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Harmonization and Integration of Water Saving options. Convention and Promotion of Water Saving Policies And Guidelines

(EU contract ICA3-CT-2002-10013)

Proceedings of the 5th WASAMED Workshop

Edited by

F. Karam, K. Karaa, N. Lamaddalena, C. Bogliotti

CIHEAM / IAMB -EU DG Research

Options Méditerranéennes

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B 59

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FOREWORD

Integrated water resources management includes a number of approaches such as integration of water sources (mainly ground- and surface-water sources); linkage of social and economic development and land and water uses within the context of watersheds, groundwater basins, and estuaries; decentralization of government services to local authorities, private enterprises, and communities; stakeholder participation in decision-making and involvement in project planning and implementation; integration of sectoral water demands; integration of water-resources planning and management into the framework of the national planning process; consideration of the needs of aquatic ecosystems for water; coastal-zone management; recognition of water as a social, ecological, and economic good; integrated management of water demands; contingency planning to mitigate the social and economic effects of natural disasters; conservation of soil and water; and prevention and reduction of pollutant discharges. These approaches take into account the interdependence among economic sectors and aquatic ecosystems. Their implementation is facilitated by the development of water data and information; the establishment of appropriate management authorities, such as financially independent river basin authorities; and public participation.

The 5th Wasamed workshop on "Harmonization and Integration of Water Saving options: Convention and promotion of Water Saving Policies and Guidelines" is the 5th of a series of workshops, which were organized in the last three years within the framework of WASAMED (Water Saving in Mediterranean Agriculture) Thematic Network, granted by the 5th Framework Program of the European Commission, and coordinated by CIHEAM-Bari Institute with the participation of more than 40 research and academic institutions and stakeholders from both private and public sector in the Mediterranean region.

The previous workshops addressed different thematic areas of water saving opportunities, from Water Use Efficiency & Water Productivity to Irrigation System Performance, and from Unconventional Water to Participatory Irrigation Management & Cultural Heritage. During these Workshops, the integration of technical, socio-economic, institutional and environmental sustainability concepts has always been taken into account and was the core of the discussion among international experts, researchers, decision-makers, end-users and other stakeholders operating in the relevant sectors.

The workshop represented a forum for discussion of different issues, such as (i) the combined effects of the integration of the different aspects of water saving opportunities, i.e., Water Use Efficiency & Water Productivity, Irrigation System Performance, Unconventional Water Use, Participatory Irrigation Management & Cultural Heritage, in order to help scientists, water professionals, users and policy makers to harmonize their actions and to build a conceptual scheme for the rational integration of different water saving options in local and regional agriculture in the Mediterranean, and (ii) the cumulative effects of single or combined implementation of water saving practices to larger scales (e.g. irrigation district, consortium, watershed, national basin, whole region) in order to estimate - at a relevant scale - the "saved water" yields that constitutes an essential information for the definition and implementation of any water reallocation strategies at regional and national levels;

This volume of Options Méditerranéennes is aimed to better describe the integration of water saving actions into a water management policy by drafting a logical framework for future policies and new guidelines for water saving in the Mediterranean. This logical framework shall aim at providing a tool for researchers, end users and decision makers for enhancing their capacity to analyse and to evaluate the effectiveness of the current water saving policies as well as to identify measures and priority actions for strengthening and improvement of integrated management policies for water saving in the Mediterranean agriculture.

INTRODUCTION

Despite the extensive efforts made by the Mediterranean countries to improve the use and management of water resources, concerns about the enormous growth in the demand of water and the increase of environmental degradation still rise. Concerted actions are needed to promote water resource management policies and to integrate them in a planning process framework. For this reason, commitments are urgently needed to implement coordinated actions that address problems related to water saving in a socio-economic and institutional development context.

Local-scaled approach proved useful when developing basic water saving methodologies, techniques or strategies, or when assessing their sustainability, showing "practical - evident" release of pressure on natural waters and advantages to poor-resources farmers. Equally, local-scaled private and public awareness, technology transfer, dialogue and participatory management are essential issues to create the knowledgebase necessary to launch water saving strategies at larger scale, or regional scale. Though small scale interventions may provide relevant information and practical experience on "saved water" yields, they may not necessarily apply on a national or international scale. In such circumstances the results of these interventions will only offer limited help to Policy and Decision Makers in drafting national and regional strategies and planning, particularly when called to develop efficient and democratic water reallocation. Moreover, the implementation of certain Water Saving opportunities could be proved successful in one location and fail in another location of the same catchement or, most likely, in another basin, due to environmental and/or socio-economic or cultural diversities.

Moreover, it becomes important to understand the cumulative effects of water saving through the combination of the different water saving. Creating awareness and understanding about the benefits of water-saving across the Mediterranean is therefore a major objective of this workshop.

Nowadays, there is also a need to formulate water saving strategies and action programs at larger scale, and to harmonize them with actions and programs implemented in other countries or in the Mediterranean region as a whole, in order to maximize the benefits of water management development. The integration of shared water saving policies includes also appropriate mechanisms of water management, and the establishment of water resources authorities, or other institutional arrangements. Regional programs that improve institutional capacity to manage water resources are also needed. However, the approaches and experiences gained in these areas still have to be transferred to a larger scale i.e. regional, catchments and trans-boundary basins scale.

To these concerns, abundant literature exists but its application still very limited throughout the Mediterranean region. Case-studies conducted in several countries need to be disseminated and, for this purpose, the workshop will provide a forum for exchange of experience and knowledge transfer. Nevertheless, there is need to understand how these knowledge and inputs can be pulled together and help scientists, water professionals and policy makers to enhance integration in new water saving and proper regionalization. A knowledgebase on the integration-combination of Water Saving opportunities based on the integrated-combined approach will be first built up on the base of the existing literature and research review (WASAMED knowledgebase of country information), and, then, it will be discussed-debated in the Workshop with the aim to identify the interactions and the impacts of water saving opportunities vs. environmental, socio-economic, agronomic and institutional factors. This will support the creation of different scenarios for water saving in the Mediterranean allowing decision makers, researchers and water managers to compare different solutions, to assess them and to propose the priorities for the on-ground implementation. Accordingly, a Logical Framework for the best water saving policies and the guidelines for their implementation need to be developed on both short-, medium- and long-term basis.

In this volume of Options méditerranéennes two different types of contributions are enclosed and organised in different regional and thematic sessions:

- Keynote papers, in which external and internal experts provided a scientific special note, derived from their past and ongoing research experience on the relevant issues of the workshop.
- Country reports, in which WASAMED partners provide an overview of their country experience accounting for the objectives and issues described above;

In order to maintain and build on the commitments of governments to sustainable water resources management, contained in the statements and agreements described above, the following actions are proposed:

- Strengthen water resources management through improved policies and information.
- Establish mechanisms to integrate water resources issues.
- Strengthen the capacity of countries to develop and manage water resources in the context of sustainable development.
- Improve integrated water resource management through socio-economic and regulatory mechanisms.

Integrated water-resources management should be linked to social and economic development and should address land and water uses and conservation. Water data and information programs must be strengthened to support integrated water resources management. The results and recommendations enclosed in this volume represent a kind of country information retrieved by the different partners in the project from existing literature and national databases. They also will help in reviewing, coordinating and updating national water policies, legislation, and institutions to guide the preparation of water-resources assessments and integration plans; and to promote the use of sustainable management practices to meet the growing needs for water and access to sanitary services.

Nicola Lamaddalena
Claudio Bogliotti
Fadi Karam
Kamal Karaa

KEYNOTE PAPERS

WATER MANAGEMENT IN ITS MEDITERRANEAN SOCIO-POLITICAL CONTEXT

Salvino Busuttil
President, Fondation de Malte, Malta

INTRODUCTION

In the concluding remarks to his fascinating account "Preziosa più del petrolio", Cosimo Lacirignola affirms: "confronted today with the dramatic evidence that water is a renewable but limited resource, we have to persuade ourselves that it supply has to be subordinated to the utility of its use in relation to the social and economic objectives to be reached. From institutions this process requires that the crucial knot of the fragmentation of responsibilities be untied and that the integrated management of water resources be generally applied".[1]

The thrust of the seminar, which brings us together today, is very valid in that, in keeping with contemporary concerns, it emphasizes the need for the education of the consumer even while providing guidelines and methods for water saving and proper water use in the Mediterranean. For although many areas of our regions suffer water scarcity – as we, in the island of Malta, are acutely aware – yet very often the shortages are due to poor consumption patterns, themselves sometimes to be attributed to inefficient distribution.

