeconomic constraints to adoption of technology (Haddad, 1999).

- Government policies have resulted in inadequate long-term investments in arid and semi-arid areas and inadequate training for research and extension staff. There is a need for greater investment in research and extension to solve the existing problems and encourage adoption of improved technologies.
- Governments, research institutions, and donor agencies should consider the social and environmental benefits of developing these areas and allocate more resources towards this.
- Governments, policymakers, and donors should realize that time horizons for progress are generally longer in arid areas than in high-rainfall or irrigated agriculture.
- Government policies and programs should be linked to integrated production technologies rather than to single dryland and resource conservation practices.
- Feed subsidies should be lifted and replaced with a farmer support program.
- Low-rainfall, high-rainfall, and irrigated agricultural production programs should be planned and implemented as integrated complementary systems.
- There are limited cropping alternatives in low-rainfall system, hence the need to adopt a more productive cropping system and provide market alternatives.
- Crops and cropping systems should be diversified; cultivation of fruit trees and medicinal plants and the use of water harvesting and supplemental irrigation techniques should be introduced wherever possible. This will reduce risk and increase production and household income.
- Drought-tolerant crop species and varieties and improved livestock breeds should be developed.
- Property rights issues in the rangelands should be properly addressed to enhance technology transfer for rangeland improvement.
- Farmers and land users should be more involved in the development and transfer of technology.
- A network of national and international organizations interested in rangeland improvement should be established to facilitate the development, adaptation, and adoption of low-rainfall farming technologies.

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Appendix

Table 1. Drainage systems and surface water flow (million m^3/year) in Jordan

	Basin	Base flow	Flood flow	Spring flow	Total flow
1.	Yarmouk at Adasiya	130.00	155.00	21.40	285.00
2.	Ghor-Jordan valley	0.00	2.40	19.30	21.70
3.	N. Jordan river (side wadis)	36.07	13.91	48.63	49.98
4.	S. Jordan river (side wadis)	24.76	5.58	28.90	30.34
5.	Zarqa river	33.51	25.67	38.91	59.18
6.	Dead Sea	53.95	7.20	57.60	61.15
7.	Mujib	38.10	45.54	16.00	83.64
8.	Hasa	27.40	9.04	3.90	36.44
9.	N. Wadi Araba	8.99	2.57	15.63	18.20
10.	S. Wadi Araba	0.00	3.16	2.44	5.60
11.	Southern desert	0.00	2.15	0.05	2.20
12.	Azraq	0.00	26.80	0.60	27.40
13.	Sirhan	0.00	10.00	0.00	10.00
14.	Hammad	0.00	13.00	0.00	13.00
15.	Jafer	0.00	10.00	1.92	11.92
	Total	352.8	332.0	255.3	684.8

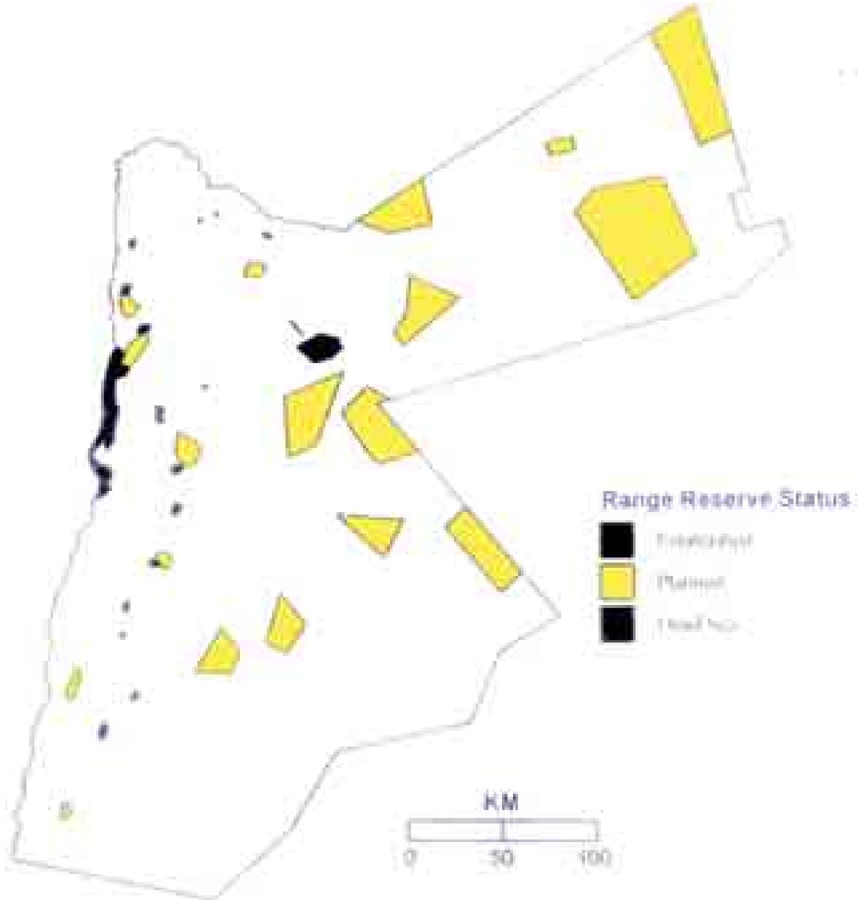

Figure 1. Rangeland reserves in Jordan

Table 2. Rangeland reserves in Jordan

District	Reserve name	Manager	Year of establishment	Area (ha)			Rainfall (mm)
				Total	%	Planted	
Mafraq	Khansary	MoA	1946	455		300	250
	Sorah	MoA	1946	396		300	180–200
	Sabha	MoA	1979	1054		900	150
				1905	2.8		
Amman	Dab'ah	MoA	1979	300		50	120
	Adasia	MoA	1983	2000		1200	200
				2300	3.4		
Zarqa	Wadi Botoom	MoA	1986	1500		100	75
	Desert Azraq	MoA	1987	30000		1000	65
				31500	46.4		
Karak	South Mojeb	MoA	1980	976		400	150
	Lajjoun	MoA	1981	1100		1100	150
	Nakhil	MoA/JCO	1983	1500		1500	
	Desertif.Proj.	MoA	1989	5000		100	120
				9276	13.7		
Tafilah	Towanah	MoA	1981	2000		1200	150
				2000	2.9		
Ma'an	Fujeej	MoA	1981	2000		1200	150
	Manshiah	MoA	1985	1000		400	200
	Manshiah	JCO	1982	300		140	
	Ashiah	MoA	1968	2000		750	100
	Rass Naqab	MoA	1986	1500		900	150
	Ail	JCO	1988	262		112	
	Qureen	JCO	1982	1500		731	
	Al-Moudaware	MoA		11200			50
				6862	10.1		
Ajloun	Rajeb	MoA		4500		600	200
				4500	6.6		
Balqqa	Aira	MoA	1986	2000		1200	200
	Al-Sahin	JCO	1992	2300		200	
				4300	6.3		
Madaba	Ma'in	MoA	1983	2000		1200	200
	Ma'in	JCO	1980	3500		3200	
	North Mojeb	MoA	1988	1500		500	150
	Thaiban	JCO	1980	375		210	
	Bani Hamida	JCO	1987	1500		470	
	Salia	JCO	1987	1500		300	
	Al-Faisalieh	MoA		2000			150–200
				10375	15.3		
			Total	67831		29.8	
			MoA	60281		29.1%	
			JCO	12737			

2.2 Strategy for Steppe Development in Jordan

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Introduction

The steppe refers to a region where Bedouins live. It is generally dry, but the severity of drought is not similar throughout the region. It occupies a transitional position between arid and semi-arid in some regions, e.g. Jordan and Syria. Steppe covers about 90% of Jordan and 55% of Syria. Although large parts of what is called steppe can be classified as desert, most people do not accept this definition, because they associate desert with sandy areas only. This is because during the last century, when animal population in the steppe was low, vegetation cover was better associated with more productive land than the desert.

As a result of increasing population, and limited availability of land in higher-rainfall areas, many countries are exploring unused resources in drier areas to increase food production and enhance livelihoods. The steppe is rich in agrobiodiversity, which can be used to develop improved crop varieties. Many of the plant species have medicinal value, providing opportunities for the development of pharmaceutical industries. Furthermore, the region has substantial arable land that is potentially useful for agricultural production. With the availability of improved and appropriate technologies, some of problems affecting the utilization of these resources can be overcome.

Technological interventions are needed now more than ever, for several reasons. There is need to improve the livelihood of growing populations while protecting natural resources from further degradation. There is also a need to create employment, contributing to economic growth and reducing pressure on resources in other areas.

Characteristics of the Steppe Region

Land resources

The steppe contains a unique mix of soil resources. Two major groups of soils have been identified.

Soils that were formed under dry climate
These are generally shallow, coarse textured, poorly fertile, and rich in salt, carbonate or gypsum. They are found along undulating or steep slopes and have poor surface properties and hence low water-holding capacity. Runoff is usually high, making them suitable for rainwater harvesting. Because these soils are found in depressions or flat lowlands they could be either saline or silty due to low rainfall and localized erosion.

Localized waterways flowing through relatively flat areas can develop deep soils with good properties, which is why these soils have the best vegetation cover in the dry region. These waterways, locally known as *marab,* constitute 10-14% of the land surface, and should be considered a priority for development. Waterways can also be found below recent wind or water sediments in the drier parts of the dry region. Therefore, the geomorphology of the region should be investigated to identify them.

Soils formed under past climate
These soils are found on flat topography and are deep with high clay content. Some of them may have silty and saline and/or sodic surfaces, or gypsum-rich sub-

surfaces. Because of the flat topography, such soils can be reclaimed for irrigated cultivation, but application of water harvesting techniques is not possible.

Water resources

Groundwater resources

The dry regions in some countries have significant groundwater resources, which are mostly used for domestic purposes. In recent times, these resources have been used for irrigation, causing them to be depleted and become saline. It is therefore necessary for countries in the dry regions to adopt strategies that will promote safe pumping to sustain water availability and quality.

Surface water resources

Most countries in the dry regions have no rivers, and where rivers are available they are used for irrigation. Rain is the main source of water, and it is usually low, highly variable, and falls in short but intensive thunderstorms. This causes floods that flow to depressions or low areas, where most of the water is lost through evaporation; little reaches the groundwater. About 85% of the rainwater is lost through evaporation. Water availability can be increased through water harvesting, to intercept the floodwater at suitable locations before it becomes unmanageable, or at locations where the topography is favorable.

Interception of floodwater has been practiced in the dry areas for many years, indicating that the technology is acceptable to local communities. This offers a good opportunity to examine the old practices, improve and expand them, and re-introduce them to communities.

Climate

Average annual rainfall in the steppe region is less than 200 mm. Rainfall varies significantly from one season to another but generally the rainfall season starts in November and ends by March. The rainfall is highly unpredictable, and drought is common. The steppe is dominated by flat or rather open topography, which provides favorable conditions for strong wind erosion. The temperature is high in some parts, where evaporation rates are among the highest in the world. There is usually a high variation in between day and night temperatures, with possibly freezing conditions at night for several days.

Therefore, there is a need to investigate the edaphic conditions associated with climate as one of the main problems affecting development efforts in the steppe.

Constraints to the Development of the Steppe

Poor soil

Soils of the steppe are either silty (with low water-holding capacity and surface crust, resulting in low infiltration rate) or deep clayey soils in flat areas. These soils may be saline or rich in gypsum or calcium carbonate. At some locations, gravelly soils with poor chemical and physical properties are dominant. The soils are mostly shallow, especially in areas with slopes higher than 5%. Therefore, the selection of an appropriate soil site is essential for any development efforts. Selection of specific landforms can serve as a guide for identifying sites for possible development.

Shortage of water resources

Shortage of water is a common characteristic of the steppe. Additional water resources must be developed after considering rainfall and surface runoff. Treated wastewater is a potential source of water, but there are concerns about the environmental impact of using such water to irrigate clayey or problematic soils. Nevertheless, the emergence of new urban centers in the steppe region may force people to use wastewater in the near future.

Increasing population

Human population in the steppe region is increasing, and migration to urban areas could become a serious problem. Local communities are finding it increasingly difficult to survive through agriculture alone. Agricultural development should therefore be integrated with other income-generating activities.

Local communities comprise large numbers of sheepherders who are highly mobile, especially during the grazing season. Such mobility can hinder the development of rangelands resources unless a participatory approach is used. Related issues include protection of targeted areas from migrant livestock.

Poorly defined land tenure system

Land tenure is poorly defined. For example, land is still being registered as government property in Syria and Jordan. Only recently was private ownership granted in some areas, where some land was allocated to tribes, mining companies, and for other private uses.

Unclear water rights

Water resources can be developed by intercepting floodwater either on-farm, or within waterways. Both methods can disrupt the natural flow of water and create two types of problems. First, development of the upland areas will reduce water flow downstream, thus affecting development in lowland areas. Issues of equitable water distribution within a selected watershed should be investigated before water harvesting projects are implemented. Second, the water rights of communities are not clearly defined, and this could be a serious problem when runoff water is intercepted within waterways.

Integrated and balanced distribution of water resources within a specific watershed are lacking in the dry parts of the northwestern costal zone in Egypt. This problem emerged after intensive water harvesting was implemented at the upper watershed, substantially reducing the amount of downstream floodwater reaching already established orchards, and forcing orchard owners to buy water. Further upstream development will further reduce downstream flow, possibly forcing some farmers to depend solely on purchased water.

Absence of land use maps

There are no proper soil maps for the steppe to determine the suitability of different soils for different purposes. This has contributed to improper selection of developmental sites and the failure of various range projects. Recently in Jordan, efforts were made to have local communities manage land for a certain period, after which ownership could be granted to organized groups such as cooperatives. This approach aimed to control grazing of degraded range and to protect range areas that are being developed.

Uncoordinated approach to development

Until recently, rangeland development efforts were uncoordinated and lacked clear objectives. In some cases, interventions were not based on the needs of local communities and their consent was not sought before implementation. Indigenous knowledge and skills on natural resource management were not properly documented. These have led to frequent project failures.

Strategies Adopted for Steppe Development

Many countries in the WANA region have recently prepared national strategies for steppe development. The strategies included characterization of available resources, assessment of prevailing problems, and exploiting opportunities through use of new technologies. Different countries used different approaches, because of differences in social and economic conditions and education levels.

The steppes are among the least developed areas in most countries, but they are rich in indigenous practices. Some of these practices are untapped or unknown, some are still practiced, others have been neglected or abandoned. Building on local knowledge and practices is important for the success of any development effort, because the technologies are suited to the respective environments, and acceptable to the local communities.

Development approaches in Jordan

Jordan has been making efforts to improve livelihoods among the steppe populations for many years. It adopted the National Policy Charter for integrated resources development in 1994 and treated the steppe as an independent sub-sector. The Charter was implemented partially before a new National Strategy for Agricultural Development was adopted in 2002. Preparation of the strategy followed a series of studies.

- The agricultural sector was divided into sub-sectors and the low-rainfall area was grouped with animal production.
- Steppe resources were investigated to understand the changes that have occurred during the last 25 years, trends and likely future changes, and the constraints to development. The focus was on farming systems in low-rainfall rainfed areas.
- Development targets were formulated taking into consideration inputs and achievable outputs, priorities, availability of legislation and other enabling environment.
- The strategy was based on key economic, environmental, and social parameters.

Accordingly, policies were formulated for steppe development. These policies were supported by specific action plans and projects, and measures to create an enabling environment for implementation. The strategy was based on several assumptions:

- Water shortage in Jordan is imminent; therefore, priority for groundwater use would be for domestic purposes.
- Interventions, e.g. range improvement or other management practices, will be based on site characteristics such as soil and topography.
- Range development (development and introduction of new plant varieties, and protection with community participation) will be a major target.
- Because of low and highly variable rainfall, integration with water harvesting technology is the only viable option for range development. Water harvesting techniques will be integrated with the production of crops that offer higher returns than the range.
- Integration of production practices utilizing water harvesting techniques will encourage adoption of improved animal husbandry practices.
- Specific landforms within the steppe, such as mud flat and waterways provide opportunities for water harvesting and will be given priority in development.
- Old water harvesting practices suitable for development, and will be rehabilitated and re-introduced.
- Drought preparedness strategy, based on water harvesting, will be a major component of development plans for dry areas.

Policy objectives and measures

The following are examples of policies formulated, and the specific projects/measures that have been proposed as part of policy implementation.

Policy 1: Protection of range areas, controlled grazing, improvement of range productivity.

Measures
- Updating legislation on land tenure and rangeland utilization by land users.
- Improvement and monitoring of rangeland to reduce degradation.

Policy 2: Establish land use allocation according to productivity, giving priority to developing areas with high range production potential and considering water harvesting technologies as an integral part of any suggested development.

Measures
- Preparation of soil maps.
- Development of a database using modern technology.
- Diversification of production systems using water harvesting, based on a watershed management approach.
- Development of local range communities after considering socioeconomic characteristics, distribution, and movements patterns.

Policy 3: Integrated development of range areas with the involvement of local communities.

Measures
- Evaluation of land resources to identify promising areas.
- Development of watersheds using water harvesting and integrated development, to ensure production diversification based on well-defined priorities.
- Intensification of construction of water storage facilities or cisterns to be used as strategic reserves to reduce the impact of drought and for irrigating trees.
- Mapping the location of *wadis* covered with recent sediments, since these are promising areas.

Policy 4: Protection of plant biodiversity and utilization, using different production systems; establishment of additional range reserve areas.

Measures
- Collection, characterization, and ex-*situ* conservation of plants.
- Use of local plant species in range development programs.
- *In-situ* conservation programs in collaboration with local communities.
- Establish range reserves on public lands, to be managed with local communities.

Policy 5: Development of range production systems integrated with water harvesting practices.

Measures
- Enforcing the use of water harvesting techniques in government-funded projects, as a condition for funding.
- Provision of soft loans for water harvesting structures, for rangeland development and livestock watering.

Policy 6: Monitor ecological changes and combat desertification.