We have, for example, not fully appreciated that a fundamental characteristic of the Mediterranean climate is the temporal and spatial irregularity of precipitation. France, Italy and Turkey, taken together, receive one-half of all precipitation, with the southern Mediterranean accounting for only 13% of the total. Benoit and Comeau, in their masterly publication "Mediterranée: les perspectives du Plan Bleu sur l'environnement et le développement" calculate that renewable natural fresh water resources, both underground and surface, reach, in the Mediterranean as a whole, some 600 km^3 annually.

At this average level, the resource can be exploited intensely without affecting adversely the rights of future generations, on condition that severe climate change does not alter present supply. That supply is, however, not evenly distributed in that 85% of the resource lies in the North Mediterranean and in Turkey which, taken together, also produce 90% of water or about 475 km^3 flowing annually into the Mediterranean.[2]

Examined globally the hydrology of the Mediterranean does not, therefore, suffer primarily from supply limitations (except of course in some islands and arid or semi-arid areas), as much as from the nature of the demand, one that is unevenly distributed, badly managed, characterized by little or no education of the consumer, and with poor user-participation. One need only refer to the fact that, in the Southern Mediterranean some 80% of overall water use is devoted to agriculture to understand the enormous water limitations encountered in these countries for home and industrial uses.[3]

Other speakers at this seminar are addressing issues and proffering solutions related to the management of demand and through water saving, including water pricing, policies, economic and environmental externalities. You will also be evaluating the advantages and disadvantages of applying full economic cost as well as opportunity costs of potential changes in demand, especially in water irrigation.

The complexities of price mechanisms are such that one cannot prescribe an overall solution applicable to all Mediterranean person and at all times. Mediterranean decision-makers are under great pressure, especially through international agencies, to stabilize or reduce demand.

Policy guidelines varying from regulatory frameworks to water tariffs ensuring sustainable (and not just efficient) water use, strengthening public awareness and public participation can be useful factors

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[1] Cosimo Lacirignola: *Preziosa piu' del petrolio,* Mario Adda Editore, Bari 2000, p.131 (free translation). Dr. Lacirignola is the Director of the Bari Institute of CIHEAM (The International Centre for Higher Studies in Mediterranean Agronomy).

[2] See Guillaume Benoit and Aline Comeau "*Mediterranée: les perspectives du Plan Bleu sur l'environnement et le développement."* Editions de l'Aube Plan Bleu, Sophia Antipolis 2005. p 73.

[3] See, Atef Hamdy and Cosimo Laciringnola "*Coping with Water Scarcity in the Mediterranean: What, why and How?"* Bari 2005, p.555

in rationalising water supply and demand the latter, as stated earlier, rather than the availability of the resource, justly becoming the focus of management.

Suez, a major industrial French group, sees its mission as one where it should "imagine, conceive, execute and exploit systems and networks in the areas of energy, water, waste management and communication". Indeed, it describes its identity as "a world group of services, a player in sustainable development" equally active "in large industrial centres as well as in the poorest quarters of the planet".[4]

However, 'worthwhile' Suez's mission may be, (and of course, as a global player its first missionaries are its stake-holders), yet we cannot leave the management of demand, in the sustainable use of water, only in the hands of multinational or of international or regional inter-governmental or even non-governmental agencies without appraising water demand in its socio-political setting.

Thomas Naff stated, some fifteen years ago, that "in the Middle East, where aridity, scarcity and some of the world's most atavistic rivalries exist, it is an inescapable reality that there is little hope for the resolution of water-based conflict - or cooperation – until sustainable political settlements are put in place." Addressing a symposium on Jordan's water resources, held in Amman in 1991, Naff further added:" At the crux of the conflict in the region is the denial of a state for the Palestinian people; water is a keystone of this issue because it is integral to the other crucial factors of security, ideology, and politics". Not much has changed since then.[5]

Indeed, the Jordan Basin demonstrates the complex socio-political context which one must consider when examining water scarcity and its attendant problems. While, for example, eighty per cent of the Jordan River system lies in Jordan, Israel and the West Bank, yet Lebanon too is a riparian State. But some seventy per cent of the groundwater required by Israel is actually in the Occupied Territories, and with forty per cent of Israeli water demand met by the West Bank alone.

If the Road Map is to become a road to reality and not a cartographic curiosity, then Israel has to seek eventually alternative groundwater resources from elsewhere. And it is Lebanon, through its Litani River that could supply Israel. An agreement with Lebanon is consequently an essential element in an enduring Middle East settlement. Meanwhile, having stabilised its water demand Israel is at the same time considering reverse osmosis as a politically viable if economically expensive solution.[6]

Indeed, water demand in the southern and eastern Mediterranean, in particular, is bound to grow as a function of economic progress. Now, there are three main factors affecting the demand in conditions of relative water scarcity:

1) With a view to increasing agricultural export-oriented output, especially cash crops destined for northern European markets, most of the southern Mediterranean countries, while improving techniques have nonetheless to cope with rising irrigation demand.

2) Rural exodus and the attendant phenomenon of urbanization pressure is fuelling demand. Very often, that phenomenon transforms itself in peripheral slum or quasi- slum conditions where, paradoxically, a greater water supply is called for especially to improve hygiene, and at the same time, water distribution systems are relatively poor.

3) Expanding tourism presents yet another pressure on water demand.

We thus have a potentially explosive socio-political and socio-economic situation dictated by water scarcity. *Politically*, the available resources are inequitably divided among riparian countries with major river systems but with complex relationships which, in situations of quasi-belligerence, endanger the quantity and the quality of the flow from one country to another, the Tigris and Euphrates basins being the classical case.

Socially, domestic water demand is rising as living conditions improve. *Economically,* the recommended motors of growth in most of these countries are better irrigation, more industry and expanded tourism, all thirsty factors.

The Blue Plan scenario, referred to earlier, foresees that water demand in southern Mediterranean countries, notably Syria and Turkey, will go up by 1.7% annually between now and 2025, or over 25%

[4] See: "*Suez, rapport d'activite developpement durable 2001-2002*" Paris 2001, pp 1-3.

[5] Thomas Naff, *Water Scarcity, Resource Management and Conflict in Jordan's Water Resources and their Future Potential,* edited by Andrä Gärber and Elias Salamek, Amman. 1992

[6] Reverse Osmosis is being increasingly introduced in the Middle East; but its costs, especially for non oil-producing countries, remain high (as Malta has experienced). The eventual commercially-viable break-through to produce desalinised water through photovoltaic energy would change the picture dramatically.

for the period as a whole. During the same time span, in the Northern Mediterranean, particularly in Italy the demand is expected to stabilise or decrease (e.g. in Italy). [7]

Looking to the future the crux of the problem seems to lie in a situation where effective water management is, essentially for political reasons, conducted nationally whereas the supply is, in the southern and eastern Mediterranean countries, regional with cross-border management largely absent.

Even *within* certain countries, water management may be subject to de facto discrimination between one area and another, the text book case being the Aswan Dam which, while augmenting water supply and ensuring perennial irrigation, practically retains all the silt (97% of the 134 million tons normally carried by the Nile) in Lake Nasser, condemning previously irrigated zones to water penury.

Quantity apart, water quality often suffers as a result of somewhat egoistic or ill-advised management, inadequate irrigation techniques not unusually increasing salinity, in turn responsible for the irrevocable loss of million of soil hectares.[8]

If the management of water scarcity is related in a considerable way to the political parameters of the region, we have to see what can be reasonably proposed in the short-term, with perhaps more ambitious solutions for the longer term.

For Israel and Palestine, to which reference was made earlier, an equitable distribution of water accruing from aquifers and from the river Jordan is a sine qua non of the overall political settlement which of course, must also have, in a water context, the assent of Jordan itself. Till that full settlement is reached, hopefully in the not-too distant future, an Israeli-Palestinian water authority, with possibly international supervision to ensure equitability and compliance with agreed stipulations, could not only help to solve the contentious issue of water demand but spur Israeli-Palestinian cooperation in other areas.

Trans-frontier difficulties in other countries could be resolved through similar arrangements. Of the twenty or so instances of cross-border water problems, which account for 46% of all water flowing into the Mediterranean Basin, the most important are the Nile, the Orontes basin in the Near East and the Drin, Vardar, Strouma and the Maritza basins in the east Adriatic. All could benefit through a trans-frontier "authority" solution.

Such approaches would, of their nature, be temporary, man's political animalism prompting, over time, belligerence for hegemony even if it is 'only' water. What, undoubtedly idealistic at this remove, could alter radically and sustainability the political management of water resources in the Mediterranean would be the creation of an intra-Mediterranean water authority which would, possibly under international aegis, oversee supply and demand for all littoral and riparian states.[9] It would also be a useful tool to apply pan-Mediterranean water-saving devices.

To do so, one would have the states concerned agreeing to a join declaration that water constitutes, part of the common heritage of humankind; and that, in consequence, access to it is a human right. On such a preamble, one could produce a Mediterranean Convention on the Preservation and Conservation of Mediterranean Waters, whose compliance would be overseen by that Mediterranean Commission for Sustainable Development which has still to sustain its name and, more so, its mission.[10]

Mr Chairman, Ladies and Gentlemen, you may now be asking: "How does water saving come into all this"? It seems to me that paradoxically we can only save what we have. And hence although the implication of our deliberations, is to use less, we must emphasize that our responsibility, as administrators, and scientists, is, in the long run, (where we are all, still alive), to ensure that water, that enduring gift of life, survives sustainability for the perpetuation of our species.

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[7] The Blue Plan scenario forecasts that Maltese demand will decrease between now and 2025.Yet rain and underground water is expected to supply only 33% of Malta's needs, the rest to be produced by desalination. See Benoit and Comeau, op.cit. p.75.

[8] See Benoit and Comeau, op.cit., p. 82-83

[9] Evidently, a full "settlement" would eventually have to include non-Mediterranean States, e.g. Sudan for the Nile Basin.

[10] Reference is, of course, implied here to the model provided, *mutatis mutandis,* by the 1976 Barcelona Convention on the Conservation and Preservation of the Mediterranean Sea, and to the administration of the Mediterranean Commission for Sustainable Development through the U.N.'s Mediterranean Action Plan.

INDICATORS TO SUPPORT DEVELOPING A NEW PARADIGMA FOR IRRIGATED AGRICULTURE

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SUMMARY - Water saving is part of a wide process of adaptation of irrigated agriculture to a new era, where pressures from the society on an improved use of the water make evident several paradoxes. These refer to pressures for decreasing water consumption, paying the full costs of water, improving irrigation efficiency and maximizing water productivity. The ideas behind are essentially correct but they need a serious adaptation to local, real conditions, otherwise they consist in paradoxes as illustrated in the paper. To overcome these problems there is a need to develop and adopt new concepts and consequently new indicators relative to water use performances and to water productivity that support the development of appropriate strategies leading to a more efficient use of water in agriculture and to improved social and economic conditions of farmers. A set of these indicators is discussed in this paper, aiming at developing a new paradigm for irrigated agriculture.

Keywords: irrigation performance, water use indicators, water productivity, economics of irrigation.

INTRODUCTION: PARADOXES OF IRRIGATED AGRICULTURE

For millennia, civilisations developed in water scarce environments. The respective cultural skills are an essential heritage of those nations and peoples, and the humanity as well. However, progress in XX century questioned the traditional know-how, which has been often replaced by modern technologies and management imported from different environments and cultures. A water economic culture is following the technical one, which was introduced, sometimes imposed when the large irrigation schemes were built. Both technologies and management are generally imported from different cultural and institutional environments and their adaptation to local conditions has not always been successfully adopted or accepted by farmers. Management faces therefore difficult challenges due to the fact that irrigators have a perception of problems, practices and objectives different from the non-farmer managers.

The last century has known an increased intervention of governmental and state institutions in water management following the enormous investments made. Traditional institutions lost importance due to increased technical complexity of management and to political trends aiming at increasing the power of the governmental institutions relative to many aspects of the society, including water and land. New centralized institutions were created following such investments and introduced technologies. Nowadays, due to a generalized unsuccessful result of those institutional arrangements, participatory irrigation management is considered in different forms to solve the resulting problems

A turn in viewing traditional irrigation is starting in the international media (Fig. 1) where a new perception of advantages of traditional know-how starts to be evidenced. However, pressures on irrigation farmers are continuing

International Herald Tribune | 17
Saturday-Sunday, August 20-21, 2005

Past methods may be better adapted to local conditions

Old ways of water management spring up again in arid regions

Water-scarce India, too, weighs a return to ancient practices

Fig. 1. Titles of an international newspaper evidencing a new perception on the value of traditional know-how in the water resources area

Pressures relative to water use in irrigation are coming from an ever growing urban society that understands less and less the rural world and, particularly, the small farmers. These include:

Pressures to decrease water consumption

When these should be to control the water demand. Reducing water consumption means reducing crop evapotranspiration (ETc), which is not feasible since yield strongly relates to ETc. Other consumptive uses non directly related with crop yielding may be reduced but with strong technological investments with limited impacts. Controlling the water demand is generally feasible but, often, is not possible because farmers may not have access to technologies better then those they are using after centuries and that made their systems sustainable. Deficit irrigation is the most common approach to reduce demand. It is generally feasible for supplemental irrigation of cereals when decreasing the Gross Margins (GM) per unit land leads is associated to increased GM per unit of water used (El Amami et al., 2001; Zairi et al., 2003). Farmer incomes then reduce but remain higher than the income resulting when reducing the cropped area. However for many summer crops, e.g. tomato in Tunisia, when GM/ha decreases due to less water application the GM/m3 do not increase. It is then questionable to adopt deficit irrigation.

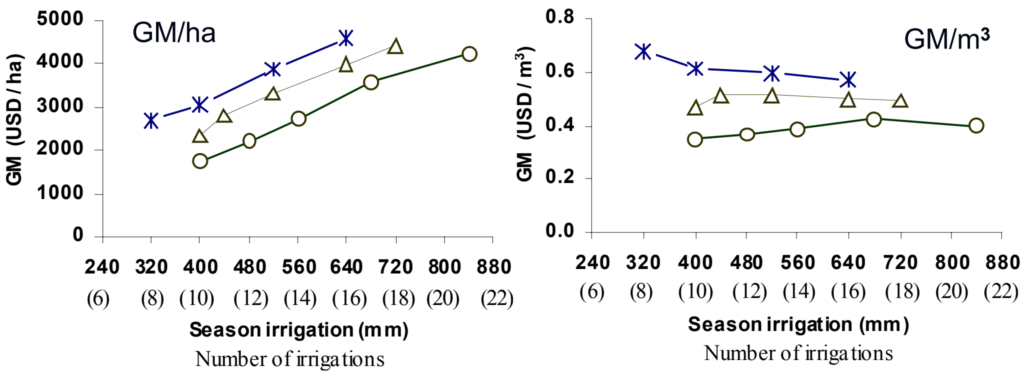


Fig. 2. Gross margins per unit surface (GM/ha) and per unit volume of water applied (GM/m^3) for alternative deficit irrigation strategies of tomato crop in Siliana, Tunisia, for average (—✳—), high (—△—) and very high (—○—) demand conditions (Zairi et al., 2003).

Pressures to pay the full costs of water

Often not considering impacts of yield prices and farmers' revenues and, more often, not taking into account the externalities of irrigation such as aquifer recharge and flood control. Impacts of water costs on water demand are very strong when common agricultural commodities are produced, but less important for high price commodities. Several papers demonstrate that such a high level of water costs would lead to not only a decrease in water demand but to a decrease in irrigated areas, farmers revenues and employment in agriculture as illustrated in Fig. 3 relative to a Portuguese case study by Pinheiro and Saraiva (2002). If the multifunctions of irrigated agriculture are recognized, the water is "fully" valued and farmers will pay what is socially and economically acceptable.

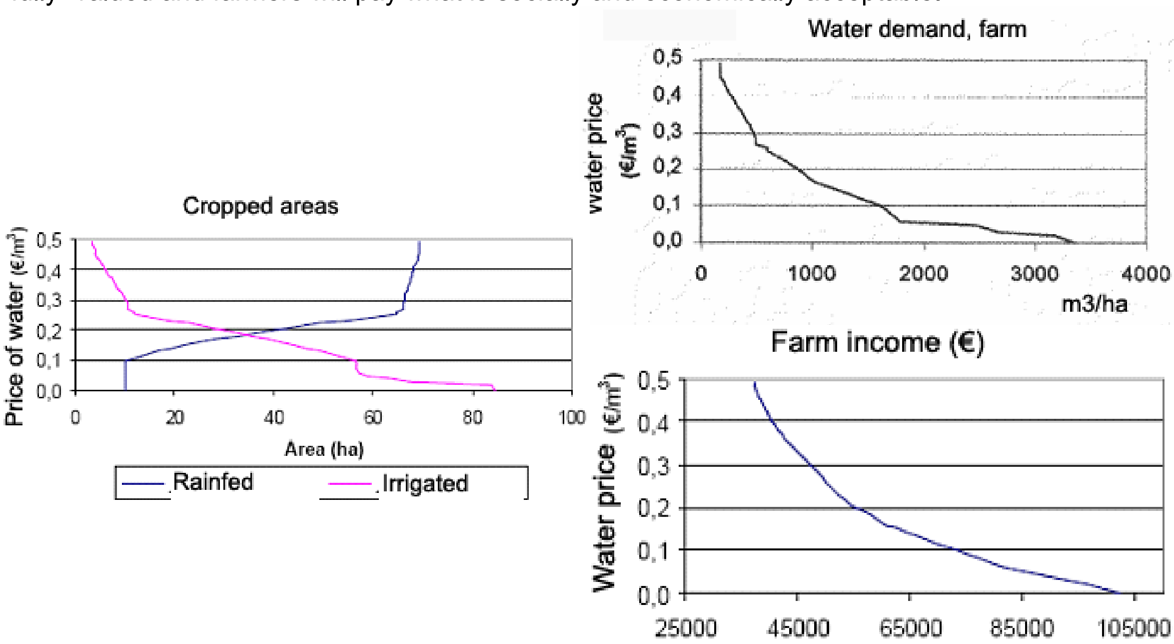


Fig. 3. Impacts of water costs on water demand, irrigated cropped areas and farmers' income in case of Alentejo. Portugal (Pinheiro and Saraiva, 2002)