Measures
- Hydrological studies to determine water availability in promising areas, especially areas suitable for water harvesting.
- Construction of small earth dams for fodder production and livestock watering in areas with rainfall >100 mm.
- Development of waterways (*marab*) with suitable crops.
- Rehabilitation of rangelands close to local communities with their participation.
- Preparation of drought emergency utilities to reduce the impact of drought.
- Introduction of fodder crops.
- Integrating cactus into range production systems.
- Monitoring land degradation and

plant cover, especially in promising areas.
- Evaluating environmental changes to determine the impact of alternative production systems on land resources.
- Assessing land, water, and vegetation degradation.
- Establishing a monitoring program for vegetation cover and biodiversity to identify promising plant varieties.

Policy 7: Develop and introduce animal feed resources and improve their quality.

Measures
- Integrating new fodder species such as Cactus, *Acacia* and *Atriplex* with suitable water harvesting techniques.
- Developing areas adjacent to depressions and waterways.
- Constructing small earth dams in promising areas, for fodder production or drinking water for animals.
- Developing waterways using range or fodder shrubs.
- Rehabilitating and expanding old water harvesting structures.
- Using plant byproducts as animal feed.
- Expanding the use of treated wastewater in feed production.

Policy 8: Support integration between plant and animal production systems.

Measures
- Development, control, and protection of rangeland.
- Production of animal feed using treated wastewater.
- Promoting the use of cactus as fences to provide green fodder or animal feed.

Strategy for development in the dry central area of Egypt

Sustainable resource management for rainfed agriculture in the northwest Coastal zone of Egypt was directed at areas with low rainfall. Average annual rainfall along the coast, and up to about 20 km inland, ranges from 100 mm in the west to170 mm in the east. Beyond the 20 km limit, rainfall drops by almost half. Research in this region was essentially development-oriented and conducted on farmers' fields with the participation of local communities.

The strategy integrated socioeconomic issues and the major constraints such as availability of natural resources, poor farming practices, and non-adoption of water harvesting technologies. Due to climatic variations and frequent drought, the strategy focused on integrating water harvesting techniques with various farming systems, and on diversifying farming practices to mitigating drought impacts. It emphasized better integration between agriculture and other sectors, and community involvement in management of natural resources.

This approach aimed to:
- Reduce poverty, meet basic domestic needs and reduce poverty-induced over-utilization of resources.
- Sensitize institutions and government departments to the needs and concerns of the Bedouin.
- Mobilize the local population for sustainable resource management existing mechanisms of community action.

The following criteria were used to identify priority projects:

Natural resource conservation
Management and utilization efficiency was considered as the most important. Projects were evaluated in relation to the (i) urgency of the problem (extent of degradation), (ii) contribution to conservation of the resource base, including the extent and value of resources, and/or improvement in the efficiency of resource use, (iii) contribution of conserved resources to the sustainability of future production.

Productivity and income enhancement
Projects were evaluated in relation to the (i) yield gains, reduction of production cost, increase in production stability, quality enhancement, and value addition, (ii) probability of achieving planned outputs, and time needed, (iii) potential for adoption.

Poverty alleviation was a key criterion. Projects were weighed according to the (i) contribution to increasing the income of poor households, (ii) applicability to low-potential environments, (iii) expected impact on vulnerable groups, particularly women and children.

Integration, linkages and participation
Issues considered were (i) integration with other programs and projects, (ii) extent of collaboration with other relevant national institutions, (iii) transferability of results to other areas with similar biophysical and socioeconomic conditions.

Based on the results of the priority assessment, emphasis was given to natural resources management, followed by improvement of crop production systems, improvement of animal production systems, and socioeconomic issues.

Resource allocation aimed to maintain the critical mass necessary to ensure that R&D projects were productive. While the priority assessment ranked projects in terms of the expected benefits and contribution to institutional goals, resource allocation reflected other considerations, notably the differences between the unit cost of activities and the critical mass required to maintain project productivity.

R&D objectives for the dry coastal region in Egypt
The main goal of R&D in rainfed agriculture is to break the cycle of natural resource degradation and poverty. This can be achieved by supporting local communities to use simple but improved technologies for sustainable resource management and production, which could alleviate poverty improve living standards.
Four themes were identified and ranked according to their importance to resources allocation. Each theme comprised four sub-themes.

- Theme 1: Natural resources management (55% of total scores)

Enhancement and optimization of water availability (35% of theme score); Watershed planning (30%); Vegetation and biodiversity (25%); Soil conservation, moisture, and fertility (10%).

- Theme 2: Improvement of crop production (25% of total scores)

Crop management/agronomic practices (45% of theme score); Production of seed and seedlings (25%); Genetic improvement (17%); Post-harvest technologies (13%).

- Theme 3: Improvement of animal production (15% of total scores)

Flock management (60% of theme score); Genetic improvement (17%); Health care (13%); Processing of products and by-products (10%).

- Theme 4: Socio-economic issues (5% of total scores)

Natural resources economics (35% of theme score); Production systems economics (28%); Development of local communities (25%); Marketing finance and credit (12%).

On this basis, seven programs were formulated, each with several projects:

Program 1: Natural resources management. Aims at more efficient, integrated, and sustainable utilization of resources for improved production. Four projects: Water planning; Enhancement of water availability and optimization of use; Soil conservation and improvement of moisture and fertility; Rangeland, vegetative cover, and biodiversity.

Program 2: Improvement of crop production: Activities will be conducted using the farming system approach to research and technology transfer. Two projects: Barley; Watermelon and other field crops.

Program 3: Improvement of fruits production: Aims to maximize and sustain income from fruit tree production through genetic improvement and genetic diversification, and improved soil and management practices. Three projects: Fig production, Olive production, Grapes and other fruits.

Program 4: Animal production improvement: Emphasis on efficient use of feed sources by small ruminants in tangled and cropped areas. Research will be conducted on local breeds, particularly for the efficiency of feed conversion. Two projects: Small ruminants; Camels and other animals.

Program 5: Socio-economic issues: Activities will build on the knowledge, perspectives, and innovation capacities of individual beneficiaries and local communities. Three projects: Socio-economics of resource management; Socio-economics of production systems; Marketing, finance, and credit

Program 6: Extension and social development: Small income-generating projects, skills training, and marketing issues, with emphasis on women. Four projects: Community action planning; Enhancing adoption of improved natural resources management; Enhancing adoption of improved production technologies; Rural women development

Program 7: Human resources development: Integration of resource management and agricultural production, complemented by socioeconomic improvements and participatory approaches for watershed management, farming systems, and community action planning. Three projects: Training of staff to enhance skill and job performance; Training for beneficiaries and local communities; Formal and informal on-the-job training for staff and local communities.

Decision-making in the steppe

Agricultural development in the steppe, as in any region, is the responsibility of the Ministry of Agriculture. However, many of the resources are managed by different authorities such as the Ministry of Water and Irrigation. Land tenure systems are an unresolved issue in many countries, although land is still classified as public (or there are private claimed rights for cultivation or grazing) in some countries. Tribal rights for cultivation or grazing also exist in some countries. These rights, whether public or private (not supported by legislation), are a major constraint to development, because most landowners generally reside outside the area. Therefore, contacts with and participation of local communities in development projects are difficult. Moreover, livestock production, mainly sheep and goats, is the main source of livelihoods. Continuous movements of local communities, poor definition of local communities, and open land tenure system hinder development. Any plans for steppe development must take these factors into account.

Recently, some countries have instituted ministerial committees to implement integrated development plans. Examples are the ministerial committee chaired by the Prime Minister in Jordan and the high commission for the preparation and implementation of development projects in Syria.

There are two main categories of development activities:

- Improvement of resource utilization, through interventions generally by the Ministry of Agriculture.
- Coordination of environment-related activities such as combating desertifi-

cation, biodiversity conservation, and climate change.

Although activities are in one way or another related to agricultural development, environmental authorities (Ministry of Environment or the Environmental Corporation) serve as focal points for coordination. Many institutions, such as research centers affiliated to government parastatals, public universities, semi-autonomous institutions, or NGOs, also participate.

UNCCD-related Activities to Combat Desertification

Some countries in WANA, such as Syria and Jordan, have prepared a strategy to combat desertification, based on the guidelines provided by the United Nations Convention to Combat Desertification (UNCCD). Strategies were developed following detailed analyses of available resources, identification of constraints to resource development, and identification of institutional organizations and stakeholders involved. All stakeholders were involved in the planning.

A national environmental action plan was also prepared, which focused on environmental degradation and environmental challenges, including the impacts of desertification. These plans generally aim at ensuring protection of human and natural and cultural resources, and proper management of resources. They included actions to:

- Halt or control land degradation and combat desertification.
- Reduce pollution and exploitation of water resources.
- Improve environmental quality especially in rural areas.
- Reduce pollution.
- Conserve natural and cultural resources.

Strategy for combating desertification in Syria

Measures suggested for combating desertification in Syria include:
- Sustainable improvement of the productive capacity of the land in regions affected by desertification.
- Improvement of the economic conditions of people affected by desertification.
- Coordination of efforts to combat desertification with other relevant conventions.
- Enhancing the role of women in all activities and ensuring the participation of local communities.

These measures will be based on: a full understanding of climatic changes and their role in the deterioration of resources; proper management of water resources; protection and conservation of soil from degradation; protection and improvement of plant cover; and training. The strategy will address various issues: soil, water, plant resources, and climate. Proposed activities in each of the areas are listed below.

Soil
- Establishment of soil database.
- Implementing programs in irrigated and rainfed areas, pasture lands and forest lands.
- Reducing soil salinity.
- Sustainable management of irrigated lands.
- Soil conservation, production of crops with high productivity, and soil pollution in non-irrigated areas.

Water resources
- Integrated management of watersheds.
- Continuous evaluation of water resources
- Planning agricultural production

based on available water resources.
- Upgrading of drinking water and irrigation networks.
- Optimization water resources: water harvesting, artificial rain, use of low-salinity groundwater and treated wastewater, use of non-traditional water storage facilities, reducing water evaporation, and modern irrigation techniques.

Climate
- Expansion of the meteorological station network.
- Establishment of meteorological database.
- Investigation of the effect of wind on soil degradation.
- Human resources development.

Plant cover
- Studies to understand biodiversity changes, supported with proper database.
- Mapping plant species to understand the relationship between plants and the environment.
- Conservation of vegetation cover.
- Biodiversity conservation using sustainable biological resources.
- Expansion of protected areas.
- Expanded *in-situ* conservation of protected areas.
- Systematic surveys of indigenous cultivars.
- Legislation on varieties with potential industrial use.

Steppe development
The steppe occupies 55% of the total area and 87% of the total natural rangelands in Syria. Efforts to combat desertification will therefore focus on rangeland development. This will include administrative measures (creating a governorate for the Syrian steppe, and specialized research centers to develop steppe resources); water resources development (rainwater harvesting, cloud seeding); use of renewable energy (wind and sun); non-traditional animal breeding projects; and food processing based on domestic production.

These rangeland development projects will be based on the following principles:

- Reconsidering the grazing system and prevailing range rights.
- Provision of appropriate date for distribution of cattle under range grazing conditions.
- Establishment of plant cover in different regions.
- Estimation of range production at different sites, determination of the nutritive value (and hence carrying capacity), harmonization of grazing systems.

Methods of development
Grazing management
- Choosing appropriate grazing and protection systems, reducing grazing, educating sheep breeders and shepherds and developing their confidence in the system.
- Range management, including seeding practices, establishment of nurseries, setting up a suitable grazing program for cultivated areas.

Provision of agricultural services
- Methods for reducing pressure on range areas.
- Fodder production in marginal zones, either rainfed or irrigated.
- Introduction of fodder crops in the rotation in areas adjacent to pastures, or expansion of fodder crop cultivation, depending on the availability of water resources.
- Use of plant by-products in high-value animal feed.
- Horizontal and vertical expansion of green fodder production by introducing new cultivars and improving the local ones.
- Establishment of fattening farms for meat production.
- Encouraging camel breeding, genetic improvement of animals.

Information, awareness, and cooperation
- Creating a higher commission to plan and coordinate policies to combat desertification.
- Introducing desertification issues into basic and secondary education; expanding educational activities outside the classroom.
- Educational programs: Radio, TV and other means.
- Training for raising environmental awareness especially among women.
- Training on management and execution of development projects related to desertification.
- Development and desertification research at universities and research centers.

Social and economic issues
- Efforts to improve rural livelihoods will include various programs to mitigate the social and economic effects of desertification:
- Poverty alleviation to reduce pressure on natural resources, e.g. creating job opportunities.
- Using alternative renewable energy whenever possible.
- Supporting and encouraging local participation.
- Enhancing the role of women in the production process and project implementation.
- Addressing the effects of migration caused by desertification and drought.
- Improving relief measures, providing early warning and food and water to vulnerable populations during droughts.
- Setting up hygiene programs for regions threatened by desertification.

Legislation to be updated or prepared
Environmental law.
- Legislative framework for land use allocation.
- Water law.
- Hunting law, covering both land and water.
- Law to regulate urban invasion of agricultural lands.
- A new law to regulate investment operations and management of protected areas.

Possible research areas
- Establishment of a natural land resources database.
- Preparation of environmental maps for plant cover and water resources.
- Agricultural zoning according to environmental variations.
- Evaluation of land deterioration.
- Evaluation of arable land productivity and fertilizer requirements.
- Introduction of new irrigation methods.
- Determination of water requirements for local plant species.
- Assessment of the water balance for different basins.
- Evaluation and rehabilitation of water harvesting structures and technologies.
- Evaluation and classification of plant cover and nutritive value in range areas.
- Identification of best pastoral systems for different natural rangelands, and best agricultural systems for marginal zones.
- Study of range behavior, feed requirements, and productive characteristics of livestock under natural range conditions.
- Use of plant by-products for manufacturing feed blocks.
- Establishment of a research center on desertification.

Strategy for combating desertification in Jordan

The government is developing a National Action Plan for combating desertification, which aims to improve the economic environment, conserve natural resources and biodiversity, improve institutional organizations, improve knowledge of desertification, and monitor and assess their effects.

It will be integrated with the overall national developmental plan, using a participatory approach to ensure commitment of all stakeholders. The National Action Plan outlines the basis for various activities and also describes the institutional framework of government agencies and NGOs participating in combating desertification.

- The action plan will make use of the best available technologies; involve local communities, landowners, academia, NGOs and other stakeholders; focus on preventive measures (the precautionary principle); and include programs on research and monitoring.
- Preventive measures will be taken without delay when there are reasonable grounds for concern that there is a risk of desertification, even when there is no conclusive evidence of causal relationship.
- Any development activities that may have negative environmental impacts, will be subject to an environmental impact assessment.

Expected program contributions

- Sustainable management of natural resources, including water, soil, and plant cover, as well as the biological diversity of flora and fauna in different agricultural environments.
- Maintenance of the productivity of environmental systems, especially forests, grazing land, and agricultural land.
- Improved human welfare is the ultimate goal of national efforts to combat desertification. The program will consider the linkages between desertification, poverty, food security, migration, and demography.

Planned activities

Several priority areas have been identified: soil degradation, water resources, establishment and selection of environmental indicators, documentation of traditional knowledge, rangeland management, enhancement of public awareness, capacity building, analysis of the socioeconomic impact of desertification, preparing and enforcing legislation, and integration and harmonization of National Action Plan with existing policies.

The main program areas include:

- Establishment of database, improvement of information and monitoring systems.
- Combating land degradation through soil conservation, afforestation, and reforestation.
- Developing and strengthening integrated development programs for poverty alleviation and alternative livelihoods.
- Integrating a comprehensive anti-desertification program into the national development and environmental plans.
- Drought preparedness and drought relief schemes, including self-help arrangements for drought-prone areas.
- Encouraging popular participation and environmental education, focusing on desertification and drought.

Proposed technical measures

- Land use suitability: development of land use suitability maps for the whole country, based on land production capacity and cover.
- Minimizing erosion: applying the concept of land suitability to minimize the effect of soil erosion by water, enhancing vegetation cover, good agricultural practices (correct plowing, retention of residues etc).
- Natural vegetation: enhancing vegetation cover especially in the range, through range management, development of range reserves, and water harvesting.
- Soil salinization: identification and mapping of saline soils in order to introduce reclamation measures.
- Land conversion: regulating the conversion of rangeland to other uses.

Rangeland rehabilitation and development

The National Program for Range Rehabilitation Development (NPRAD) complements the efforts of other strategies. Jordan's Agenda 21 defines the objectives of rangeland management as increasing productivity and improving land management, strengthening capacity, ensuring sustainable utilization of forest and range resources, and defining land rights.

Gender perspectives in combating desertification

The National Action Plan will incorporate gender perspectives in environmental policies and programs. The aim is mainstreaming gender perspectives in water management, biodiversity conservation, and anti- desertification efforts. This will include:

- Inclusion of women, including indigenous women, in environmental decision-making at all levels, as managers, designers, planners, and implementers of environmental projects.
- Financial and policy support for the participation of indigenous women at national and international meetings.
- Strengthening women's capacity to participate in environmental decision-making by increasing their access to information and education.

Training programs for women are envisaged in several areas: re-establishment of pastures, irrigation techniques, methods for reducing the use of pesticides, herbicides, and other chemical products, livestock breeding (including preventing the use of hormones and growth proteins), techniques for conserving water and energy, which they can teach their children, recycling and reuse of products.

Projects listed in the action plan

- Identification of desertification-prone areas in Jordan, based on the analysis of factors and processes causing desertification.
- Establishment of a national center for combating desertification.
- Introduction of the concept of safety nets to sustain farmers' livelihoods.
- Establishment of a national database on desertification.
- Establishment of a national framework for assessing potential desertification risks of current and future land uses.
- Strengthening the capacity of rural women.
- Enhancement and utilization of traditional knowledge in conserving and managing land resources.
- Introduction of local vegetable varieties in home gardening projects.
- Implementation of projects on medicinal and herbal plants.
- Raising awareness of environmental degradation and desertification.
- Study of the economical impact of desertification in terms of the cost of loss of productivity.
- Utilization of rangelands as sites for eco-tourism activities.
- Establishment of a rangeland database.
- Establishment of a national monitoring unit to track desertification and build the capacity of existing desertification units at the Ministry of Environment.
- Building the capacity of range management and monitoring personnel.
- Establishment of pastoralists cooperatives.
- Improvement of treated wastewater quality by using zeolite filtrating system.
- Integration and harmonization of NAP with other existing conventions.
- Collection and processing of sheep raw milk in rural steppe region.
- Strengthening the capacity of service organizations to implement natural resource management.
- Monitoring program for environmental indicators for land degradation.