Pressures to improve irrigation efficiency as considering that such an improvement would lead to water saving. This question is well discussed by many authors relative to the poor understanding that may be behind the concepts of irrigation efficiency (e.g. Jensen, 1996; Burt et al., Pereira et al., 2002a, b) or the impacts that occur at system and watershed level (Goussard, 1996; Bos et al., 2005). Farmers generally know they need to apply water in excess to leach salts, to store water in the soil when deliveries are not reliable, or to overcome the poor distribution uniformity of the system. The farmer will increase the application depth (D) as much as the risk for not having enough water at the next irrigation or as poor are the land conditions regarding uniformity of water application through the field.

It is well known that the depth D depends upon the technologies available as it is well analysed by Keller and Bliesner (1990) relative to sprinkler irrigation. Improving technologies to achieve a high uniformity - defined by the classical coefficient of uniformity (UC) – which could provide for approaching D to its optimal value Dopt is an economic decision. On the one hand, it depends on the costs of required equipments; on the other hand, it depends upon the relationship between the price of the yield commodity (PY) and the cost of the water (PW) as analysed by Mantovani et al. (1995). If the ratio PY/PW is high, i.e. the irrigation costs are a small fraction of the yield value, the farmer may not be interested in saving water and in achieving high uniformities; when that ratio is small, then irrigation costs are high and a strategy may be to use a system that provides for high UC (Fig. 4). However, if the required investments are high the strategy may be to irrigate another crop that provides a higher GM without such a costly investment.

Instead of putting the pressure on increasing irrigation efficiencies, it is more rational to look for conditions that favour improving irrigation uniformity.

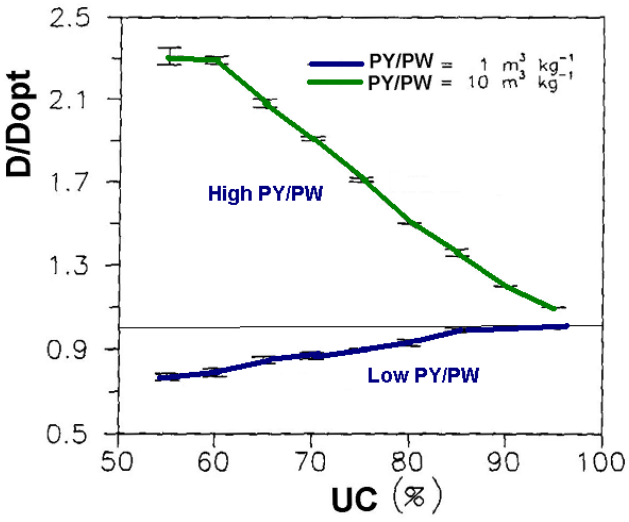


Fig. 4. Relationships between the application depth ratio D/Dopt and the coefficient of uniformity UC for conditions of high and low yield to water costs ratios (adapted from Mantovani et al., 1995)

Pressures for increasing water productivity, commonly said “more crop per drop”. Attaining a high water productivity (WP) in irrigation is extremely important (Molden et al., 2003; Shideed et al., 2005) but this may be achieved by improving agronomic practices and water use, not decreasing water use. Moreover, for a small farmer, for whom the limiting factor is not water but land, the priority is to increase land productivity (LP) because the total revenue depends on the available land.

There is a contradiction between water and land productivity that is solved differently by a water manager, who calls for Max(WP) and a farmer which primary objective is Max(LP). Maximizing yields, i.e. LP, or maximizing WP follow different objectives which relate to the socio economic farming conditions. A key issue is to know the relationship among “applied water” - “costs” - “revenues” (Fig. 5) as discussed in a previous paper (Pereira, 2006).

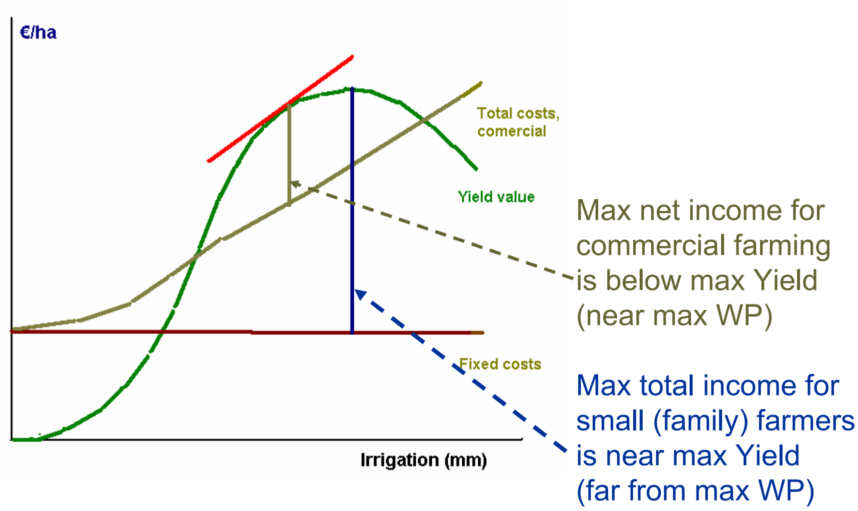


Fig. 5. Schematic representation comparing how maximizing farm incomes for a commercial and a family farm lead to different approaches to economic water productivity (costs relative to water volumes used are not considered for simplification) (Pereira, 2006).

WATER USE AND INDICATORS AIMED AT IMPROVED WATER USE

The objectives of irrigation demand management can be summarised as follows:

- *Reduced water demand* through selection of low demand crop varieties or crop patterns, and adopting deficit irrigation, i.e. deliberately allowing crop stress due to under-irrigation, which is essentially an agronomic and economic decision.

- *Water saving / conservation,* mainly by improving the irrigation systems, particularly the uniformity of water distribution and the application efficiency, reuse of water spills and runoff return flows, controlling evaporation from soil, and adopting soil management practices appropriate for augmenting the soil water reserve, which are technical considerations.
- *Higher yields per unit of water,* which requires adopting best farming practices, i.e. practices well adapted to the prevailing environmental conditions, and avoiding crop stress at critical periods. These improvements result from a combination of agronomic and irrigation practices.
- *Higher farmer income,* which implies to farm for high quality products, and to select cash crops. This improvement is related mainly to economic decisions.

Efficient water use in irrigation may be achieved through adopting best farming practices and appropriate irrigation technologies. However, technologies face a peculiar paradox: the market is oriented for commercial farms, not to small farms, when small producers largely dominate worldwide.

Excellent performances may be achieved with surface irrigation when land levelling and irrigation technologies are appropriate. A challenge is to provide incentives and support to farmers for improving their systems. The challenge is to make available the required tools and facilities that allow surface irrigation to produce an efficient water use. Modern sprinklers may produce excellent performances if design is adequate and the selected system is appropriate for the local environmental constraints and farming conditions. When micro-irrigation – drip, SDI, micro-sprinkling - are well designed and managed, performances can be excellent, but these are not achievable without appropriate support to farmers. Field evaluations in farmer fields, extensive use of design models such DSS, expert systems and Information Technologies for supporting farmers. These aspects have been previously reviewed (Pereira, 1999; Pereira et al., 2002a, b).

To solve the identified paradoxes and make irrigation viable also for small farmers there is the need to develop a new irrigation paradigm and adopt new indicators that support such paradigm. Water use indicators must be universal, not specific of irrigation, and supported by a logic analysis of water use paths such as in Fig. 6.