Research activities in the steppe

Research activities in the steppe began only recently. There is an urgent needs to develop resources in this region. Accordingly, priority should be given to adaptive research that will meet immediate developmental needs, i.e. soil, water and range management, socio-economic studies. In the longer term, basic research is also needed, mainly in biotechnology, and biodiversity conservation and use. Priority research areas (short and long term) are listed below.

Improvement of range resources:
- Introduction of new crops and varieties, indigenous or introduced.
- Integration of range improvement with water harvesting practices.
- Participatory development, which emphasizes participation of local communities at all stages of research and technology transfer.
- Protection of range areas from soil denudation.
- Selection of suitable range sites with potential for improvement.
- Socio-economic characterization of range livestock communities.
- Identifying legislation and land tenure system suitable for rangeland improvement.
- Range management through controlled grazing, investigation of indigenous systems, local community participation incentives, fertility improvement etc.
- Integration of range resources with other sectors to reduce pressure on range resources.

Utilization of land and soil resources:
- Management of land resources under conditions of water shortages and unfavorable soils.
- Identification and improvement of appropriate sites .
- Optimizing farming practices.
- Selection of proper soil sites suitable for the introduction of water harvesting techniques and favorable for range or other production systems.
- Improvement of soil conditions (infiltration, crusting, nutrient deficiency, organic matter content).

Development of water resources:
- Introduction of farming systems with higher production potential than range.
- Integrating water-harvesting techniques with suitable high-value crops.
- Better integration of crops, range and livestock.
- Introduction of treated wastewater and other non-conventional resources.
- Monitoring the impact of water harvesting techniques or use of treated wastewater on environment, and health of plant cover.
- Water rights.
- Introduction of organic farming.

Socio-economic research
- Proper characterization of the socioeconomic status of local communities and livestock razing owners.
- Investigation of new job opportunities provided by new farming systems, and integration with other relevant sectors.
- Introduction of new farming systems that integrate plant and animal husbandry.

Biodiversity research (long term)
- *In-situ* and *ex-situ* conservation of agro-biodiversity.
- Surveys and characterization of plant biodiversity.
- Selection and domestication of plant varieties with potential for high production and industrial use.
- Domestication of plant species with potential for traditional food production.
- Identification and use of plants with medicinal value.

Biotechnology research (long term):
- Introduction of plants adapted to specific edaphic conditions such as drought and salinity.
- Domestication of wild relatives with desired properties and high production potential.

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Chapter 3

Rainfed Agroecosystems

3.1 Characteristics of Rainfed Agriculture in Morocco

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Introduction

Rainfed zones, called *bour*, cover around 90% of the arable land, and house around 65% of the rural population in Morocco. They play a major role in agricultural production. Unfortunately, these areas are characterized mainly by extensive production systems that are based on cereals and traditional livestock (Fig. 3.1.1). The government has placed emphasis on the development of irrigated zones, neglecting the rainfed areas. This has led to low investment in agriculture, lack of infrastructure and basic services, and high levels of illiteracy and poverty in these areas.

Physical Environment

Morocco has a Mediterranean type of climate, which is subject to oceanic, mountainous, and Saharan influences. It is characterized by two distinct seasons: a hot dry summer and a winter, which is short, relatively wet and cold, and variable from region to region. Rainfall is highly variable. Precipitation decreases from the north to the south and can reach more than 1000 mm in the mountains, especially in the Rif (north). However, in the pre-Saharan and Saharan regions rainfall is lower than 150 mm (Fig. 3.1.2).

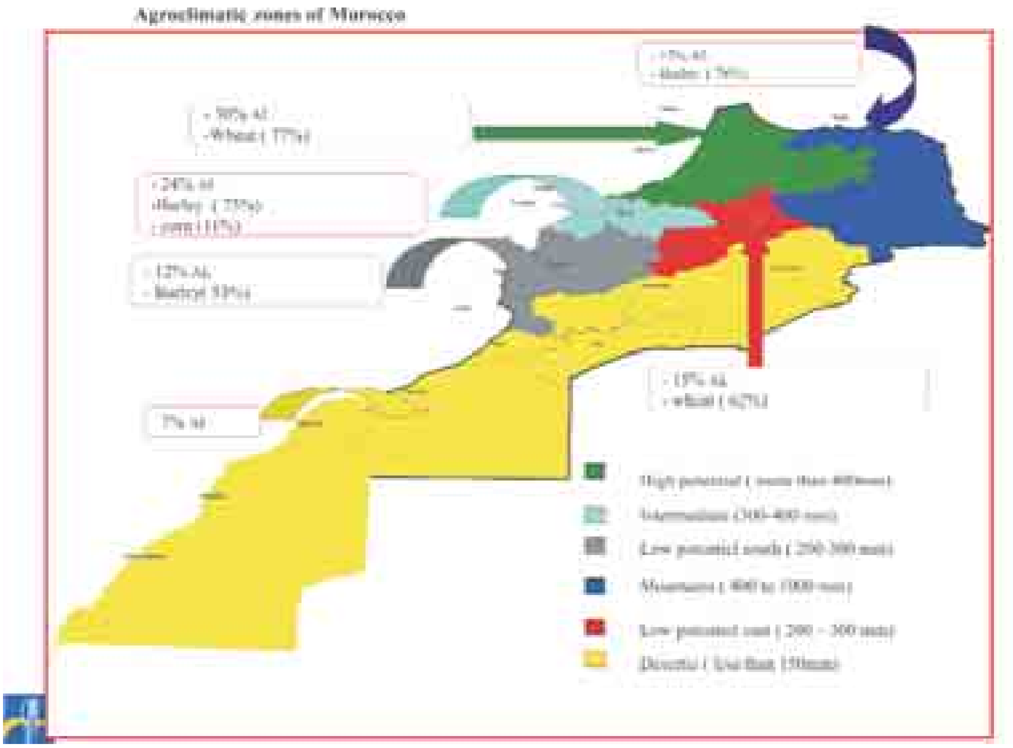

Figure 3.1.1. Agroclimatic zones of Morocco

The mean annual temperature is around 10°C, but the maximum temperature could reach 27°C. The absolute maximum can reach 45°C in the central part of the country and 50°C in the Saharan regions. The average minimum temperature varies from 5°C to 15°C, but the absolute minimum in the mountains and nearby regions is 0°C.

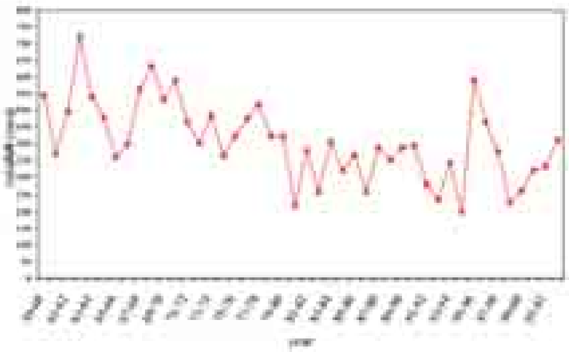

Figure 3.1.2. Average monthly rainfall variation in Morocco, 1959-2002

Morocco has experienced nine years of drought during the last two decades, and the frequency of drought has increased from one in four years before 1990 to one in two years during this last decade. The driest year during the last century was 1994/95, with an average rainfall of 198 mm and average cereal yield of 0.45 t/ha. Cereal production was 1.8 million tons, a record low. The highest production of 10 million tons was in 1995/96 (average rainfall 591 mm, average yield 16.9 qx/ha).

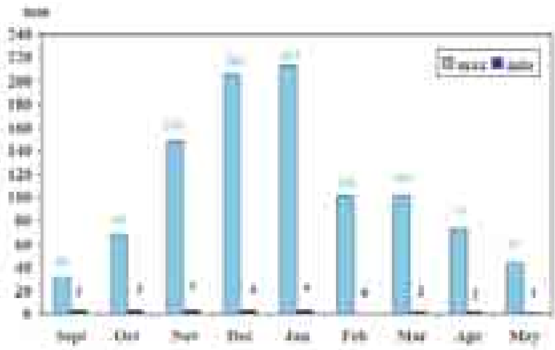

Figure 3.1.3. Monthly maximum and minimum rainfall in Morocco since 1984-85

Fig. 3.1.3 illustrates intra-annual rainfall fluctuations in Morocco. Longer periods of water deficit or drought can occur at any time during the growing season and available rainwater will be less than the water requirements for the crop (40-80% depending on the region).

Soils

Morocco's rainfed areas are characterized by diverse types of soils. The main types are isohumic, calcimagnesic, vertisols, halomorphic, and soils formed from sediments. The quality is variable, depending on the depth, texture, presence of stones, permeability, calcification, salinity/alkalinity, and organic matter content. In some cases, the soil requires improvement, such as the application of manure or appropriate tillage because of the poor texture.

The presence of stones and rocks hinders soil valorization, and there is a need for field cleaning. Cleaning can be done manually by collecting soil surface stones or mechanically using powerful trenching plows. Studies conducted at the national level indicate that around 1.13 million ha out of the 2 million ha agricultural lands require de-stoning using a trenching plow. The soils generally have low organic matter content, resulting in poor structure and a high risk of compaction in many regions (like Gharb, Chaouia, Loukkos and Doukkala) where heavy soils exist. Another problem is the accumulation of salt in the soil, mainly in irrigated areas. This can be solved by washing the soil with fresh water or by adding calcium-containing material such as gypsum.

Topography

Morocco's rainfed areas contain mountainous chains, plateaus, plains, and valleys. Land suitability for agriculture varies with the type of relief. In the plains, plateaus and valleys, which represent 65%

of the total arable land, farmers practice crop intensification of cereals, legumes, oilseeds, forages, and diversification through the introduction of new crop species. Cereal crops, followed by trees, dominate the mountainous zones, which cover 35% of the total arable land. The priority in these areas is to protect the environment and preserve natural resources.

Research has shown that 50% of the arable land in Morocco is vulnerable to different forms of erosion, and 25% of the watersheds present erosion risks. The vulnerability of natural environments is a serious problem in the arid and semi-arid zones, and is manifested as reduced soil depth and water storage capacity.

Water resources

Average annual precipitation is about 150 billion m^3 (BCM), of which 20% (30 BCM) is considered as useful rainfall and constitutes the annually renewable water. This consists of 22.5 BCM surface water and 7.5 BCM groundwater. Two-thirds of the annual renewable water could potentially be mobilized; in practice, only 45% (13.5 BCM) is mobilized.

Available water resources, which are already too low to meet demand, are increasingly diminishing because of frequent drought during recent decades. Water allocation per inhabitant, which was 700 m^3 in 1997, remains lower than the critical threshold of 1000 m^3.

Rainfed areas are most vulnerable to water deficits because only limited surface and ground water is available for use. Water resources are vulnerable or declining as a result of high demand for agricultural, domestic and industrial uses; losses due to drought; and poor planning and management. Of the estimated 4 BCM potential groundwater, about 2.6 BCM is effectively being mobilized; and the water level in many aquifers is decreasing because of excess pumping.

Some of the measures to alleviate the effects of water shortage include conjunctive use of available water resources, more efficient water management, and greater use of non-conventional sources such as treated wastewater.

Other Factors of Production

Land ownership and utilization

About 1.5 million ha of the total arable land in Morocco belong to farmers (General Census in Agriculture, 1996). Farms can be classified according to size, parceling of land, land tenure, joint ownership, and property rights.

<u>Farm size</u>: There are both small and large farms in Morocco. Small farms (<5 ha) make up 70% of the total number and occupy 24% of the total arable land. Big farms (>50 ha) represent less than 1% of the total farmed area and occupy 15.4% of the total arable land. Medium-sized farms are the most common, representing 29% of the total farms and 60% of the arable land.

<u>Parceling of land</u>: The total arable land is divided into 9.5 million plots, the average number of plots per farm is 6.4, and the average area of each plot is about 0.92 ha. Although parceling reduces risks due to climatic uncertainty, it reduces valorization of land by limiting the possibilities of mechanization and increasing the cost of production.

<u>Joint possession</u>: Joint possession (i.e. sharing benefits with other co-owners) is a consequence of not registering or not dividing landed property among heirs. About 45% of farms are jointly owned. Joint possession somewhat hinders valorization because no co-owner is willing to invest in land that does not solely belong to him.

Land tenure: Indirect land tenure accounts for 12% of the total arable land. It has only a small effect on farm productivity.

Property rights: There are two major types of property right. *Melk* (private) land rights is the most common, accounting for 76% of total arable land. It is based on Islamic laws. Collective lands comprise 12 million ha, of which about 1.5 million ha (17.6% of total arable land) is exploited by individuals. Farming on collective lands does not encourage sustainable management since there is no security of investment. Other types of property rights are less important, covering less than 7% of the country's arable land.

Land use and production

The predominant crops in rainfed areas are cereals, and this causes an unbalanced crop rotation (Table 3.1.1). This can be adjusted based on available natural resources, for example, by increasing the area planted with olive trees and increasing the acreage of food legumes and forages by at least 50%.

Table 3.1.1. Land use in rainfed areas

Crop	Area ('000 ha)	%
Cereals	5000	63.0
Legumes	400	5.0
Forages	200	2.5
Industrial crops	100	1.2
Vegetables	100	1.2
Fruit trees	550	7.0
Other crops	100	1.2
Fallow	1500	19.0
Total	7950	100.0

Source: DPV Reports, 1998-2002

Table 3.1.2. Average vs potential yields of main crops in rainfed areas

Crops	Average yield (kg)	Potential yield (kg)
Cereals	900	2000–2500
Legumes	500	1200
Olive trees	800	1500
Forages	11,700	18,000
Sunflower	800	1500

Source: DPV Reports, 1998-2002

The large differences between actual and potential yields (Table 3.1.2) are due to various factors:

- Limited use of inputs due to low technical knowledge of farmers, high input prices, and lack of infrastructure for the supply of inputs. The rate of use of certified seeds and fertilizers did not exceed 11% and 30 units, respectively.
- Lack of farm mechanization; only 50% (43,000 units) of agricultural machines were available in rainfed zones. The number of machines needs to be tripled to achieve the recommended rate of one tractor per 120 ha.
- The predominant use of offset disk for tillage, which has a negative effect on soil structure and production.
- Lack of extension education for farmers on how to use new technologies. In addition, most (80%) of the farmers are illiterate and are more than 50 years old.
- Low investment in rainfed agriculture due to lack of guarantees, high interest rates, and drought.
- Low organization of producers, lack of integration between production, commercialization, and valorization. These limit general efficiency.

Agricultural production is also largely determined by climatic conditions. Rainfall variability has a direct effect on the choice of crops and cropped areas; and indirect impact on the level of intensification, especially the use of factors of production (Fig. 3.1.4). Low and poorly distributed rainfall in Morocco accentuates the vulnerability of rural populations and has severe consequences for the economy.

In order to meet increasing local demand, annual cereal imports increased from 800,000 tons in the early 1970s to 3.5 million tons in 1995-1998. Imports have become very high particularly in durum wheat and barley (Table 3.1.3). The total annual expenditure on cereal imports increased from 500 million Moroccan dirham (MAD) to 5000 MAD.

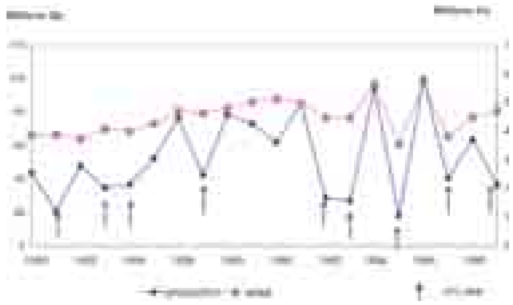

Figure 3.1.4. Cereal production and cropped area (source: DPV Reports, 2000)

Table 3.1.3. Cereal imports in Morocco (% of national consumption)

Product	1970-74	1995-98
Bread wheat	61	49
Durum wheat	0	25
Barley	2	17
Corn	6	74

Source: DPV Report, 2000

Repeated droughts have caused migration from the rural areas. Data from the General Census of Agriculture shows that the total number of farms decreased by 22% from 1974 to 1996, affecting mainly farms that are less than 1 ha. The most alarming problem is the reduction of landless farmers by 85% (from 45,020 to 6470) and landless stockbreeders by 80% (from 30,686 to 6247). Fluctuations in cereal production also have impacts at macro economic level. For example, a 40% decrease in agricultural GDP in 1995 caused 12.4% reduction in the national GDP, 7.3% directly and 5.1% indirectly. Conversely, a 58% increase in agricultural GDP in 1996 caused 14% increase in national GDP.

Table 4. Contributions of rainfed zones to national crop and animal production

Product	Contribution (%)
Cereals	75-85
Forages	75
Food legumes	100
Red meat	74
Milk	25
Sunflower	80

Source: DPV Reports, 1998-2002

Despite these fluctuations, rainfed zones still contributed significantly to the total crop and animal production (Table 3.1.4).

Human resources

Population: The total population of Morocco is 29.17 million, of whom 65% live in the rainfed zones and 44% (12.86 million) live in rural areas. More than 40% of the rural population is less than 15 years old. However, the farmers are relatively old; 45% of them are above 55. The sex ratio in rural areas remains balanced at 1:1.

Rural women: Women cultivate 4% of the farms. They are involved in water and wood transport as well as other aspects of agriculture including social and cultural activities. They play important roles in specific activities like apiculture; rabbit, sheep and caprine raising; valorization of certain products (milk, olives, oranges); and maintenance and collection of some agricultural products, especially vegetables. However, despite their key roles rural women are generally neglected and rarely benefit from development projects.