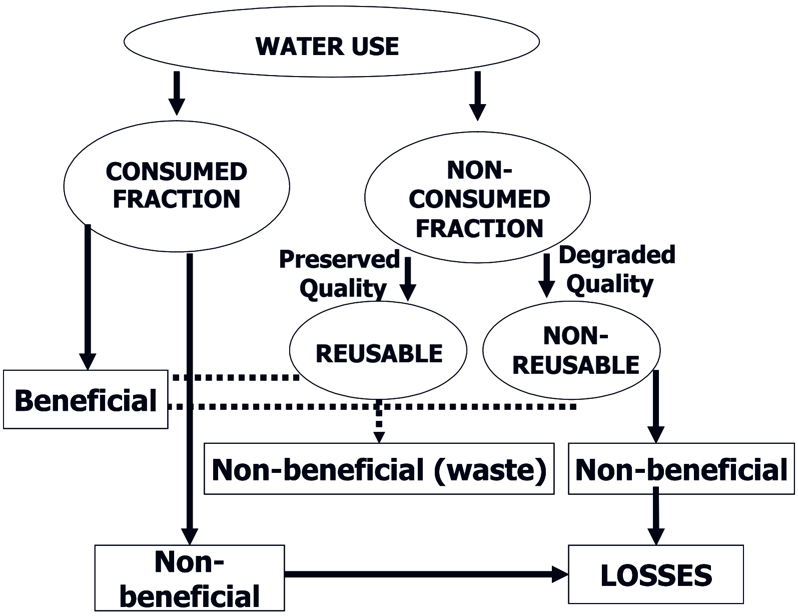


Fig. 6. Water use and consumption, beneficial and non-beneficial, wastes and losses

The scheme in Fig. 6 applies to irrigation and non-irrigation water uses such as for industry and urban uses (Pereira et al., 2002b). Relative to irrigation, it is more interesting than to know which water use is beneficial or not (Fig. 7) than to know if a system or an irrigation event is more or less efficient, or to know which and how much water is lost or can be reused in the farm or by other users downstream.

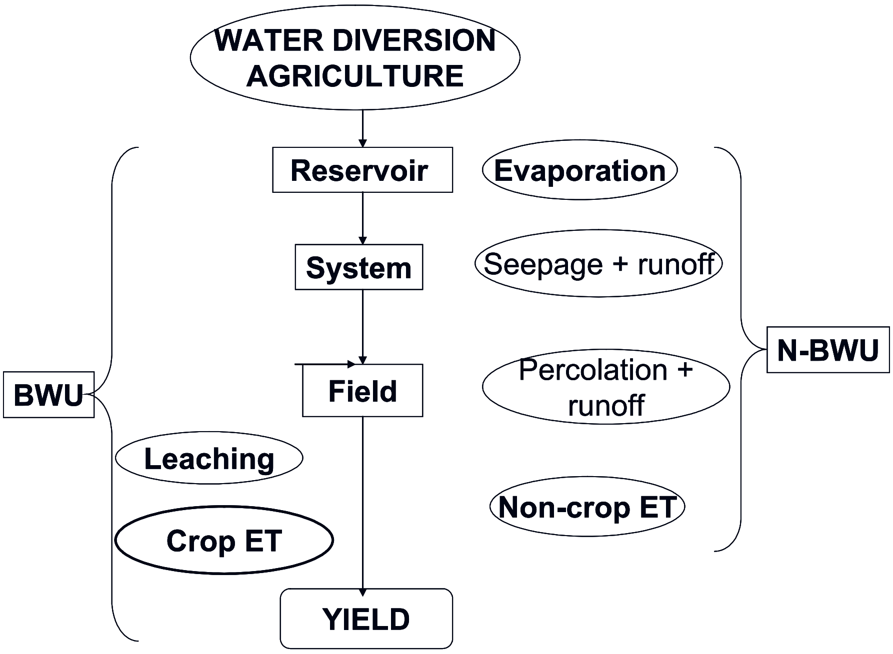


Fig. 7. Beneficial and non-beneficial water uses in irrigated agriculture

The logics of schematic representations in Figs. 6 and 7 supports new water use indicators (Pereira, 2003). These can be defined as follows for both irrigation and non-irrigation water uses:

The consumed or consumptive use fraction (CF), consisting of the fraction of diverted water which is evaporated or incorporated in the product, or consumed in drinking and food, which is no longer available after the end use. For irrigation water use it is

$$CF_{IRRIG} = \frac{E + ET_{crop} + ET_{weeds} + IN_{product}}{TWU} \qquad (1)$$

and for non-irrigation and non-agricultural water uses is

$$CF_{NonIrrig} = \frac{E + ET_{landscape} + ET_{weeds} + IN_{food} + IN_{product}}{TWU} \qquad (2)$$

where the numerator refers to process evaporation (E) and evapotranspiration (ET) and incorporation in products (IN) and the denominator is the total water use (TWU). Subscripts identify the main sinks of water consumption.

For both cases one should identify in CF the beneficial consumed fraction (BCF):

$$BCF_{IRRIG} = \frac{ET_{crop} + IN_{product}}{TWU} \qquad (3)$$

$$BCF_{NonIrrig} = \frac{E_{processes} + ET_{landscape} + IN_{food} + IN_{product}}{TWU} \qquad (4)$$

and the non-beneficial consumed fraction (NBCF)

$$NBCF_{IRRIG} = \frac{E + ET_{weeds}}{TWU} \quad (5)$$

$$NBCF_{NonIrrig} = \frac{E_{non\text{-}processes} + ET_{weeds}}{TWU} \quad (6)$$

The reusable fraction (RF), consisting of the fraction of diverted water which is not consumed when used for a given production process or service but which returns with appropriate quality to non degraded surface waters or ground-water and, therefore, can be used again:

$$RF_{IRRIG} = \frac{(Seepage + Percolation + Runoff)_{non\text{-}degraded}}{TWU} \quad (7)$$

$$RF_{\mathbf{NonIrrig}} = \frac{(Seep + Perc + Run)_{\mathbf{non\text{-}degraded}} + (Ret\ flow + Effl)_{\mathbf{treated}}}{TWU} \quad (8)$$

where the numerator consists of non-consumptive use processes that did not degrade the water quality, thus allowed further uses, including when the return flows (Ret flow) and effluents (Effl) are treated. As above, RF should be divided into a beneficial reusable fraction

$$BRF_{IRRIG} = \frac{(Runoff_{processes} + LF)_{non\text{-}degraded}}{TWU} \quad (9)$$

$$BRF_{NonIrrig} = \frac{(LF_{landsc} + Run_{proces})_{non\text{-}degraded} + Contr\ Effl_{treated}}{TWU} \quad (10)$$

which include water used for salts leaching, runoff necessary to the processes such as furrow and border irrigation, and controlled effluents (Contr Effl) required by non agricultural uses, as the case for many domestic uses. The non-beneficial reusable fraction (NBRF) is then

$$NBRF_{IRRIG} = \frac{(Seepage + ExcessPerc + ExcessRunoff)_{non\text{-}degraded}}{TWU}$$

(11)

$$NBRF_{NonIrrig} = \frac{(Seep + Perc + ExcRunoff)_{non\text{-}degraded} + Exc\ Effl_{treated}}{TWU} \quad (12)$$

and refers to excess water use in the processes involved such as seepage and leaks from canals and conduits, spills from canals, excess percolation in irrigation uses or excess runoff that are non-degraded, and effluents due to waste of water in non-agricultural uses when treated.

c) ***The non-reusable fraction*** (NRF), consisting of the fraction of diverted water which is not consumed when used for a given production process or service but which returns with poor quality or returns to degraded surface waters or saline ground-water and, therefore, cannot be used again

$$NRF_{IRRIG} = \frac{(Seepage + Percolation + Runoff)_{degraded}}{TWU} \quad (13)$$

$$NRF_{NonIrrig} = \frac{(Seep + Perc + Run)_{degraded} + (Ret\ flow + Effl)_{non\text{-}treated}}{TWU} \qquad (14)$$

which refer to the same process as the RF but where the water looses quality and not being treated can not be used again or is added to water bodies non-usable for normal processes, such as saline groundwater, saline lakes and the oceans. The NRF shall also be divided into a beneficial non-reusable fraction (BNRF)

$$BNRF_{IRRIG} = \frac{(Runoff_{\ processes} + LF)_{\ degraded}}{TWU} \qquad (15)$$

$$BNRF_{NonIrrig} = \frac{(LF_{landsc} + Run_{proces})_{degraded} + Contr\ Effl_{non\text{-}treated}}{TWU} \qquad (16)$$

and a non-beneficial non-reusable fraction

$$NBNRF_{IRRIG} = \frac{(Seepage + ExcessPerc + ExcessRunoff)_{\ degraded}}{TWU} \qquad (17)$$

$$NBNRF_{NonIrrig} = \frac{(Seep + Perc + ExcRunoff)_{degraded} + ExcEffl_{non\text{-}reated}}{TWU} \qquad (18)$$

An illustration of main processes of water use in irrigation referring to the above described water use fractions is presented in Table 1. The corresponding processes for non-agricultural uses are given in Table 2.

Indicators shall be used to assess how water use could be improved in any water system, not to detect low performances but to identify the pathways for improvement. Indicators must be selected according the nature of problems and processes in view of allowing a deeper understanding about measures and practices to be implemented and improved. This applies not only to irrigation but to any water use. The framework in Fig. 8 shows that indicators allow to identify the water use pathways and then which processes require improvements, including water productivity. In other words, indicators referred are meant to provide for efficient water use.

Table 1. Consumptive, reusable and non-reusable water fractions in irrigation water uses

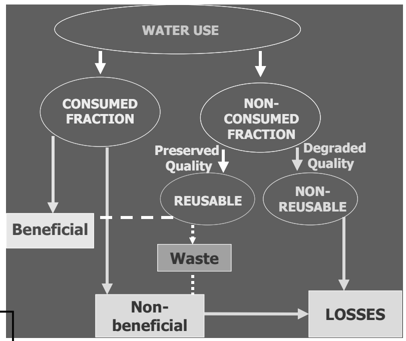
	Consumptive	Non-Consumptive but Reusable	Non-Consumptive and Non-Reusable
Beneficial uses	▪ ET from irrigated crops ▪ evaporation for climate control ▪ water incorporated in product	▪ leaching water added to reusable water	▪ leaching added to saline water
Non-beneficial uses	▪ excess soil water evaporation ▪ ET from weeds and phreatophytes ▪ sprinkler evaporation ▪ canal and reservoir evaporation	▪ deep percolation added to good quality aquifers ▪ Reusable runoff ▪ Reusable canal spills	▪ deep percolation added to saline groundwater ▪ drainage water added to saline water bodies
	Consumed fraction	**Reusable fraction**	**Non-reusable fraction**

Table 2. Consumptive, reusable and non-reusable water fractions in non-agricultural water uses

	Consumptive	Non-Consumptive but Reusable	Non-Consumptive and Non-Reusable
Beneficial uses	▪ human and animal drinking water ▪ water in food and drinking ▪ water incorporated in industrial products ▪ evaporation for temperature control ▪ ET from vegetation in recreational and leisure areas ▪ evaporation from swimming pools and recreational lakes	▪ treated effluents from households and urban uses ▪ treated effluents from industry ▪ return flows from power generators ▪ return flows from temperature control ▪ non-degraded effluents from washing	▪ degraded effluents from households and urban uses ▪ degraded effluents from industry ▪ degraded effluents from washing ▪ every non degraded effluent added to saline and low quality water
Non-beneficial uses	▪ ET from non beneficial vegetation ▪ evaporation from water wastes ▪ evaporation from reservoirs	▪ deep percolation from recreational and urban areas added to good quality aquifers ▪ leakage from urban, industrial and domestic systems added to good quality waters	▪ deep percolation from recreational and urban areas added to saline aquifers ▪ leakage from urban, industrial and domestic systems added to low quality waters and saline water bodies
	Consumed fraction	**Reusable fraction**	**Non-reusable fraction**

Pathways to improve water use

➢Identify the water pathways



Maximized beneficial uses

Minimized non-beneficial uses

Controlled, avoided water losses

High water productivity

➡ **Efficient water use**

Fig. 8. Pathways for efficient water use.

WATER PRODUCTIVITY

Water productivity (WP) was analysed in detail in a previous paper (Pereira, 2006) but, as evidenced in Fig 8, it has to be considered for any water use analysis. Adopting the framework defined in Fig. 9, main indicators should be referred,

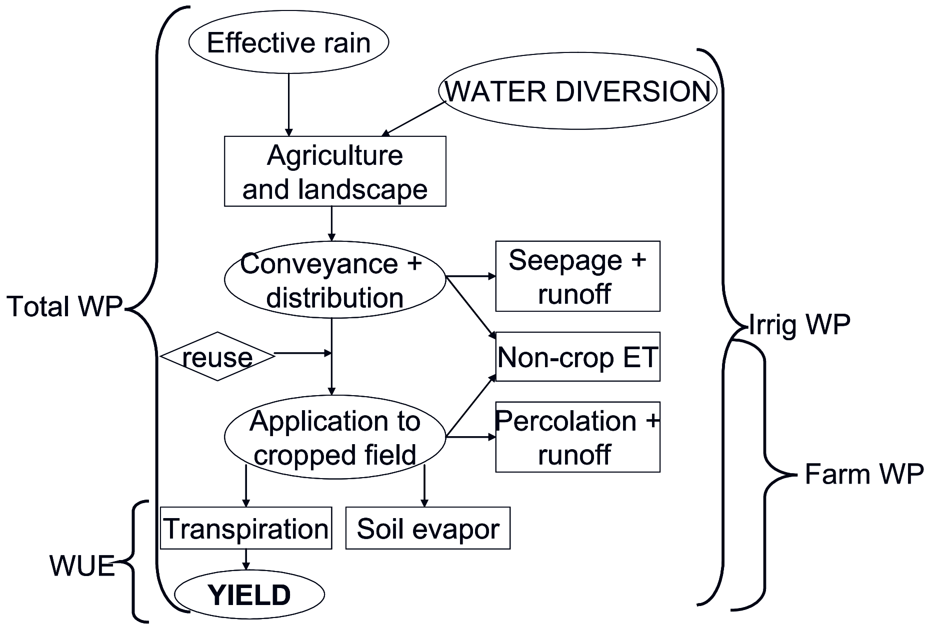


Fig. 9. A framework for defining water productivity in irrigated agriculture

WP is defined by the ratio

$$\text{Water poductivity} = \frac{\text{Actual yield}}{\text{Actual water use}} \qquad (19)$$

or, referring to the sources of water use

$$WP = \frac{Ya}{P + CR + \Delta SW + Irrig} \qquad (20)$$

where Ya is the actual yield, P is rainfall, CR is the cumulative capillary rise, ΔSW is the contribution from stored soil water and Irrig is the season irrigation depth. If considering the concepts defined above (see Fig. 7), WP is defined by

$$WP = \frac{Ya}{ETa + LF + NBWU} \qquad (21)$$

where the denominator is the sum of actual crop ET, the leaching fraction and the non-beneficial water uses NBWU with NBWU = NBCF + NBRF + NBNRF that are defined in the previous section.

In equations above it may be more interesting to replace the yield quantity by the yield value or by the gross margin resulting from that yield, which defines the economic WP (EWP), because the EWP is helpful to understand how much the farmers are able to pay for water.

Fig. 9 evidences that when rainfall is not considered WP refers only to irrigation water and should be termed irrigation water productivity (Irrig WP). If only the water applied at farm level is considered, then it becomes farm WP. When the objective is to analyse the plant or crop efficiency, then soil water evaporation is not considered and the ratio WUE = Yield/Transpiration defines the water use efficiency. However, since in the farming practice it is not possible to avoid soil evaporation, this concept of WUE is of reduced interest in water use analysis.

WATER USE AND ENERGY

Energy is main concern in the XXI century not only because mining the fossil energy sources may lead to problems in future but because energy uses are a main causes of emissions responsible for the climate change problems that we want to avoid in future. In addition, the energy prices are contributing to increase the costs of irrigation. Biodiesel and sunfuel are now products of agriculture and when hydrogen will become usable agriculture will also contribute for that energy source (Fischer and Finnell, 2006).

Because agriculture is both a consumer and a producer of energy, and irrigated agriculture is a high consumer while market conditions may bring opportunities for irrigated crops to be used for energy production, it is important to recognize how water use may relate with energy efficiency in crop production. Different from indicators above, which were proved in several analyses, indicators relative to energy are just an attempt to contribute for a rational use of energy in irrigated agriculture. The framework for defining the respective indicators is shown in Fig. 10 and it was developed similarly to water productivity concepts (Fig. 9).

There is, however, a problem of terminology. The term energy ratio was preferred relative to energy efficiency. Both are non-dimensional but while the first is neutral the second may imply some judgements or opinions. Of course, these concepts apply to any crop, whatever irrigated or non-irrigated.