Employment and income: The unemployment rate in Morocco is generally high, 12.5% of both women and men were jobless in 2001. However, in the rural areas, where agriculture accounts for 81.4% of all activities, only 5.6% of men and 1.6% of women were unemployed. About 5.4% of the total population (1.4 million) is socially marginalized and 44.5% (13 million) is vulnerable to poverty. Most of the poor people live in rural areas and 44% of the rural population is below the absolute poverty threshold. Although income level is generally low in the rainfed areas, the distribution is not uniform. Poverty is more pronounced in north central and south central Morooco, affecting 25% of the population, while only 5% of people in the coastal zones are poor.

The Policy and Institutional Environment

Infrastructure and services

In the past, rural areas received only 40% of agricultural public spending and very little investment in basic infrastructure. In 1998, maximum access to drinking water and electricity was 38% and 32%, respectively. More than 57% in rural areas had no access roads. However, infrastructure and basic services have improved during the past few years, as a result of many development projects implemented by the government.

Legislative framework

The legislative framework that governs government actions in rural, and especially in rainfed areas, has been adjusted during the last few years in line with new strategies for rural development. In addition to the partial update of the Agricultural Code of Investments, promulgated in 1969, different new laws and texts have been promulgated. These are:

- Law 33–94, on the valorization of rainfed perimeters, promulgated in 1995 to improve state intervention in rainfed areas. The law defines the principles guiding intervention in these zones, which include targeting, integration, participation of the concerned actors, de-concentration, and contracting actions.
- Law 33–94, relating to the limitation of parceling.
- Law 10–95, on water, which updated existing statutes and introduced the principle of conservation and efficient use of water resources at the watershed level, thus allowing for decentralized management.
- Law 13/97, which allows the creation of groupings of economic interests.
- Law 18/97, on bank micro-credit, which defines the framework for intervention by associations offering this type of credit.
- Decree 298974 of 5 January 1999, which sets up the Council and the Inter-Ministerial Committee on Rural Development.
- Circular 7/2003 of 27 January 2003, relating to partnership between the state and the associations.

Institutional framework

Various institutions are involved in agricultural and rural development:

- The Ministry of Agriculture and Rural Development (MADR), which is in charge of agriculture and rural development, and overseas the Administration of Rural Engineering (Administration du Génie Rural, AGR). AGR is composed of 11 central directorates, one of which is in charge of land reclamation and valorization of rainfed zones and three other (Crop Production Directorate or DPV, Animal Production Directorate or DE, and Directorate of Education, Research and Development or DERD) are involved in the development of rainfed areas. At the regional level, MADR is represented by three administrative structures, the Provincial Directorates of Agriculture, DPA (40 in number); the Centers of Agricultural Works, CT (122 in number), involved in the development of rainfed areas; and the Regional Authorities, in charge of the development of the large-scale irrigated perimeters, ORMVA (9 in number).
- High Commissary Ship of State, in charge of waters and forests, and desertification. It is composed of central and regional directorates of waters and forests, forest aggregations at provincial levels, and local structures.
- Ministry of Equipment and Transport, in charge of roads, ports, and transportation.
- State Secretariat within the Ministry of Territory, Water and Environment, which is in charge of water.
- "North Agency" for the promotion and

development of provinces in northern Morocco, and integration of these regions within the national economy through financing and execution of development projects, especially in agriculture.
- Agency for Social Development, which focuses on ameliorating social conditions of the most vulnerable populations.

Professional organizations

Three types of professional organizations are represented in the rural rainfed zones.

Chambers of agriculture

There are 37 chambers of agriculture, which are grouped into a federation. They are public institutions guided by a law, *Dahir* of 24 October 1962, recently modified and complemented by another law, *Dahir* of 2 April 1997. These chambers represent the agricultural sector, therefore the administration is obliged to consult them, and the government can assign them on missions of public interest. They are financed exclusively through state subsidies and do not have autonomy and resources like other professional chambers.

Agricultural cooperatives

There are 2700 agricultural cooperatives, with a membership of about 185,000 farmers, who cultivate 1.37 million ha. Agricultural cooperatives in the rainfed zones make up 63% of all existing cooperatives in Morocco. They are particularly important in rural areas, because of the small and scattered farms. The different categories of agricultural cooperatives, besides those of the agrarian reform, are as follows:

Milk cooperatives	813
Service cooperatives	731
Animal production cooperatives	478
Cooperatives for agricultural equipment use	286
Horticultural and citrus cooperatives	192
Irrigation cooperatives	91
Forest cooperatives	81
Cereal cooperatives	11

Agricultural associations

There are 180 associations, made up of 56 national associations and 124 regional associations. They are divided into 11 groups and distributed in 14 regions (Tables 3.1.5, 3.1.6).

"Territorialization" of rainfed zones

Biophysical conditions, natural resources and human capital are highly variable across the rainfed areas. In order to target interventions to specific environments, the Ministry of Agriculture and Rural Development adopted different forms of "territorialization" based on the needs and type of intervention. The first level of "territorialization" are the six agro-climatic zones, defined according to climate, topography, natural resources, and production systems (Table 3.1.7).

The north-western part is the most favorable zone, with an average rainfall of more than 400 mm. The environment allows diversification of crops; the cropping system is composed 60% cereals (wheat represents 77%), 10% food

Table 3.1.5. Agricultural associations in Morocco

Type	National level	Regional level	Total
Milk	2	14	16
Meat (red)	2	14	16
Horse	4	12	16
Fruits and vegetables	3	9	12
Cereals and legumes	5	4	9
Export crops	5	3	8
Sugar plants	–	7	7
Seeds and seedlings	2	3	5
Oleaginous and textile crops	2	2	4
Aviculture	4	–	4
Other	3	–	3

Source: DEPAP Report, 2001

legumes, 12% fruit trees, and 15% fallow. The rest is made up of sunflower, vegetables, and forage crops.

Table 3.1.6. Regional distribution of agricultural associations in Morocco

Region	No. of associations
Meknes-Tafilalt	28
Sous-Massa-Draa	17
North-east (oriental)	15
Gharb-Chrarda-Ben Hssen	12
Doukkala-Abda	10
Tanger-Tetouan	8
Chaouia-Ouardigha	7
Marrakech-Tensift-Haouz	7
Tadla-Azilal	5
Rabat-Salé-zemmour-Zaer	5
Great Casablanca	4
Fes-Boulmane	3
Taza-El Houceima-Taounate	2
Oued Ed Dahab-Lagouira	1
Total	**124**

Source: DEPAP Report, 2001

The mountainous zone is characterized by relatively high average rainfall. Cereals dominate the cropping system (62%, of which 60% is wheat), while fallow and fruit trees represent 33% and 4%, respectively.

The Saharan zone is characterized by very low and it is not suitable for rainfed crops. Agriculture is based mainly on camel production and oasis activities.

Conclusions

Although the rainfed zones of Morocco are diversified in human and natural resources and benefit from many government development projects, they remain vulnerable to climatic variability. Sustainable management of natural resources, especially water, is essential to improve the livelihoods of people living in these areas, who are largely dependent on agriculture.

Table 3.1.7. Agro-climatic zones in Morocco

Zone	Rainfall (mm)	Normal average rainfall (mm)	Arable land (ha)	% arable land composition
Favorable	>400	565	2610	30
Intermediate	300-400	347	2088	24
Unfavorable south	200-300	320	1044	12
Unfavorable north-east	200-300	248	1044	12
Mountains	400-1000	510	1305	15
Saharan	<150	113	609	7

Source: DPV Report, 1986

The intermediate zone is found in the plains of central zone (Chaouia, Doukkala), where the cropping system is composed of 75% cereals (barley 40%, corn 11%) and 22% fallow. Food legumes and fruit trees represent 2.5% and 1%, respectively.

The unfavorable zones are in the south and north-east of the country. The natural land cover has deteriorated due to water and wind erosion. Fallow, which provides feed for livestock, and barley, which represents 53% of the cereal cultivation in the south and 78% in the northeast, are important in these zones.

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3.2 Development Strategies for Water and Rainfed Agriculture in Morocco

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Introduction

Morocco covers 71 million ha, but only 12% (8.7 million ha) of this is arable land. The rest consists of bare and non-productive land (44%), pasture (30%), forest (8%), and native alfalfa (5%). The arable land is divided into rainfed (83%) and irrigated (17%) zones, and about 21% is fallow. The main crops grown in Morocco are cereals, which occupy more than 60% of arable land, fruit trees (7%), food legumes (5%), industrial crops (3%), forage crops (2%), and horticultural crops (2%).

Morocco is characterized by low and sporadic rainfall, and rainfall deficits are becoming more frequent. The frequency of drought was, on average, one in four years before 1990, but this increased to one in two years during the last decade. This has affected crop production and water resources. Rainfall variability causes corresponding instability in production. Annual production of cereals, the most important crops in Morocco, especially in rainfed zones, varies from 10 million tons in wet years to 1.8 million tons in dry years.

This has a severe impact on the national economy, because agriculture plays an important role. Agricultural GDP, which represents 15-20% of total GDP, fluctuated between 37 and 62 billion Moroccan dirham (MAD) during the last decade. Agriculture provides 18% of total exports, and more than 40% of total employment, and 80% of rural employment in the country. Irrigated agriculture contributes 45% of total production (70% during dry years), more than one-third of rural employment, and 75% of agricultural exports.

Domestic production in relation to basic food needs is 72% of cereals, 52% of sugar, 25% of oil, 87% of milk, and 100% of meat, vegetables and fruits.

Availability and Allocation of Water Resources

Average annual precipitation in Morocco is estimated to be 1.5 Bm^3 (Benazzou, 1994; Arafa, 1982). Around 80% of this water goes back to the atmosphere through evaporation and transpiration. Only 20% represents infiltration and runoff, which is considered as the potential water resource.

The potential surface water is about 30 bm^3 in wet years and 15.6 bm^3 in dry years, giving an average of 22.5 bm^3. About 6.5 bm^3 cannot be controlled and is subsequently lost through runoff, leaving 16 bm^3 that is potentially divertible The existing storage (dams, aquifers) allows the mobilization of around 14 bm^3 of water (11 bm^3 in 1995) (AGR, 1995).

Availability of water resources depends on the amount and distribution of rainfall. Rainfall decreases from north to south and from west to east of the country. Annual precipitation varies from 1500 mm in some regions of northern Morocco to less than 50 mm in the south. There is considerable spatial variation: 50% of the precipitation falls on just 15% of the country's arable land.

The wet season is from November to April and precipitation is erratic. Although water deficit can occur at any time during the season, two types of droughts are common. Early drought occurs usually in November and December and affects stand establishment of winter crops. Late drought occurs during the spring and early summer; it is more frequent and reduces grain setting and grain filling of annual crops (El Mourid and Watts, 1993).

In the 1990s, water supply generally exceeded demand (Table 3.2.1). Nevertheless, basins such as Moulouya, Souss and Tensift have already shown some deficit. Projections are that by the year 2020 this balance will be mostly negative and the country-wide deficit will be 0.5 Mm^3. Consequently, water allocation for domestic and agriculture use will be reduced.

Yacoubi (1994) showed that in 1990, 833 m^3 of water per capita could be potentially mobilized; the actual mobilized water was 432 m^3. Potential mobilization will fall to 411 m^3 in 2020. Moreover, the share allocated to agriculture will drop from 92% in the 1990s to 81% in 2020 (Table 3.2.2).

Fig. 3.2.1 shows the evolution of total available water in the three main hydraulic basins. The amount of water varied from around 2 to 16 BCM. From 1979-80 to 1994-95. From 1998-99 to 2002-03 this amount was less than 7 BCM. It was higher than 10 BCM only during 3 consecutive years (1995-96 to 1997-98) of the whole period.

Table 3.2.2. Water use in Morocco, billion cubic meters (BCM).

Sector	1992	2000	2020
Agriculture	10.05	12.07	17
Domestic + industry	0.85	2.04	4
Total	10.9	14.1	21
% agriculture	92	86	81

Source: AGR, 1995

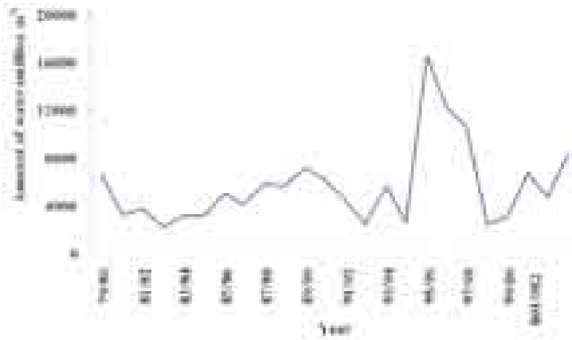

Figure 1. Available water resources in three main hydraulic basins (Loukkos-Sebou-Beht, Oum Rabia and Haouz-Tensift)

Fig 2 shows fluctuations in water availability for the basins. Trends were different from one basin to another. The observed fluctuation is due mainly to the variation of precipitation and storage capacity of dams.

Table 3.2.1. The balance between water resources and demand in Morocco in TCM.

Hydraulic basin	1992			2020		
	Resources	Demand	Balance	Resources	Demand	Balance
Rif-North	464	403	61	1545	1052	493
Moulouya	1122	1205	–83	1670	1816	–146
Sebou	2329	1704	625	4768	3916	852
Bouragrag	339	327	12	852	902	–50
Oum Rabia	3977	2846	1131	4067	4869	–802
Tensift	644	1067	–423	1221	1630	–409
Souss	675	734	–59	777	1175	–398
Massa	143	118	25	144	185	–41
Total	9693	8404	1289	15044	15545	–501

Source: AGR, 1995

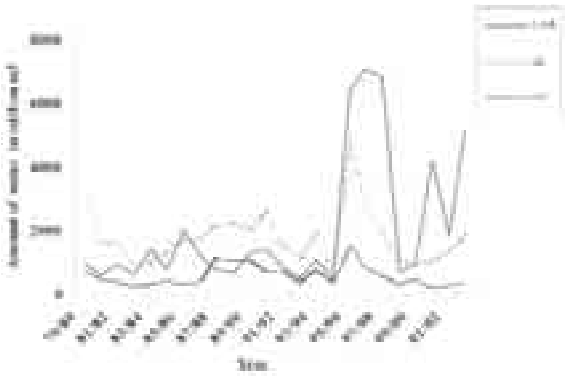

Figure 3.2.2. Water availability in three main basins (Loukkos-Sebou-Beht, Oum Rabia and Haouz-Tensift)

Current National Strategies in Agricultural Development

Role of the state in agricultural development

Large-scale extension programs were conducted before 1969, involving promotion of tillage operation, fertilizer techniques and seed production. During this period the state set market prices and implemented development programs. In 1969, the "Agricultural Code of Investment" was established. This is the legal statute governing the organization and development of agriculture. From 1969 to 1993, many land and water management and commodity-based programs (milk, meet, sugar, cereals, oil, citrus, horticultural crops) were implemented. The role of the state shifted from execution to participation in development programs; but market regulation was maintained. Since 1993, the state has become just a participant and referee in development programs. The process of state disengagement, which started in the 1980s, was achieved in 1993 by liberalization of prices and imports.

Since 1993, a new strategy of the development of agriculture has been elaborated. Many laws were promulgated, including the law on water (Law 10:95) and another on creation and development of rainfed perimeters (Law 33:94).

New law on water (Law 10:95)

Previous approaches for water management and allocation were not successful. The new law on water was therefore promulgated in 1995. It introduces innovations and an integrated strategy in water management and takes into account both conservation and efficient use. The law is based on the principle of "polluter pays, uses pays"; meaning that whoever pollutes or uses too much water has to pay a higher price for each cubic meter used. The law also aims to solve the problem of fragmented responsibilities (six ministries and several public institutions were involved in water management) and to modernize the administration of water. New authorities acting in cooperation were created at national, regional and local levels. These are (i) high water and climate council, in charge of formulating broad national water policy and studying plans for water resources development and legislation, (ii) hydraulic basins agencies that are managed by an administration council composed of all partners involved in water management at basin level, and (iii) commissions of water at the prefectural and provincial levels. The objectives are to ensure the participation of local collectives and promote decentralization of water management.

Creating associations of water users; reviewing water price in large-scale irrigation

In Morocco, large-scale irrigation was initiated in the 1960s. This strategy was consolidated with legal and institutional measures such as the "Agricultural Code of Investment" and was reinforced, since the early 1980s by the management of small and medium-scale irrigation programs. The experience of Morocco in dam construction and modernization of irrigation systems has been successful in terms of the development of the economy. But to keep the ORMVAs (regional extension authorities in large-scale irrigation perimeters) financially autonomous, it was decided in the 1970s that water users have to pay fees to cover expenses related to exploitation, maintenance of irrigation equipment, and amortization of the cost of irrigation equipment. Unfortunately, these dues were not paid and the development of large-scale irrigation has remained dependent on public funds. In fact, more than two-thirds of total agricultural investments by the Ministry of Agriculture go towards irrigation development and half the expenses mentioned above are paid by the state. To solve this problem, it was decided that water users should participate fully irrigation management. Associations of agricultural water users (AUEA) have been created in the ORMVAs, in order to improve water management and sustainability of irrigation systems, reduce water costs, and convince farmers to pay their dues and work in genuine partnership with the ORMVAs.

To encourage farmers to stop wasting water and hence increase water-use efficiency, water prices were increased. They had been, in general, equal or lower than 0.2 MAD/m^3 and were increased in most ORMVAs. Nevertheless, prices are different from one basin to another and varied in 2002-03 from 0.20 to 0.62 MAD/m^3. This variation is due to differences in pumping and irrigation system costs. The only ORMVAs where the price remained constant and low (0.2 MAD/m^3) were those of Tadla, Ouarzazate and Tafilalet.