The first term defined is crop energy productivity (EP_{crop}) and intends to show that a crop is an energy converter, particularly from sun but using other sources of energy. It represents the ratio between the fuel equivalent energy and the cropped area. It corresponds to the land productivity of any cereal or forage crop.

$$\text{Energy Productivity}_{\textbf{crop}} = \frac{\text{Energy in crop yield}}{\text{Area cropped}} \text{ (L diesel eq/ha)} \qquad (22)$$

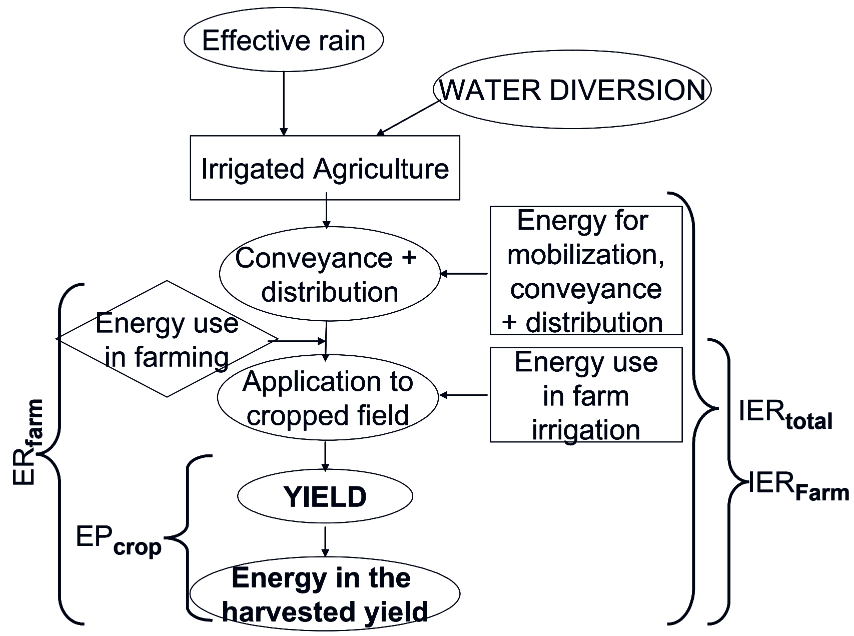


Fig. 10. A framework for defining energy performance in irrigated agriculture

The energy performance may be defined at farm level by the farm energy ratio (ER_{farm}) defined as

$$\text{Energy ratio}_{\textbf{farm}} = \frac{\text{Energy use at farm}}{\text{Energy in crop yield}} \tag{23}$$

or may be defined relative to an irrigated crop by the irrigation energy ratio (IER_{total}) referring to the ratio of energy used for the processes relative to irrigation, e.g. pumping and tractors usage in operations relative to irrigation

$$\text{Irrigation ER}_{\textbf{total}} = \frac{\text{Total energy in irrgation processes}}{\text{Energy in crop yield}} \tag{24}$$

It may be defined for all farming operations relative to the irrigated crops (IERfarm) irrigation or it may refer to just a given irrigated crop.

$$\text{Irrigation ER}_{\textbf{farm}} = \frac{\text{Energy use in farm irrigation}}{\text{Energy in crop yield}} \tag{25}$$

What is important at this time is to consider that improvements in water use require also the consideration of energy factors and that an efficient water use implies not only limiting water wastes and losses and high water productivity, but also a rational use of energy.

EXAMPLE APPLICATIONS OF WATER USE AND PRODUCTIVITY CONCEPTS

These concepts were adopted in studies developed for improved water use in irrigated agriculture of North China, and in Uzbekistan. For the analysis it was required to perform field studies at system and farm level and to use models that provide for a rational data analysis. DSS models were therefore developed since it was required to consider not only the physical results in terms of water use but also relative to economic impacts at farm level since the technical solutions have to be feasible for the main irrigation actors.

The case for China was recently presented in the framework of WASAMED as described by Gonçalves and Pereira (2005). It applies to the Upper Yellow River Basin, an arid region, with very cold winter and rain < 200 mm, where main crops are rice, wheat and maize, often intercropped. Main problems consist of excess water diversion, insufficient drainage that produced watertable rising and salinity, and less good irrigation systems, Pre-conditions for farm water savings and increased productivity were identified in relation to these problems; 1st: cut to about half the diversions from the river but improve delivery conditions; 2nd: rehabilitate the drainage system (without great investments); and 3rd: reduce percolation to the level required for leaching. Using a DSS multicriteria model applied to the system to analyse the foreseen improvements, results relative to water use and to utilities show that more stringent improvements (after level 4 or 4th year of implementation) have relatively reduced impacts (Figs. 10 and 11)

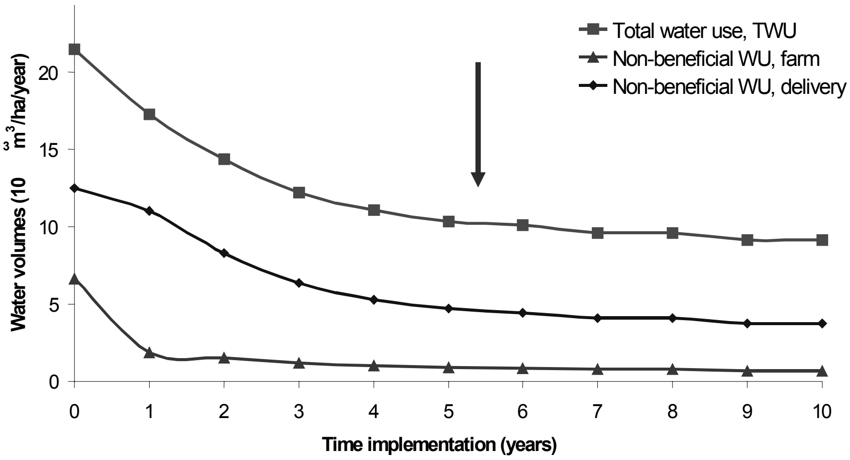


Fig. 11. Foreseen dynamics of total water use and non-beneficial water use at farm and system levels along the process of implementation of improvements in irrigation and drainage systems

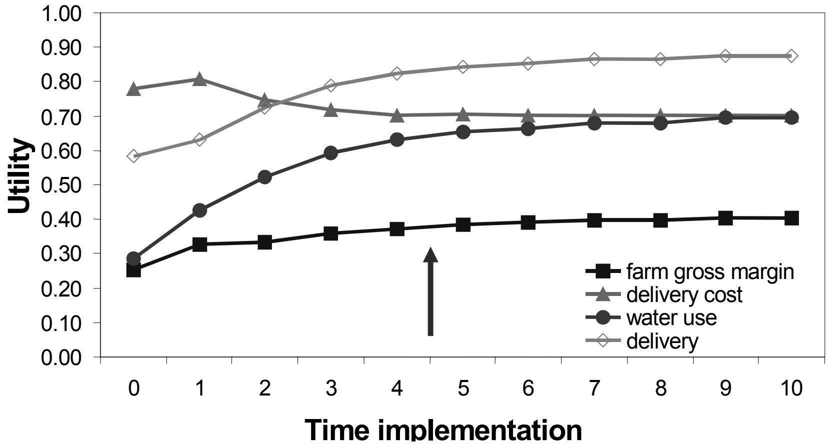


Fig. 12. Foreseen evolution of utilities - farm gross margin, delivery costs, water use and delivery water use –along the process of implementation of improvements in irrigation and drainage systems (Gonçalves and Pereira, 2005)

Fig 10 shows that non-beneficial water uses could be well identified and the selection of actions with help of the DSS model could focus on limiting them both at farm and system levels. Fig. 12 identifies two problems: 1) considering the existing economic conditions, mainly relative to production costs and prices of products, impacts on farmers revenues are quite small, so reducing the interest in further application of more demanding modern technologies; 2) water saving and drainage improvements are not economically interesting for the deliver system managers without changing cost recovery policies but these would imply further charges to the farmers that are not in conditions to pay for higher water costs. This example supports the analysed paradoxes and calls for a new irrigation paradigm.

Analysing the economic water productivity expressed by the gross margin per unit irrigation water use it becomes evident that EWP increases substantially while non-beneficial water uses are controlled (compare Fig. 13 with Fig. 11). Conditions for more stringent improvements at farm and system level do not lead EWP to increase enough to make modernisation interesting for this farmers community.

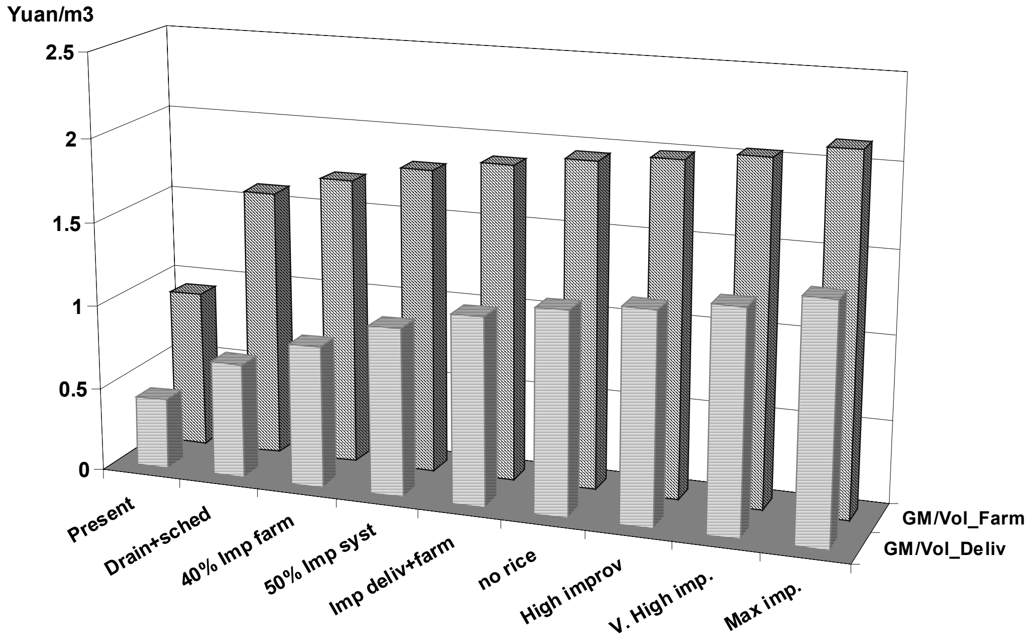


Fig. 12. Foreseen evolution of the economic water productivity as a function of the progressive irrigation and drainage improvements at farm and system level (Gonçalves and Pereira, 2005)