New law on creation and development of rainfed perimeters (Law No. 33.94)

Unlike the irrigated areas and until 1994, rainfed zones, called "Bour" in Morocco have been neglected in terms of investment and development priority. Development projects remained sporadic and extensive; but some programs for tillage and fertilizer recommendations and oil and almond production were undertaken in the late 1960s. These were followed in 1980 by large integrated development projects that proved difficult to implement and manage. These projects and experiences led to a new development strategy for rainfed zones that is supported by a law (No 33.94) on the creation and development of rainfed perimeters. The new law envisions an integrated and participatory approach where different stakeholders in the perimeter are involved. This approach is based on community adherence to the agreed program of actions within their perimeter and on their commitment to participate in implementing and financing the projects. Involvement of farmer associations of agriculture chambers will also facilitate participation of the farmers in implementation, follow-up and expansion of projects. These projects are designed for small areas (not more than 2 communities) for better management. The strategy is likely to succeed because it takes into consideration not only agricultural development but also other social components such as infrastructure development (roads), drinking water, education and health. One disadvantage of this law is that it mainly targets intensification of crop production, rather than conservation of natural resources.

Programs for drought mitigation

Because of high frequency of drought, the government initiated a development program, coordinated by an inter-ministerial commission. The objectives are to provide financial aid and drinking water to rural populations, ensure livestock safeguard (subsidy of barley grain and other feed products), create jobs, and preserve natural resources (e.g. forest).

Development program for cereal production

Cereal production contributes one-third of agricultural output in Morocco. In 1999-2000 a development program was launched (MADRPM, 1999) to secure cereal production (6 million tons in an area of 300,000 ha). This program is also justified by the fact that the yield gap between farmers and research stations (which is extremely high in dry years) can be reduced if farmers use improved technologies. Technology adoption can be enhanced if production costs are reduced and markets are guaranteed. Activities under this program include:

- Establishment of drought insurance to reduce the impact of crop failure and encourage farmers to invest in cereal production.
- Price subsidies for agricultural machinery, including irrigation equipment, and inputs (certified seeds and phosphate fertilizers).
- Annulment of farmers' bank loans (loans below 10,000 mad).
- Guarantee of cereal products market.
- Training and extension programs to accelerate diffusion and adoption of new technologies.

Supplemental irrigation

Research has shown that supplemental irrigation can play a key role in reducing production fluctuations and increasing yields and water productivity. A study was undertaken to identify areas suitable for this technique, and evaluate the available water resources to be used. Using these two criteria (suitable areas, availability of water), the potential total area suitable for supplemental irrigation was estimated as 1 million ha:

- 200,000 ha in large-scale irrigation perimeters, for currently rainfed cereal crops.
- 300,000 ha in Gharb, Tadla, Abda-Doukkala and Chaouia-Rhamna regions. Here the objective is to substitute part of conventional (full) irrigation by supplemental irrigation.
- 500,000 ha in Sais and Chaouia plains. The objective is to exploit the hydraulic basins where there is surplus water: exploitation of the Saiss aquifer; transfer of water from Sebou basin for example to cereal production zones where there is shortage of water resources such as Chaouia; collection of water in small dams for aquifer recharge.

The amount of water needed to irrigate the 1 million ha was estimated as 2.1 BCM, which corresponds to around 2100 m^3 per ha.

To implement the supplemental irrigation program, the Ministry of Agriculture initiated, in year 2000, a program of creating cereal production perimeters of 14,260 ha. These zones were chosen because they are suitable for supplemental irrigation and water resources are available. To encourage the farmers to use this technique, the following approach was adopted:

- Financial aid to farmers to acquire irrigation equipment, equivalent to 30% of the cost of the equipment.
- The state will provide further equipment, at the farm level, of the existing perimeters Farmers will pay 40% of the costs.

Potential supplemental irrigation projects have been identified for 14,260 ha (12,260 ha belong to the private sector and 2000 ha are located within the public perimeters). However, these projects have not been implemented because of persistent drought and also because public funds were not adequate. It is important to note that the contribution of the farmers (70% of the cost of the project) is supposed to be paid back to the state after all the equipment and land management work are provided.

In 2002, a 5-year action plan on supplemental irrigation was launched by the Ministry of Agriculture in partnership with farmers. The agreement states that, first, farmers have to pay and establish supplementary irrigation projects and then the state guarantees the allocation of loans and 30% subsidy of the investment cost.

Drought Mitigation Research in Morocco

Supplemental irrigation

In Morocco, supplemental irrigation research has been conducted mostly in large agricultural areas like Chaouia, Abda, Doukkala, Saiss, Gharb and Tadla (Handoufe *et al.*, 1987; Belbsir, 1990; Chaouch, 1990; Boutfirass, 1990, 1997; Boutfirass *et al*., 1992, 1994; Ouattar et al., 1992). These studies are mostly on wheat; but some cover other crops such as sunflower (El Asri, 1990), sugar beet (Chati, 1996) and winter chickpea (Boutfirass, 1997).

<u>Effect on yield and water use efficiency</u>: In all studies mentioned above, grain yield and total biomass gain were shown when supplemental irrigation is applied. However, the percent gain, when compared to the rain-fed situation, varied depending on the region, rainfall, experimental conditions and soil types. For grain yield production, this gain varied from 20% under low drought stress (Lahlou, 1989) to more than 200% during very dry season (Boutfirass, 1997). Biomass production showed also the same trend with a minimum increase of 10% and a maximum of more than 100%. Several authors showed a positive effect of supplemental irrigation on water use efficiency (WUE) under different rainfall conditions (Table 3.2.3.). WUE increases due to supplemental irrigation varied from 30% in high to 100% in low rainfall seasons, respectively. However, this increase depends also on rainfall distribution during the growing season.

<u>Critical stages of water supply</u>: The effect of supplemental irrigation can be improved if critical stages are targeted and if adapted varieties and crop management techniques are used. In most studies mentioned above, supplemental irrigation was applied at one or more critical stages of wheat growth, i.e. tillering, booting and grain filling. In the case of a single irrigation (at one stage only), yield is increased more when water is supplied at pre-anthesis than at post-anthesis. This difference in yield increase is explained both by the production of a minimum source (biomass) threshold at anthesis, that is needed for grain production (sink) which is estimated to be 6000 kg/ha (El Mourid, 1988) and by the fact that the two most important grain yield components (number of spikes and number of grains) are elaborated early during wheat development and benefit from the early irrigation. Post-anthesis irrigation can help only to increase kernel weight.

Considering pre-anthesis stages (tillering and booting), differences in response to supplemental irrigation can be explained by (i) differences in water storage capacity of different soil types, (ii) differences in soil profile recharge that can vary with crop life cycle positioning as compared to the rainfed season (seeding date, thermal amplitude and evaporative demand during the vegetative phase), rainfall intensity, and number of rainy days during the vegetative phase, (iii) differences in the soil water depletion rate, depending on:

- Use of different cultural practices (seeding rate, planting depth, seed

Table 3.2.3. Water use efficiency (kg/mm/ha) in wheat under supplemental irrigation (application of 60 mm of water at once) (Boutfirass, 1990 and 1997).

Year	Rainfall (mm)	Irrigation Treatment			
		Rainfed	Tillering	Booting	Grain filling
1988–1989	341	14.90 d	19.10 a	18.00 b	16.10 c
1989–1990	332	13.10 b	13.90 b	16.10 a	13.40 b
1990–1991	342	11.82 b	15.25 a	12.85 b	12.26 b
1991–1992	247	4.99 c	9.78 a	6.28 b	3.93 c

(Means followed by the same letter do not differ at the 0.05 level of probability)

bed preparation).

- Weather conditions (evaporative demand).
- Crop type and varieties used.

Plant cover early in the season.

Rate of water applied: The amount of water should not be to satisfy full crop water requirement or to produce maximum yield per unit area, but rather to satisfy several criteria of which yield stabilization and water-use efficiency are the most important. Several studies have been conducted on irrigation water rates at different growth stages in wheat (Boutfirass, 1997; Belbsir, 1990). In these studies, the maximum irrigation water used was around 200 mm. In the areas where average rainfall is around 350 mm, the minimum irrigation water to apply is 60 mm. However, with 120 mm of water applied early in the growing season, grain yield is significantly improved, especially in deep soils with high water storage capacity. If more water is available for irrigation, the best way is to target the three critical stages of wheat (tillering, heading and grain filling), applying around 60 mm at each stage (Tables 3.2.4 and 3.2.5).

Genotype effect

To evaluate genotypic responses to water supply, different wheat varieties have been compared under supplemental irrigation in different years and different locations. Data showed that the genotype effect was either significant (Table 3.2.6) or not significant (Table 3.2.7). The genotype effect was significant when the cultivars used were different in their life cycle length, yield potential and morphology. Medium and early-maturing genotypes with large leaf area indices and a harvest index of around 0.40 are the best suited to supplemental irrigation (Table 3.2.8). For instance, durum wheat varieties Sarif, Karim and Tassaout and bread wheat Marchouch 8 (Table 3.2.6) achieve high yield gain from supplemental irrigation, compared to other cultivars.

Table 3.2.4. Grain yield and total biomass (kg/ha) of wheat under different irrigation regimes (Boutfirass, 1997).

	Season 1993-94 (307 mm)*		Season 1994-95 (129 mm)*	
Regimes	**Grain yield**	**Biomass**	**Grain yield**	**Biomass**
Rainfed	1815	7667	616	3000
T30**	1923	9583	1041	4088
H30	2321	8611	1072	4000
T60	2532	11917	1432	4688
H60	2795	9750	713	2938
T30+H30	2394	10583	795	3500
T90	3559	12000	1667	5938
H90	2936	9139	1309	3188
T45+H45	3025	11333	1418	5125
T120	5177	15445	2153	6750
H120	3125	10138	1444	4438
T60+H60	3129	11611	1821	4938

(*): annual rainfall; (**): T and H are tillering and heading stages; 30, 45, 60, 90, 120 are irrigation water.

Table 3.2.5. Wheat grain yield (kg/ha) under supplemental irrigation at three growth stages (60-70 mm of irrigation water applied at each stage).

Author	Region and annual rainfall (mm)	Irrigation (mm)	Grain yield (kg/ha)
Boutfirass, 1990	Chaouia, 332	180	6712
Belbsir, 1990	Saiss, 460	180	7908
Karrou et al.,1993	Tadla	-	8722

The yield gain also depends on the timing of irrigation time in relation to the growth stage. Irrigation at the tillering stage was the most effective for all the cultivars tested (Table 3.2.7).

Planting date effect

In Morocco, the last growth stages of wheat are subjected to high temperatures and hot dry wind (Sirocco). Climatic demand is therefore very high and irrigation efficiency becomes very low. Early planting allows plants to mature earlier and escape heat and water stresses (Table 3.2.9) that occur late in the season and adversely affect wheat grain filling. Early supplemental irrigation combined with early planting, improves tillering capacity, spikes per square meter and 1000-grain weight (Ait Yassine, 1995; Lamsallek, 1991). Consequently, grain yield and biomass production are increased.

Table 3.2.6. Grain yield and total biomass (kg/ha) of different genotypes under supplemental irrigation (Laaroussi, 1991).

Varieties	Grain yield (kg/ha)		Total biomass (kg/ha)	
	Irrigated*	Rainfed**	Irrigated	Rainfed
Kyperounda	2677	3083	10200	9100
Cocorit	3040	3145	9500	8400
Jori	3165	2188	12000	6900
Marzak	3625	3545	9500	7900
Karim	4063	2608	10500	6600
Acsad 65	3528	3355	9600	8300
Isly	3393	3043	11300	10200
Oumrabia	3185	3053	10200	9900
Sarif	4392	3113	12200	9500
Tassaout	4192	3597	12500	10000
272	3500	2525	12400	9000
Belbachir	3445	2920	9500	9400
Massa	3355	2432	11300	7700
Nesma	1580	1420	8900	7400
Siete cerros	2130	1100	6500	7600
Teggey 32	2785	2513	8900	6900
Jouda	1485	1495	7500	6300
Marchouch 8	3269	2258	8400	5900
Acsad 59	1303	1305	5400	6400
Saada	2310	2758	9600	9300

(*): 90 mm of irrigation water (**): 368 mm rainfall

Table 3.2.7. Grain yield (kg/ha) of different genotypes under supplemental irrigation. (Boutfirass, 1997).

Genotype	Rainfed	Tillering	Booting	Grain filling
Karim	3095	6003	4138	4765
Sebou	4063	5306	4857	4749
O. Rabia	3355	5487	4435	3696
Marzak	3541	5825	4444	3351
Marchouch	3398	5132	4218	3885
Saba	2744	4945	3614	4321
Achtar	3626	5570	5155	4608
El Khair	3416	5184	4478	4256
Average	3382 c	5421 a	4417 b	4202 b

Means followed by the same letter do not differ at the 0.05 level of probability

Table 3.2.8. Grain yield (kg/ha) under different supplemental irrigation treatments and genotypes. (Lahlou, 1989 and Boutfirass, 1990).

Irrigation	Varieties*		Varieties**	
Treatment	Teguey	Potam	Teguey	Potam
Tillering	6600	5680	4337	4246
Booting	5320	5820	5472	4319
Grain filling	5300	3910	4458	3365
Rain-fed	3900	3850	3413	3014

**: Lahlou, 1989; **: Boutfirass, 1990.*

While comparing four planting dates under different water regimes as supplemental irrigation Bahaja (1994) found that, besides yield increase in all irrigated treatments, higher yields were obtained with the earliest planting date, and decreased as planting was delayed (Table 3.2.10).

Seeding rate effect

Most supplemental irrigation studies have been conducted using rainfed area management techniques such as low fertilizer and moderate seeding rates. However, these techniques allow limited yield increase when irrigation water is supplied. The optimal input levels for supplemental irrigation technology have to be determined. Investigations on seeding rates (Bahaja, 1994; Ait Yassine, 1995) showed that a medium seeding rate of 300 grains/m^2 is suitable, particularly when supplemental irrigation is applied early in the growing season. Although higher planting densities gave higher biomass productions, the highest grain yield was obtained with the medium seeding rate (Table 3.2.11).

Table 3.2.9. Evaporative demand and water deficit for different planting dates in two regions of Morocco (adapted from Baidada, 1989).

Planting dates		Saiss region			Chaouia region	
	10 Oct	20 Nov	1 Jan	10 Oct	20 Nov	1 Jan
Max. ET mm	382	498	540	379	473	523
Actual ET mm	294	318	294	272	274	242
Water deficit mm	88	180	247	108	199	281
Water deficit index %	23	36	46	28	42	54
Satisfaction rate %	77	64	54	72	58	46

Table 3.2.10. Grain yield of wheat (kg/ha) under different planting dates and water regimes (Bahaja, 1994)

Water regimes	Planting dates			
	27 Oct	30 Nov	30 Dec	28 Jan
125 mm	5754	5287	4745	2478
70 mm	4856	4090	3454	1817
45 mm	4256	3537	2944	1479
Rainfed	3492	2447	1966	1063

Table 3.2.11. Grain yield (kg/ha) of different seeding densities under supplemental irrigation (Bahaja, 1994 and Ait Yassine, 1995)

Seeding density	Grain yield *	Biomass*	Grain yield**	Biomass**
200 grains/m²	4409	9868	6067	14381
300	4530	11140	6948	15087
400	4330	12793	6023	15648
500	–	–	6175	16078

** Bahaja, 1994 with 60 mm irrigation water. ** Ait Yassine, 1995 with 170 mm irrigation water*

Simulation of supplemental irrigation

A simulation of the effect of supplemental irrigation for different growth stages was carried out using a wheat growth model SIMTAG (Boutfirass et al., 1992). The authors used a climatic data series of more than 20 years in two contrasting regions. For each region, the simulation was made for two soil types (deep and shallow soils) and three bread wheat varieties (early, medium and late-maturing). Results showed that the effect of supplemental irrigation varied with the soil and variety types. On a deep soil, supplemental irrigation at tillering stage gave the best yield increase, whereas in a shallow soil, irrigation at booting stage yielded better. The same results were also obtained in terms of probabilities. Early and medium-maturing varieties gave the best simulated results in arid and semi-arid zones. Late-maturing varieties should be avoided in these areas. Yield variability over years was greater for shallow soils with low water storage capacity. The best yield stability was obtained for deep soils irrigated at tillering stage. In terms of water-use efficiency, the same trends as for grain yield were obtained. These results confirmed those of Boutfirass (1997) who concluded that in semi-arid regions with deep soil, it is better to apply supplemental irrigation early in the season.

Supplemental irrigation in other crops

Preliminary results on other crops also showed the importance of supplemental irrigation in yield improvement and stabilization. In sugar beet, Chati (1996) concluded that if the crop was well watered at seedling stage, subsequent water application can be delayed and hence the number of irrigations can be reduced during the vegetative stages. He also found that the number of irrigation events was not as important as the timing of irrigation.

For winter chickpea, a single irrigation of 60 mm water at pod elaboration stage helped the crop to maintain green area duration for more than 45 days as compared to the rainfed plot (Boutfirass, 1997). This green area duration is an important contributor to grain yield increase.

For sunflower, supplemental irrigation at the most sensitive stages of the crop (floral bud, flowering) considerably increased yield, oil and protein content (Table 3.2.12). The highest grain yield was obtained with one irrigation at the floral bud stage.

Table 3.2.12. Performance of sunflower under supplemental irrigation (kg/ha) (El Asri, 1990)

Irrigation regime	Grain	Biomass yield	Oil content
Full irrigation	3365	12474	1472
Floral bud irrigation	2873	10836	1236
Early flowering	3147	9737	1358
Late flowering	2567	7603	1149
Non-irrigated	1691	7006	706

Economic evaluation of supplemental irrigation

Since supplemental irrigation requires an investment in equipment and supplies, relative profitability studies under different conditions and with different irrigation systems were undertaken. Different approaches were used in these studies, but in all investigations, the bank interest was 14-15%.

Ouattar et al. (1992) presented a case study using the mobile ramp irrigation system. In their calculations they considered the pre-anthesis supplemental irrigation outputs and found that this technique was economically justified when the minimum area exceeded 10 ha. Moreover, when they increased the bank interest from 14 to 28%, the technique started to be profitable only beyond 13 ha.

Lamrani et al. (1992) evaluated the economics of supplemental irrigation through the analysis of "farm models" where they considered three typical farms of 5, 30, and 50 ha, respectively equipped with a classic sprinkler system, a self-propelled ramp, and a center pivot system. Simulation of output gains was run for over 30 years. To make the technique profitable, the upper limit of investment is 2250 USD/ha for an output of 6 t/ha, 1740 USD/ha for an output of 5 t/ha and 1230 USD/ha for an output of 4 t/ha. This last alternative was therefore possible only with a self-propelled ramp. It is not clear whether the calculations took account of government subsidies.

Another economic study was undertaken by the AGR (1995) to identify which irrigation system (surface, sprinkler, center pivot, or linear pivot) was best for supplemental irrigation. This study took into consideration the initial investment to acquire the equipment, the annual amortization, operational costs and the average yield that can be obtained using supplemental irrigation. Water amounts to be used are 1500 m^3/ha split into 2 irrigations (each 75 mm/irrigation) for surface irrigation, 3 (50 mm/irrigation) for sprinkler, and 5 (30 mm/irrigation) for center pivot and linear pivot.

Initial investment and operational costs were estimated to be 460 USD/ha. The economic comparison is presented in Table 3.2.13. The highest revenue was obtained with sprinkler and the lowest with surface irrigation.

Rainwater conservation and crop management

In Morocco, as in other Mediterranean countries, rainfed zones are characterized by high evaporation. This water loss can vary, depending on soil texture and roughness, from 5 to 70% of annual rainfall. This loss represented 35-55% of total annual evapotranspiration for barley in Syria (Cooper, 1983), and 37-47% for wheat in Morocco (El Mourid, 1988). In Morocco, most of this water is lost during the beginning of the growing period of cereals when the soil is not yet totally covered by vegetation.

The amount of water lost by evaporation is influenced by soil and crop management. Unfortunately, most farmers wait until the first significant rains in order to prepare seedbeds and remove weeds. The use of conventional tillage (disking) in wet soils enhances evaporation and consequently, increases the gap between potential and actual yields. One alternative to conventional tillage is conservation tillage techniques. Among practices that have been tested in Morocco are the no-till (Bouzza, 1990 and Mrabet, 1997); minimum tillage (Kacemi, 1992); and chemical fallow, where weeds are controlled by herbicides.

The effect of no-till on soil moisture conservation is generally significant when plant residues are left on the soil surface (mulch). This technique also reduces the capital investment and time for tillage and seedbed preparation. Minimum tillage is practiced using implements such as a chisel and a sweep that till the soil without turning it over. Residues left on the soil surface in the case of no-till and minimum tillage play also an important role in rainwater interception and infiltration in the soil. Studies on chemical fallow showed

Table 3.2.13. Economic comparison of different irrigation systems under supplemental irrigation (AGR, 1995)

Irrigation system	Investment (Dh/ha)	Yield (q/ha)	Production cost (Dh)	Operational costs (per year)	Revenue (Dh/ha)
Sprinkler	17,000	50	12,500	6,400	6,100
Linear pivot	30,000	45	11,250	7,900	3,350
Center pivot	25,000	45	11,250	7,625	3,625
Surface irrigation	5,000	35	8,750	6,000	2,750

(1 $ = 10 Dh)

that this practice could allow conservation and transfer of up to 75 mm of rainwater to the following crop (Table 3.2.14).

Apart from conservation issues, greater water-use efficiency can increase and stabilize yields in rained areas. This can be achieved by the early planting to take advantage of the entire rainfall and help the plants escape terminal drought. It was shown that early planting increases water-use efficiency, water use and grain yield of wheat (Table 3.2.15).

Early weed control reduces competition from weeds and makes more water available to the crop (up to 50 mm) especially when the growing season is relatively wet. Early weed control can increase water use efficiency and grain yield of wheat (Table 3.2.16).

Table 3.2.14. Effect of no-till and minimum tillage on soil water storage and fallow efficiency (Bouzza, 1990)

Technique	Water storage (mm)	Fallow efficiency (% of rain)
No-till	75	21
Minimum tillage	35	10

Water-use efficiency, yield and yield stability can be also be increased by using varieties that can resist drought events. It was shown that well adapted varieties had the following characteristics: earliness at heading and maturity, early growth (early soil covering), high grain growth rate and translocation of assimilates from the source (vegetative organs) to the sink (grain) under drought, kernel number stability, and maintenance of transpiration late in the life cycle of the crop. Among varieties that resist drought are Merchouch 8, Kanz, Achtar and Amira for bread wheat and Marzak, Oum Rabia, Yasmine for durum wheat and Tamellalt, Aglou and Taffa for barley (Karrou and El Mourid, 1993).

Conclusions

- Morocco has developed a new strategy and outlined new laws to encourage agricultural development. Nevertheless, implementation of this strategy has to be accelerated in responses to the challenges of drought and water scarcity.
- Supplemental irrigation and other drought mitigation technologies have been demonstrated and proven at research level, but their transfer and use at the farm level remain low.

Table 3.2.15. Effect of planting date on water use efficiency (WUE), water use, and grain yield of wheat (Bouchoutrouch, 1993)

Planting date	1984-85 (384 mm rain)			1985-86 (286 mm rain)		
	WUE kg/mm	Water use mm	Grain yield kg/ha	WUE kg/mm	Water use mm	Grain yield kg/ha
Nov: 1st week	9.8	286.0	2801	12.2	295.0	3570
Dec: 1st week	7.2	251.0	1818	12.8	285.0	3630
Jan: 1st week	6.1	226.1	1375	6.0	244.0	1470

Table 3.2.16. Effect of weed control on water use efficiency (WUE), water use, and grain yield of wheat (Tanji and Karrou, 1992)

Weed control	1986-87 (203 mm rain)			1987-88 (469 mm rain)		
	WUE kg/mm	Water use mm	Grain yield kg/ha	WUE kg/mm	Water use mm	Grain yield kg/ha
Weed free	6.80	161	1085	9.58	316	3021
Weedy	5.51	182	994	2.66	366	931

- Supplemental irrigation has been considered as a single technique and not as a system. More studies are needed to develop agronomic packages to be used in combination with supplemental irrigation.
- The effect of supplemental irrigation (as a system) on water productivity, environment preservation and socioeconomic aspects needs to be studied.

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Chapter 4

Irrigated Agroecosystems

4.1 Characteristics of Irrigated Agriculture with Emphasis on Water-Use Efficiency in Egypt

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Introduction

Amongst natural resources in Egypt, water is the most critical. Scarcity and misuse of freshwater pose a serious and growing threat to the sustainable development and protection of the environment. Water resource management and water availability are critical issues, politically, socially and economically (Harsh et al., 1989; Krug, 1989; Medany et al., 1997). There is growing competition between domestic, industrial and agricultural use for limited freshwater sources, fuelled by population growth. Simultaneously, water resources are affected by increasing pollution.

A realistic approach will be to focus on improving management and allocation practices; upgrading and modernizing the water delivery system; and establishing a framework for water management functions that can accommodate future technical advances, and takes into account education tools, economics of application, and environmental issues.

During the next 25 years, substantial quantities of freshwater supplies will be diverted from agriculture to industry, tourism, and households. Efforts must be intensified to collect essential water databases, organize them into usable and accessible form, and disseminate them to all stakeholders in water management.

Engineering studies and system management are required before recommendations can be made for selecting the proper irrigation system, integrated crop management (ICM) plans and planting dates. From an agronomic standpoint, all irrigation methods that maximize crop production are equally important. However, irrigation efficiency will depend on soil type, crop species and climate. Poor ICM and unsuitable planting dates, or unsustainable delivery systems will lead to yield reduction.

The use of high-value crops and water-saving techniques such as protected agriculture and soilless culture may be important future components of a sustainable and economically viable water management system in Egyptian agriculture.

Climate and Major Weather Parameters, Soils and Other Parameters in Irrigated Areas

Climate and water resources

Egypt extends between latitudes 22-32° N and longitudes 25-35° E, with long costal areas on the Red Sea and the Mediterranean. It has a total area of about 1,002,000 km^2. The main agricultural area does not exceed 3.3% (3.5 million ha) of the total area and is confined to the narrow strip along the river Nile from Aswan in the south to Cairo in the north; plus the Nile Delta which covers the area from Cairo to the Mediterranean shoreline between the cities of Damietta in the east and Rosetta in the west.

The weather is hot and dry in summer, and warm and somewhat rainy in winter. Table 4.1.1 illustrates weather parameters in some regions. Mean annual rainfall is 18 mm, ranging from zero in the desert to 200 mm/year in the north costal region.
The water resources in Egypt (Table 4.1.2)depend on the Nile. The country's

Table 4.1.1. Weather conditions in some Egyptian regions

Location	November to March			April to October						
	Temp (C°)		RH%	Rain (mm)		Temp (C°)		RH%	Rain (mm)	
	Max	Min	Av			Max	Min	Av		
Alexandria	25.0	15.8	16.5	69	179	33	21	22.5	69.0	13
Suezs	24.5	12.5	17.0	66.5	18	31.5	19.0	25.0	60.5	5
Cairo	25.5	16.1	17.5	60.0	22	34.0	20.0	22.5	58.0	1
Sharkia	33	3.9	19.3	55.4	0.7	45.0	16.0	26.5	43.9	2.8
Asyout	23.5	9.5	15.5	65.5	6	34.0	18.5	25.5	45.5	1.0
Aswan	26.5	13.0	19.0	37.5	-	38.0	22.5	29.5	29.0	3

annual abstraction from Lake Nasser is limited to 55.5 billion m^3 according to the 1959 agreement between Egypt and Sudan. However, there is about 200 mm of winter rainfall along Egypt's northern coast, allowing some seasonal agriculture. Rainfall decreases southwards, leaving little chance for rainfed agriculture beyond the coastal belt. Groundwater aquifers in the Western Desert and Sinai are mostly deep and nonrenewable (El Quosy and Ahmed, 1999).

It is expected that water demand, particularly for agriculture (which consumes over 85% of total available water), will increase sharply in the future. The gap between supply and demand will widen, with a projected deficit of almost 21 billion m^3 by the year 2025. The country has to take harsh measures to cover this deficit:

- Implementing Upper Nile projects to reduce evaporation and seepage losses; development of low-cost desalination methods for brackish water.
- Improving water-use efficiency both irrigation, domestic and industrial use. Agriculture, being the largest consumer, should be the major target, e.g. through rehabilitation of conveyance and distribution networks, use of modern irrigation systems wherever possible, recycling of land drainage and treated wastewater, change of cropping patterns, use of short-duration varieties, use of varieties

Table 4.1.2. Egyptian water resources up to year 2000.

	Water quantity (106 m^3)
Releases from Aswan Dam	57.9
Productive use	46.9
Municipal	3.5
Industry	1.4
Old land consumptive use	35.1
New land consumptive use	3.9
Power and navigation	3.0
Losses	11.0
Sea and terminal lakes	10.0
Evaporation and seepage from canal	1.0
Nile water use efficiency	81%
Irrigation efficiency	67%
Cropping intensity	200%
Crop consumption use	2269 m^3/ ha
Rain	1.4
Aquifer	3.6
Total	**62.5**

Source: Hanna and Osman, 1996

tolerant to drought and low water quality, etc.
- Conservation of water bodies through better pollution treatment on one hand; and the use of separate conveyance networks for low-quality water on the other hand.

Therefore, irrigation has to be protected in order to grow crops. Drip irrigation was introduced in the early 1970s, and several foreign and national companies constructed irrigation projects in Egypt. Drip irrigation is being used successfully to grow crops on newly reclaimed areas in the western and eastern deserts.

In April 1997 the government published its socio-economic development plans for the next 20 years. The cabinet documented a 5-year plan which aims to expand the percentage of Egypt's surface area which is populated from 4% to 25% by establishing new industrial and agricultural communities in Sinai and the New Valley of the western desert.

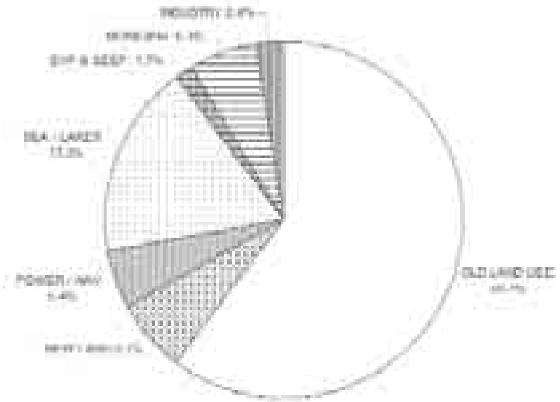


Figure 4.1.1. Water consumption pattern in Egypt (source: USAID, 1987)

Soil properties

The classification of irrigated areas in Egypt is illustrated in Table 4.1.3.

Irrigation methods

The following methods of irrigation are common in Egypt:

- Conventional surface methods: surface irrigation for over 80% of Egypt's irrigated area.
- Modern and sprinkler irrigation methods: sprinkler systems significantly reduce the number of operators directly involved, and thus protection measures can be enforced more easily compared with conventional hand-operated or portable sprinkler systems.
- Drip irrigation systems: might be potentially suitable for irrigation with effluents, particularly if the common problem of clogging can be prevented by filtration.
- Bubbler irrigation: a localized irrigation technique with regulated flow, developed for irrigation of fruit trees; it performs better than trickles and mini sprinklers.
- Sub-surface irrigation: allows water to be supplied to the root zone, thus reducing evaporation losses from the soil. It also facilitates proper management, and can help prevent deep percolation beyond the root zone.

Table 4.1.3. Classification of cultivated soils depending upon productivity (1000 ha) during 1976-95.

Prod. Class	1976-80		1981-85		1986-90		1991-95	
	Area	%	Area	%	Area	%	Area	%
First	884	38.3	1329	25.8	332	12.5	1026	31.26
Second	899	39.0	885	35.2	1243	46.7	1229	37.44
Third	384	16.7	205	8.1	768	28.9	579	17.64
Fourth	98	4.3	76	3.0	231	8.7	142	4.32
Fifth	41	1.8	24	0.9	87	3.2	307	9.34
Total	2306	100	2518	100	2661	100	3282	100

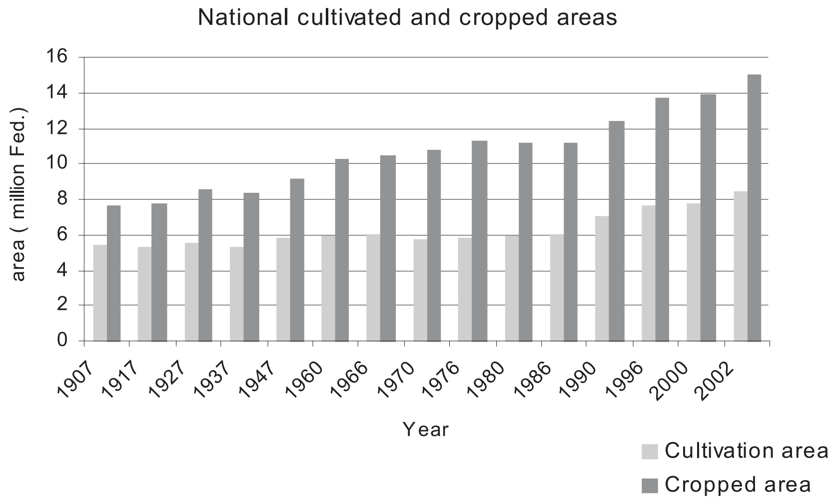
Source: Alaam, 2002

Irrigated Cropping Systems in Egypt

The extent and location of irrigated agriculture

The agricultural land base of Egypt totals about 3.5 million ha. Old lands represent 75% of agricultural area, and new lands 25%. The following points should be considered:

- Demand is higher than the production capacity of currently cultivated areas. Consequently, per capita cultivated area has declined from 0.48 to 0.12 (1fed. = 0.42 ha) between the years 1907 and 2000. Similarly, per capita cropped area has declined from 0.68 to 0.21 feddan (Fig. 4.1.2).
- About 82% of cultivated areas lie in the old land of the Nile Delta and Valley. The remaining 18% represents expansion into irrigated soils during the period 1982-96.
- National cultivated area increased by 355,000 ha during 1976-90, but high quality soils decreased from 38% to about 13%. This might be due to rising water tables, poor drainage, soil degradation, intensive cultivation, chemical fertilizers, pesticide over-use, and construction of housing on agricultural soils.



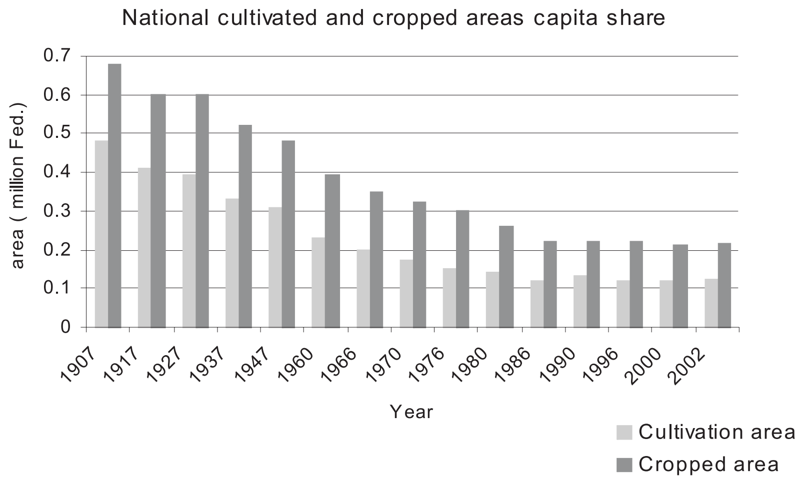


Figure 4.1.2. National cultivated and cropped areas during the period 1907-2002 (1 fed. = 0.42 ha). Source: CAPMAS, 2000 and Agricultural Statistics, 2002

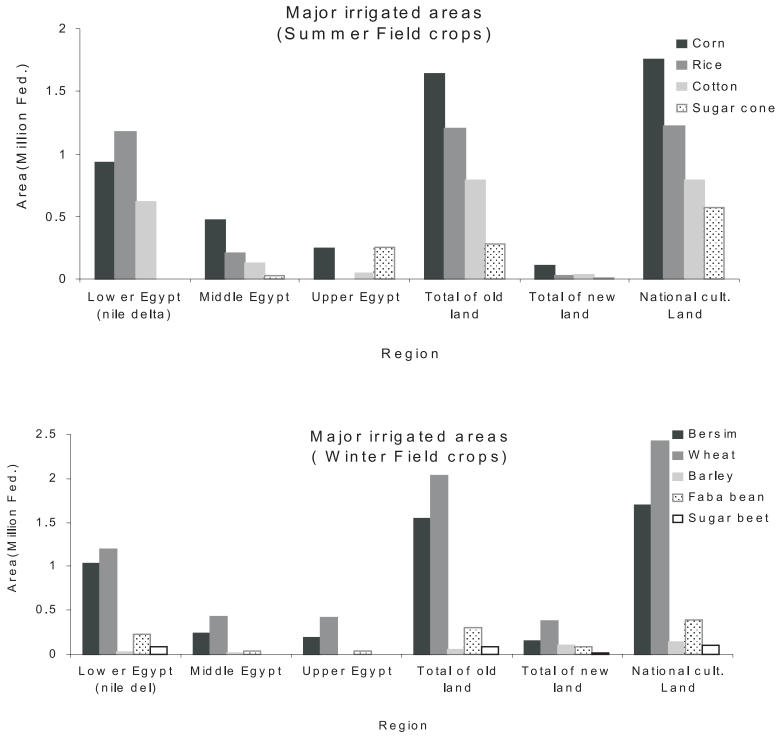


Figure 4.1.3. Major irrigated areas, and their main summer and winter field crops in 2002 (1 fed. = 0.42 ha). Source: Agricultural Statistics, 2002

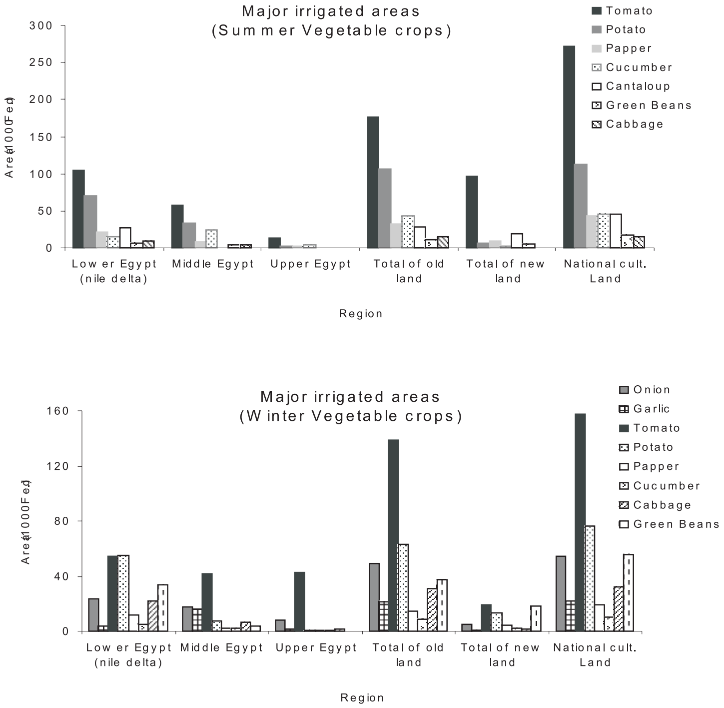


Figure 4.1.4. Major irrigated areas, their main summer and winter vegetable crops in 2002 (source: Agricultural Statistics, 2002)

Cropping systems and patterns

The annual total cropped area is estimated at 6.3 million ha (2000), giving a cropping intensity of about 180%. Crop production contributes about 68% of agricultural GDP. Field crops account for about 66% of the total crop production value; vegetables and fruits are estimated at 17% and 15%, respectively. Both winter and summer crops may be irrigated. Figs. 4.1.3 and 4.1.4 show the main irrigated areas, and the major crops in each.

The main features of cropping systems and patterns in Egypt are as follows:

- Due to the different environmental conditions (soils, climate, availability and quality of water), there are two main cropping systems a year, namely, winter and summer cultivation. The agricultural calendar starts on 1 October.
- The main summer crops are corn, rice, cotton, sugarcane and some vegetable crops such as tomato, potato, cucumber, cantaloupe, pepper and green beans. The main winter crops are bersim, wheat, barley, faba bean and sugarbeet, as well as onion, garlic, tomato, potato, and cabbage.
- Under the privatization and open market policy, farmers are free to choose which crops to grow.
- Irrigated areas comprise both old and new land; the latter lies outside the Valley. The old land region consists of Lower Egypt (Nile Delta) and Valley, which included the Middle and Upper Egypt sectors.
- According to 1998 statistics, the national vegetables cultivated area is about 1.5 million Feddan (nearly 650,000 ha), producing 15.21 million tons in the three seasons, summer, winter and autumn.

Crop Yields and Water-Use Efficiency

Water resources problems are often associated with low water-use efficiency. Hamdy and Lacirignola (1999) reported that agriculture was the most important water-use activity. It is also probably the sector least efficient in water use. Low irrigation efficiency is primarily due to water mismanagement, in addition to technical problems of conveyance, distribution, or on-farm application; as well as poor maintenance of irrigation structure. The phrase "efficient water use" or "water-use efficiency" is intrinsically ambiguous in relation to crop production. It may mean saving water from a given supply for crop use, or increasing production per unit of water evaporated from soil and/or transpired from the plants in the field (Abou-Hadid, 2002).

For agronomists, Gregory (1991) reported that water use efficiency is commonly defined as:
WUE = Yield per unit area/ Evapotranspiration m^3

Abou-Hadid (2002) summarized the main factors affecting water use efficiency as follow:

- Water delivery system.
- Irrigation system.
- Crop shape and morphology.
- Climate factors.
- Management options.
- Economic considerations.
- Techniques for predicting yield.
- Social and political factors.

Attributing WUE values to the unit of irrigation cost is one method of describing the efficiency of producing crops by using irrigation. In this case, the resulted value is known as "Economical Irrigation productivity" (EIP) (El-Gindy, *et. al*, 2001). PIE, which is expressed as kg/LE, describes the relationship between crop yield and water consumption in economic terms.

Under Egyptian conditions the following points are important.

- WUE reflects the yield obtained per unit of water consumed during the growing season.

- National water consumption by irrigated crops in 1998 was estimated to be about 37.5 BCM, while nearly 60 BCM of water was used. Thus, average irrigation application efficiency (Ea) at the national level was 62.5% (Alaam, 2002).
- The dominant irrigation system in Egypt is surface irrigation, especially in the Nile Delta and Valley (i.e., in the old land); while pressurized irrigation systems are implemented in the new land.

For any crop, WUE differs among regions due to variations in both yield and consumptive water (CU). WUE values for old land (the main production area) are as follows: 1 m^3 of water produces 1.27 kg corn, 0.32 kg cotton, 6.26 kg tomato, 9.84 kg bersim, 1.38 kg wheat, 0.84 kg barley, 0.88 kg faba bean, 7.56 kg sugar beet, 5.56 kg tomato, 6.21 kg potato, 4.86 kg onion, 2.15 kg pepper, and 4.09 kg cucumber.

WUE and economic irrigation productivity for the main field crops and vegetables are shown in Figs 4.1.5 and 4.1.6. Higher WUE value means better water usage and less water losses under certain conditions. However, even with high WUE, the EIP value could be low, because of high irrigation costs. For example, while the WUE of winter tomato crop (6.5 kg/m^3) is higher than the WUE of cabbage (5.1 kg/m^3), the EIP of cabbage (135 kg/LE) is higher than tomato (124 kg/LE) under the same conditions. This is due to the higher irrigation cost of tomato.

WUE of vegetable crops grown under protected cultivation are significantly higher than the values obtained under open field conditions. For example, WUE of strawberry is 17 kg/m^3, cantaloupe is 29kg/m^3, tomato 16 kg/m^3, melon 24 kg/m^3, lettuce 59 kg/m^3, and cucumber 31 kg/m^3.

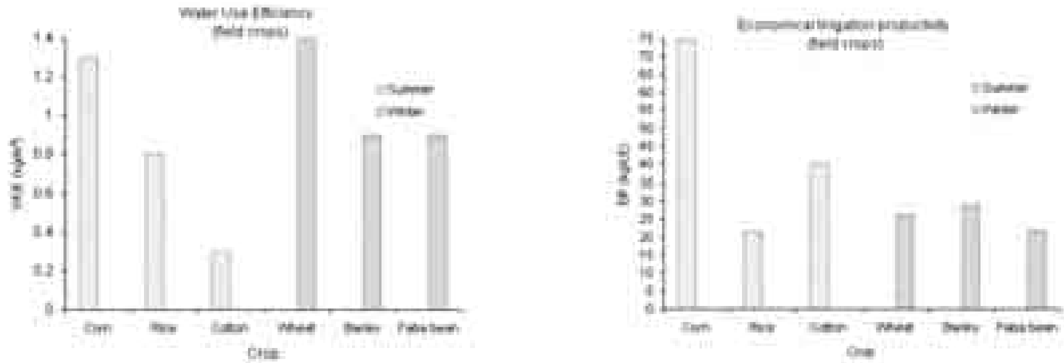


Figure 4.1.5. Water-use efficiency (WUE) and Economic irrigation productivity for the main field crops in major regions

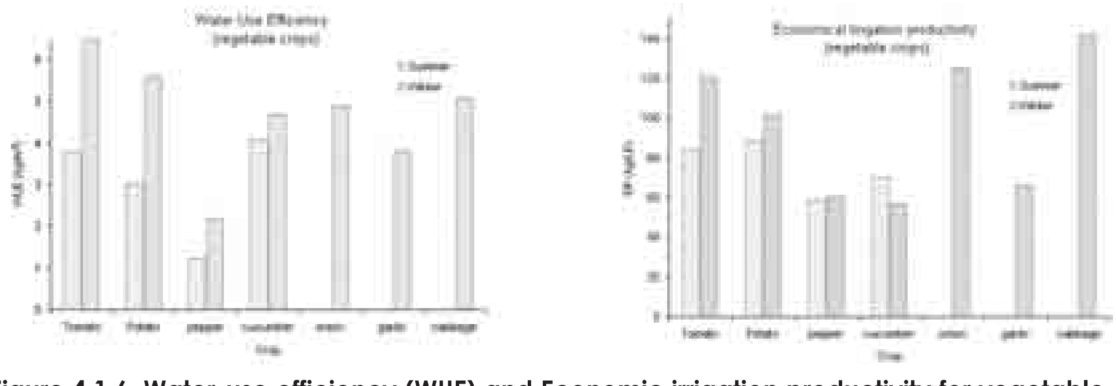


Figure 4.1.6. Water-use efficiency (WUE) and Economic irrigation productivity for vegetable crops in major regions (source: Agricultural Statistics, 2002)

Changing the crop pattern to save water

The proposed strategies are:

- Rice and sugarcane are the most water-consuming crops. Therefore, some areas of sugarcane could be replaced with sugarbeet, which requires less water.
- Reducing the rice areas to 294,000 ha, which is the minimum for protecting the Delta from seawater intrusion. This reduction in area along with the use of short-duration rice varieties, could result in savings of over 3.5 BCM per year.
- Decreasing the gap between the net return from winter and summer cultivation.
- Defining a crop pattern for each region according to climatic conditions, soil type and water availability – and penalizing offenders.

Salinity of water and land

One-third of Egypt's irrigated area is salt-affected with different levels and types of salts. These areas, which have very low yield potentials, lie mostly in the Nile Delta. Extensive salt-affected areas are cultivated with rice; which protects soils from severe salinity by leaching salts yearly. In general, cultivation of these areas also prevent seawater intrusion.

- Most of the Nile Delta and Valley have been provided with tile drainage systems which discharge into a network of open drains to keep the water table level below 1 m to prevent waterlogging and minimize salinization hazards.
- All drainage water of Upper Egypt is returned to the Nile river. Consequently, the total dissolved salts in the Nile is estimated around 120 ppm at Aswan, gradually increasing to 180 ppm at Cairo and further increasing through the Rosetta and Damietta branches (about 250 ppm).
- In southern Nile Delta, the shallow water table moves downward discharging into the aquifer and its salinity is higher than that of the groundwater. But in the northern Delta, groundwater salinity is higher due to the upward movement of seawater intrusion. Accordingly, drainage water salinity increases from less than 600 ppm in the southern Delta to about 600 ppm in some parts of the northern Delta (Amer et al, 1997).
- Irrigation methods and efficiency are directly related to excess water discharged into drains or stored in the soil profile.
- According to recent drainage monitoring data (DRI, 2000), the average salinity of reused drainage water in the Delta region was 1.76 ppm. The reuse potential presented in Table 9 was estimated on the basis that 75% of the available drainage water in the Nile Delta can be reused. The table is based on the average of 5 years, 1997 to 2002.
- Agriculture in the northern Delta is based on irrigation with saline water. The soils are generally clayey, slowly permeable, with a fluctuating shallow water table with different levels of salinity. Soil salinity buildup depends on irrigation water salinity, leaching fraction, and frequency of irrigation (Amer *et al.*, 1997).
- The new lands that are irrigated by wells (which are considered as non-renewable sources), are actually highly vulnerable to salinity problems, Salinity of the water is increasing by the increasing water depletion from the well, and this is affecting the irrigated soils.

Constraints to improved water-use efficiency

In 1990, Egypt reached the so-called water poverty line, i.e. 1000 m^3 per capita per year. This is expected to decrease to less than 500 before the year 2030 when

the population will be 100 million. The only available solutions for such a situation are: (i) add new water resources, (ii) improve the water management techniques to save wasted water.
The cultivated and cropped areas in Egypt are increasing over the past few years and will continue increasing due to the government policy to add more agricultural lands. The largest consumers of irrigation water are rice and sugarcane because they have high water requirements and also occupying large areas. On-farm irrigation from distributary canals is carried out in 80% of the areas by lifting. Gravity irrigation takes place only in Aswan and Fayoum Governorates. Almost all irrigation canals in the old lands are unlined. The problems connected to these types of canals are:

- Aquatic weed growth: emergent, submerged and floating weeds.
- Seepage from irrigation canals is a function of the water level in relation to the adjacent land levels and groundwater elevation. It is also a function of the soil type. Seepage rates are higher in distributary canals, which crack during the off-period, increasing water losses.
- Unstable and oversized cross sections are caused by sedimentation, erosion of canal banks by water scoring, and animal traffic.

Loss of agricultural land and deterioration of crop yields

With no changes in current trends in crop patterns and water use, agriculture will experience an intensifying loss in available land to waterlogging, salinization, and urbanization. Field water application efficiency values (the fraction of the water applied that is actually used, or transpired, by the crop) in Egypt are typically around 50%, i.e. about half of the water applied in the field is lost due to the inefficiency of flooding irrigation, which is low compared with the new irrigation systems. Drainage problems reduce crop yields by impeding aeration, leaching nutrients, and inducing water table rise, salinization, and creating the need for expensive drainage. Irrigation water quality is expected to deteriorate, resulting in a decrease in productivity. If this is the case, crop yields will decline notwithstanding the expectable improvements in varieties, fertilization and pest control. Especially vulnerable to the progressive degradation of land and water resources are the ill-drained areas of the lower Nile Delta that are already subject to land subsidence, water table rise, and sea water intrusion.

Research issues to improve water productivity at farm level

Use of weather data for agricultural development

There are several studies in Egypt on developing and modifying the utilization of climatic data in crop management (Abou Hadid, 1997), many by the Central Laboratory for Agricultural Climate (CLAC). CLAC was established to conduct research, training and extension activities related to agricultural climate, in cooperation with other institutes to serve the specific needs of different regions in Egypt.

The main objectives of the CLAC weather

Table 4.1.4. Maximum possible drainage water reuse in Nile Delta (BCM) (Agricultural Statistics, 2002)

Region	Available drainage water	Currently reused	Potential reuse
Eastern Delta	408365	204989	151902
Middle Delta	584914	200773	288106
Western Delta	381915	112356	238433
Total	1375194	518118	678441

data system are to develop water and fertilizer management, horticultural and field crops management, integrated pest and disease management, and appropriate planting dates in both old and new lands. This is to be achieved by introducing modified or improved irrigation systems for uniform water distribution, early prediction systems for insects and diseases, and accurate calendars for vegetable crops to maximize yield. Finally, it aims to provide information on the chilling requirement of deciduous fruit trees to allow growers to start management practices timely in relation to chilling hours.

The long term objectives include generating information related to:

- Greenhouse heating, ventilation and cooling systems.
- Animal and poultry farming including expected heat waves, possible flux of diseases, and water consumption in relation to animal farm management.
- Aquaculture systems: temperature, humidity, radiation and other factors affecting fish production.
- Policy making information system, to determine the best possible use of land and water resources for agricultural production.

IRRICLAC is a software developed by CLAC to calculate either daily irrigation requirement or irrigation scheduling for a growing season. The software has three major screens. The first deals with the crop and includes four major groups, vegetables, fruits, field crops and greenhouses. Selecting a crop-group, one can select the desired crop from a drop-list. Almost crops grown in Egypt are included and the list could be modified. From the plant age, or planting date, the program selects crop coefficient (Kc) and root depth as a function of time. The program uses the Penman-Montieth equation, and soon will be able to use more than ten different equations.

The second screen is related to location and includes the farm area to select the nearest weather station to calculate the potential evapotranspiration (ETo) for that location. It also includes soil type; the program selects soil field capacity and permanent wilting point, and then calculates the maximum amount of water that could be given to refill the soil-water reservoir down to a root depth. The program can estimate the frequency and amount of water needed for a given crop at a given location according to plant soil and crop age; i.e. how much and how often to irrigate. The last section is related to the irrigation system type, efficiency and discharge per unit length as well as distance between laterals. This section allows the program to estimate the duration of irrigation, i.e. how long to irrigate using the specific irrigation system. The software has options to run in Arabic or English, with capabilities to be adapted to other languages after translating a list of words from English during installation. A flow chart of data collection, processing and information distribution is shown in Fig. 4.1.7.

Role of the Ministry of Agriculture

- Change field layouts, furrow and size of the basins to improve irrigation efficiency.
- Land leveling in order to increase application efficiency.
- Suggest cropping patterns and provide new cultivars tolerant to drought and water salinity.
- Determine the optimum water requirement for field crops.
- Prepare irrigation schedules that match stream size and time to crop water requirements.
- Provide extension services that would optimize irrigation with other cultivation activities such as fertilization, subsoiling, gypsum application etc.
- Develop guidelines for water management practices with the participation of farmers.

- Estimate ET, crop and water needs for different crops in the old and new lands and under different irrigation systems.

Role of the Ministry of Water Resources and Irrigation

Mesqas are private property of the Water Use Associations (WUAs) which are responsible for its operation, maintenance and management. This includes the following activities:

- Purchase of pump to be used for single points lifting at the head of the *mesqa*.
- Operation and maintenance of the improved *mesqa* and the pumping plant.
- Irrigation scheduling among water users.
- Resolving disputes and conflicts.
- Developing financial plans, fees schedules and bank accounts.

Importance and degree of autonomy of WUAs

WUAs aim to create a much closer working relationship between water suppliers and beneficiaries. This can be reflected in:

- Reduction of financial and operational responsibilities of Ministry of Public Works and Water Resources.
- Improved *mesqas* that reduce evaporation and seepage losses and increase water delivery efficiency.
- Equity of distribution between head and tail reach farmers.
- Reduced size of canals by shifting from rotation to continuous flow, which can add to the area of cultivated land.
- Fewer pumps and lower pumping costs.
- Reduced irrigation timing and greater flexibility in irrigation.

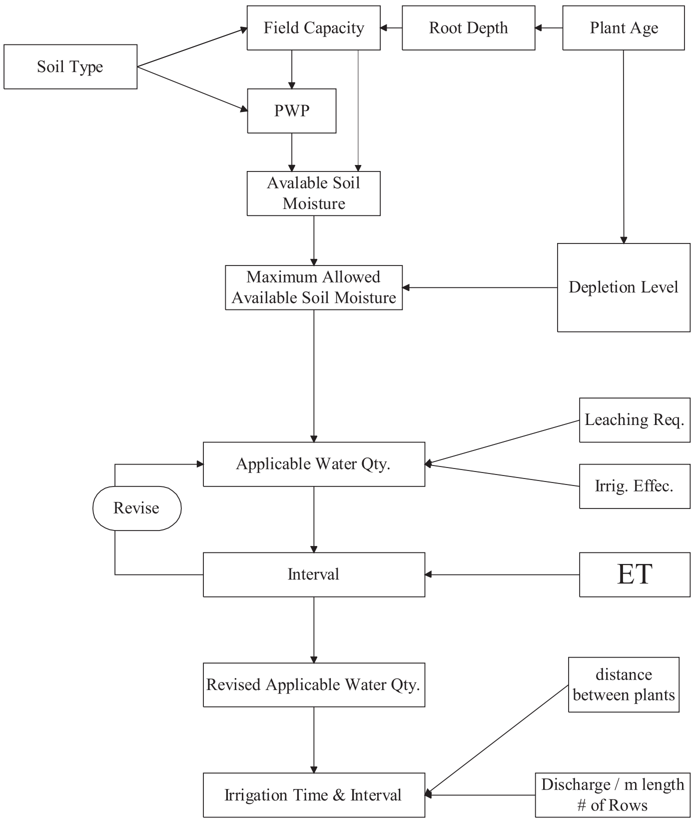


Figure 4.1.7. Flow of data for estimating of irrigation scheduling (Abou Hadid, 1997)

Government efforts to improve agricultural water management

Sugarcane water conservation

As part of the government's efforts to promote improved water conservation and management in Egypt, the MLAR and MWRI are working together to reduce the amount of water applied to agricultural production while maintaining high levels of productivity and improving farm incomes. Efforts have concentrated on the sugarcane crop because it uses the most water of any crop in Upper Egypt.

A minimum of 3 BCM of water is applied to about 1,050,420 ha of sugarcane (traditional irrigation of sugarcane averages 12,000 m^3 of water per feddan). To reduce the amount of water consumed, MLAR and MWRI staff, the sugarcane council, and sugarcane companies will work to develop and implement a policy of improved irrigation of sugarcane using less water while maintaining current levels of production.

In 1977 the sugarcane working group implemented a pilot program to install a piped on-farm irrigation system on 315 ha of privately owned sugarcane farms in the Governorates of Minia, Luxor, and Qena. The improved irrigation system is expected to reduce water application to between 8000 and 9000 m^3 per feddan, while maintaining current levels of production. The improved irrigation system has been shown to reduce water use for sugarcane by 20-25%, with yield increases of 10-25%, improved water quality and efficiency of water use, improved drainage, improved fertilizer efficiency, increased production area of land by up to 10%, improved weed control, and considerable time and cost savings associated with irrigation, such as less diesel to operate irrigation pumps and lower hired labor costs. The improved irrigation system requires farmers to substitute for the traditional system of flood irrigation used on all other crops in the Nile Valley, a more structured and efficient system including: subsoil plowing, laser leveling of the field prior to installation of pipes, installation of a new high-capacity water pump, and connecting main pipes to over-ground perforated pipes (PVC or aluminum) with valves to control water flow.

<u>Laser land leveling</u>: This can increase crops yields and save 10-15% of irrigation water. This technology was introduced in 1984 and has been expanding in Egypt on a large scale. The Ministry of Agriculture and Land Reclamation (MIRA) and Ministry of Water Resources and Irrigation (MWRI) are working together to enhance the technology of laser land leveling through private contractors and government rental stations. Laser land leveling is widely implemented in paddy fields in the Delta.

Irrigation Improvement Project (IIP)

The irrigation improvement project is designed to respond to the technology transfer challenge to improve water management for Egyptian farmers to meet two major goals: to increase agricultural production, and to save water by improved irrigation practices.

The OFWM demonstration program of IIP has been implemented since 1997. The demonstration includes laser land leveling, gypsum treatment, leaching, and various improved crop management practices. The IIP led to large improvements in the conveyance efficiency of the branch canals and *mesqas* (from 60% to about 90%) and in the uniformity of water distribution along the *mesqa*.

Conclusions

- Egypt is unique in that almost all cultivated land is under irrigation. Irrigation is the core factor in both agricultural production and the national economy.
- Greater efforts are needed to maximize usage of each drop of water.
- Two parallel programs are needed,

first to upgrade the conveyance efficiency of the irrigation channels network; and the second for effective on-farm irrigation management.

- The overall objective of effective on-farm irrigation management is to maximize yield per unit of applied water. This could be achieved through several means:

    - Accurate determination of applied irrigation water.
    - Irrigation scheduling should be based on actual plant water needs.
    - Irrigation method ought to be chosen depending upon local soil, water, crop and environment conditions.
    - Cultural practices for rationalizing irrigation water at farm level, such as good leveling and growing short-duration varieties, especially for crops like rice, with high water consumption.
    - Public awareness and water user association are vital to spread knowledge and technologies among irrigation stakeholders.
    - Use of marginal water (brackish) for crop production in desert areas and for city beautification and regreening (treated sewage water).

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4.2 Socioeconomic, Policy, and Institutional Aspects of Irrigated Agriculture in Egypt

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Background

Irrigated agriculture has been practiced in Egypt since the dawn of history. The ancient Egyptians established a system where the status of natural flow of the river Nile partly determined the level of taxes to be collected from citizens. The Romans exported grain from Egypt to most surrounding countries. Irrigated agriculture received a major boost during the rule of Mohammed Ali; in less than 40 years (1810-50), cultivated area increased from 2.5 million feddan (1 feddan = 0.42 ha) at cropping intensity of less than 100% to more than 5 million feddan with cropping intensity >150%. Progress was slower in the second half of the 19th century, but the country managed to establish a major development project, the excavation of the Suez Canal.

The beginning of the 20th century witnessed the construction of the Aswan Dam and a number of head regulators on the main Nile and its branches, namely Isna, Nag Hammadi, Assiout, Delta, Zifta and Edfina barrages. The construction of the High Aswan Dam in the mid 60s brought complete control of Egyptians on the Nile water.

Irrigated agriculture in Egypt is not only a business from which 40% of the work force earn their living. Nor is it not only the source of the country's food and natural fiber; agriculture in Egypt is a way of life. It has created the Egyptian charisma, hard work, ability to stand pressure, even their sense of humor.

Water Resources in Egypt

Egypt is the gift of the river Nile. The inhabited areas are only the floodplain of the river in the upper part, and the delta which forms the lower part. Life is concentrated in the Nile Valley and Delta, close to water. Egypt's share of Nile water is fixed according to an agreement signed with Sudan in 1959 (just before the construction of High Aswan Dam) at 55.5 billion cubic meter per year (bm^3/y). At that time the per capita share of water was almost 2000 m^3/y. This has dropped to less than 1000 m^3/y today. If the population grows at the current rate of about 2%, it will fall to 500 m^3/y by the year 2025.

Groundwater is the second resource, found in a number of aquifers – some of which are shallow, others are deep; some are renewable, others are not. Shallow aquifers include the one under the Nile Valley and Delta. It is fed by surplus irrigation water, and therefore considered more as a store rather than a resource. This aquifer is used for conjunctive use to supplement the irrigation of areas at the tail end of canals where shortage of water may take place occasionally, for fruit trees and/or vegetables. Withdrawal from this aquifer stands now at 3-4 bm^3/y. Shallow aquifers are also found in coastal areas where rainwater infiltrates sand dunes and stands in small quantities over saline water reservoirs.

Major deep aquifers are in the eastern and western deserts, they are mainly nonrenewable. Less than 1.0 bm^3/y is withdrawn from deep aquifers at the present time, expected to reach 3 bm^3/y in the near future.

Rainfall and flash floods are minor resources, however they are considered together with groundwater in the desert as a vital resource, because Nile water is not available. Use of desalination plants is growing because the conveyance of Nile water to the eastern and western ends of the country is proving more and more to be economically unfeasible.

Socioeconomic Aspects

Almost 50% of Egyptian farming communities live below poverty line. The obvious reason is that landholdings are so fragmented that the average holding is less than one feddan. The vast majority of landowners have less than one feddan. This is due to two main reasons:

- The agrarian reform adopted by the 1952 revolution which distributed the land owned by big landlords to landless farmers.
- The heritage system in which land is divided between sons and daughters when the father or the mother dies.

The second reason for farmers' low income is the cheap price of agricultural products. This is mainly because of the low income of average citizens, who cannot afford expensive food. The cheap output together with the expensive inputs creates a situation where farmers are subsidizing the national economy.

Farm inputs include seeds, fertilizer, pesticides, harvesting, picking, labor, energy (for lifting water) and more important the rent of land, which has increased very substantially during the last five years. All other inputs are not subject to any subsidy and they are all sold in the free market.

In such a situation it is fairly difficult to charge farmers for any other extras including water. On the contrary farmers enjoy subsidized bread, fuel, electricity and potable water like any other citizens.

Water Management: Policies and Strategies

Until recent times water management in Egypt was carried out in a very centralized fashion. The Ministry of Water Resources and Irrigation (MWRI), being the public body responsible for water distribution in the country, prepared and implemented dynamic water policies to cope with the rapid change in society's needs for water, particularly rapid population growth and the need to raise standards of living.

Working in close co-operation with the Ministry of Agriculture and Land Reclamation (MOALR), MWRI allocates water according to a water balance in which supply appears in the right hand side and demand on the left. The growing population puts more and more pressure on the demand side while the supply is fixed. The solution is always twofold: increased productivity per unit of water and increased efficiency of the water supply system.

In old lands, increased productivity per unit volume of water is managed though the introduction of subsurface drainage, land leveling, night irrigation, short-duration varieties, irrigation improvement projects, deep plowing, improved seeds, etc. These measures are called vertical expansion. Horizontal expansion is to add new lands reclaimed from desert areas. Since the construction of the High Aswan Dam, Egypt added new areas of 2 million feddan of desert lands located on the fringes of the Nile Valley and Delta. In 1997 the country's water policy called for the reclamation of 3.4 million feddan by the year 2017. By then the total cultivated area would be in the neighborhood of 11 million feddan, which can hardly be exceeded under present conditions.

Egypt is maintaining excellent relationships with the Nile Basin countries and the opportunity to develop water resources in the basin for the benefit of all the riparian countries appears to be promising. Increased efficiency of the supply system includes:

- Reduction of evaporation from Lake Nasser through efficient regulation of its operation rules.
- Reduction of losses from the conveyance network through canal lining, aquatic weed control, tightening of gates, reducing tail end losses, etc.
- Reduction of losses on the farm level by reducing surface runoff through land leveling and reducing deep percolation.

The fact that the water multiplier in Egypt has reached 150-200% is a major factor in increased efficiency. The overall efficiency of supply in Egypt is touching 75%, which is high for a gravity irrigated system. It is mandatory in newly reclaimed lands to use modern irrigation systems (drip and sprinkler). This partially increased efficiency. However, one of the major limitations of continuous reuse of water is soil salinization. The second limitation is the pollution of soil and water, which appears to be extremely difficult to control.

The MWRI has local offices down to the district level. The average area covered by the district offices is 30-40,000 feddan. Prolonged discussions are taking place to transfer the management of irrigation at its lowest level (*mesqa*) to farmers. Some 2000 Water Users Associations (WUAs) have been formed already. Some of them are functioning successfully. Further discussions are in progress on upgrading WUAs to farmer federations, which are composed of leaders of *mesqas* on the same distributary canal. Ambitious groups call for handing over to farmers, the management up to the level of irrigation districts. Opposition to these ideas is based upon the fact that going up the scale brings in other stakeholders such as potable water supply, fish farming and navigation, which makes the matter more complicated than farmers could manage. However, farmer participation is high on the government agenda and it is not expected to stop since the government can no longer manage at this very low level while simultaneously taking care of major aspects like development of water resources and pollution control.

Based upon the recommendations of international organizations, Egypt is strongly heading towards the application of integrated water resources management, demand management, cost sharing/recovery systems, and the reform of institutions from top to bottom.

Constraints to Improved Water Productivity

Rapid population growth is a major constraint to the country's development plans in all sectors. Agriculture is not an exception. However, even under existing circumstances there is still plenty of room for improvement. The major obstacles to this improvement are as follows.

Water allocation

Egypt has important relative advantages both with respect to individual activities and between different activities. The main advantages are the central location, the moderate weather and well educated and trained labor.

Concentration on common farm crops which can be cultivated anywhere else is against nature. Egypt should concentrate more on the production of vegetables, fruits, ornamentals, aromatics and the like. This can only be achieved with strong marketing policy, strong private sector, strong commercial ties, etc.
In terms of competition between activities, return of water from agriculture is small compared with activities like industry and tourism. A small portion of water transferred from agriculture can support large industrial and tourism activities.

Water valuation

One of the fixed policies of successive Egyptian governments is the rejection of the idea of water pricing. The reason is that farmers, being at the bottom of society, cannot afford any extra burden represented by water price, especially as they are subsidizing the national economy by selling fairly cheap farm products. Potable water as well as water supply to industry are sold at subsidized prices affordable to the average citizen. However, waste in water use in all aspects is clear. Using better tariffs – where minimum charge is imposed on small consumers and higher charge on large consumption – could be an incentive. The same applies to irrigation; this can be done by fixing a quota per feddan and charging for any extras. It is also necessary to impose penalties for water wastage either by deviating from the fixed areas and locations of water-consuming crops (rice, sugarcane and banana) or by applying excessive irrigation gifts.

Water pollution

Pollution is the major negative impact caused by unplanned urbanization and industrial extension. The solution is three-fold:

- Increase treatment capacity (potable water supply is far more than the capacity of sewage treatment plants).
- Reduce potable water supply and lower pressures until sewage treatment plants catch up with supply.
- Force industry to treat water locally inside factories.
- Separate freshwater networks completely from sewage or industrial effluent.
- The application of a "polluter pays" approach could solve the severe problem.

Water resources development

Only 5% of the Egyptian water budget is local, 95% comes from sources far from the country's boundary. Maintaining friendly relationship with Nile Basin countries helps in converting slogans on water wars into a shared vision and shared benefits. However, the possible alternative is desalination. The relative advantage in this respect is the extended coastline on the Mediterranean, Red Sea, and its two gulfs, the possibility of generating renewable energy (solar, wind, waves) and the existence of huge reservoirs of brackish water. These three factors may lower the cost of desalination to affordable levels.

Farmer participation

Farmer participation is very important aspect in better use of water. Although it is more than 20 years old since the idea was first implemented, progress is fairly weak. There are three reasons for this:

- Government is not offering sufficient support to young associations.
- Farmers are not clear of the benefits of the exercise, since water has no price.
- Service providers as individuals or organizations still do not exist.

Institutional reform

Egypt began the complete modernization of its water system only a few years ago. The existing central organization not only in the MWRI but also in other ministries and institutions needs to change in order to cope with the changes taking place. The first step to implementing integrated water resources management plans was the Irrigation Improvement Project (IIP) in which the old system in old land is renewed. Also, drainage projects were established, where over 4 million feddan are covered with subsurface drainage and more than 6 million feddan are covered with open drainage. The second step was to improve the software by introducing the Integrated Improvement Irrigation Project (IIIP) in which local offices will supervise irrigation, drainage, groundwater, survey and mechanical-electrical works within their districts.

Private-public partnership (PPP)

This is a major challenge to the irrigation system which is very central, very public and is supported by oldest bureaucracy in history. Unfortunately, water projects are not rewarding, offering small and long-term return. However, if water is valuated properly, PPP will certainly be in the center of events.

Public awareness

In order to transfer a society from being fully run by state and public authorities to private sector activities, it is necessary to change the mindset of the population. This can only be achieved through strong public awareness programs capable of slowly but surely taking care of this task.

Proposed Research Issues

- Integrated water resources management applied to old and new land in Egypt.
- Demand management as a tool for improved water resources management.
- Virtual water and its effect on local, regional and international water relationships.
- Desalination plants: can they contribute to alleviate water shortage in Egypt? What is the feasibility (both economic and social) of using desalinated water for different activities (irrigation, industry, fish farming, domestic, etc)?
- Trade and cropping pattern reform and their effect on Egyptian irrigation.