The second case study application concerns furrow irrigation in Fergana Valley, Uzbekistan, which is a great irrigated oasis in the Aral Sea Basin (Gonçalves et al., 2005a, b; Horst et al., 2006). The area is characterized by an arid climate and main crops are wheat and cotton, furrow irrigated. Because excessive water use has been the rule in the Aral Sea Basin, enormous changes in the Aral Sea and the river ecosystems have been produced, A reduced demand for irrigation is therefore required. With this objective, since furrow irrigation is by far the dominant method, alternative processes were evaluated together with improvements in irrigation scheduling. Only a few aspects referring to cotton are referred.

Every furrow continuous flow provides for maximizing yields (Ya/Ymax) but to minimal water use ratios such as CF and BWUF. Opposite, alternate surge irrigation do not achieve maximal yields but the highest irrigation WP, the highest beneficial water use fraction and the highest water consumed fraction (Fig. 14).

Comparing alternative improvements through a multi-criteria analysis (Fig. 15), results expressed in terms of utilities show that for the actual farming economic conditions in Fergana, the best alternatives are the present one – no changes - or adopting an improved irrigation scheduling and alternate furrow irrigation (Sched + AC in Fig. 15). If the multicriteria option would be dictated by water saving criteria then the best solutions are those relative to the application of surge flow applied to alternate furrows (Surge + Alt); further deficit irrigation (Def) do not lead to better results.

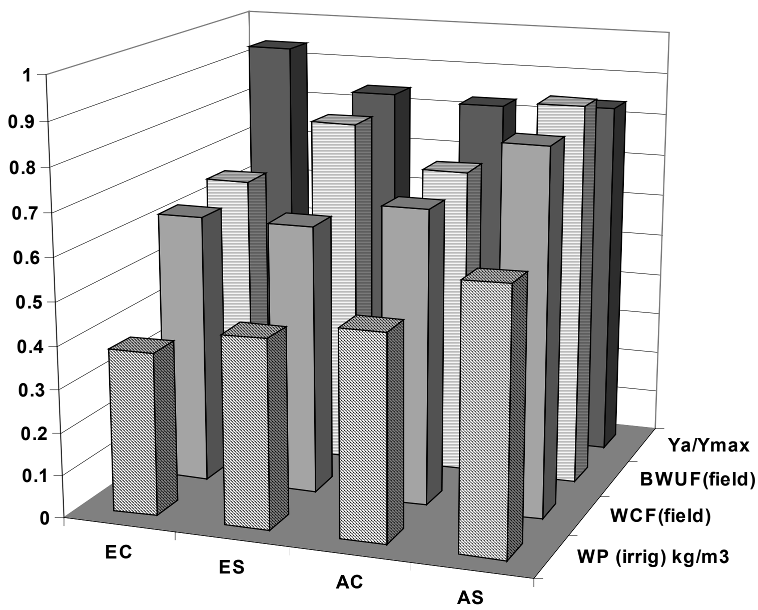


Fig. 14. Relative yield, beneficial water use fraction, consumed fraction, and water productivity relative to four improved furrow irrigation conditions: EC and ES – every furrow irrigation with respectively continuous and surge flow; AC and AS – irrigation of alternate furrows with continuous and surge flow (based on Horst et al., 2006)

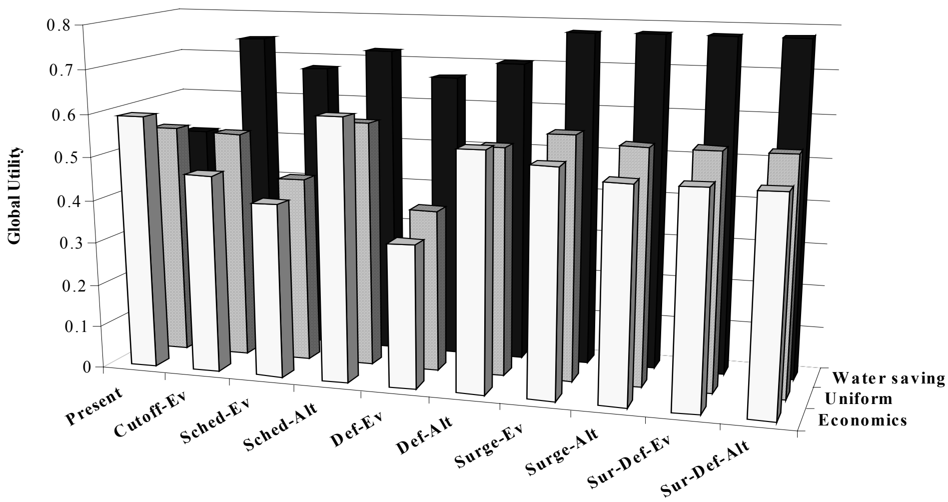


Fig. 15. Global utilities relative to several alternative furrow irrigation improvements when criteria refer to priorities to water saving, priorities to farm economic results or a uniform weighing is adopted (based on Gonçalves et al., 2006b)

Results show that the price of products, cotton, do not compensate for improving farm irrigation, i.e. to pay for investment and increased labour. Surge flow, contrarily to commercial farms, has not enough economic return to be used as a water saving practice. Results also show that when prices of production factors are high and those of commodities are low the farmer option is to maximise the land productivity, Again results evidence the referred paradoxes and support the need to develop a new paradigm.

CONCLUSIONS

The present irrigation paradigm is leading to several paradoxes related to Insufficiencies in current efficiency indicators, contradictory uses of water productivity indicators, social and economic issues relative to small farms, practical availability and use of technological developments, which were also demonstrated in examples given.

Solving the paradoxes requires developing a new paradigm. Knowledge and technologies exist that allow to make a more efficient use of water in irrigation and therefore to find a sound base for such new paradigm. Innovation in using indicators should help adopting a new irrigation paradigm. With this objective, indicators must be:

- universal, i.e. be applied as well to irrigation and to other non-irrigation water uses
- simple and able to make light on water use in terms of both quantity and quality of water use
- able to identify the pathways for improved water use
- adapted to support an economic (and social) analysis of benefits of improved water use and productivity, both at farm and of-farm system level
- covering aspects relative to other resource uses, e.g. land and energy, and to non-tangible benefits of water use, such as landscape and cultural heritage

The availability of technologies should mean capability to transfer into practice and to improve the existing irrigation, both at farm and system levels. However, knowledge and technologies progress much faster than technology transfer in case of small family and peasants farms. Technologies are easily available when manufacturers have an easy market, as it is for a variety of irrigation scheduling equipment adopted by commercial farms and for sprinkler and micro-irrigation equipment, In case of surface irrigation such market is generally not existing and surface irrigation becomes synonymous of "old fashion"

Knowledge and technologies that exist to provide for a more efficient use of water in irrigation need that appropriate quality control of equipments and management tools be enforced to support farmers in modernizing the systems. The constraints imposed to farmers, which they know well, need to be recognized, such as inappropriate delivery conditions, high costs of production factors, of irrigation equipments, low prices of commodities, low incomes, lack of technical assistance and poor systems design.

Using indicators need to be carefully done and taking into consideration the irrigator constraints, not to be used to describe environmental and managerial objectives.

Incentives that compensate for the upgrading costs, society responsibilities, recognition of cultural skills, and farmers decision making need innovative approaches.

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STRATEGIES TO CONVERGE LOCAL WATER MANAGING PRACTICES AND WATER POLICY WITH WATER SCIENCE AND ENGINEERING IN SOUTHERN AND EASTERN MEDITERRANEAN COUNTRIES

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SUMMARY - Policy making in developing countries is still ad hoc and does not fully use research-based information. One of the main reasons for this is the weak linkages between researchers, especially the policy research community, and policy makers. Development of local and regional actions to narrow the gap between research community and other social solidarities, especially the policy makers, is desperately needed and of paramount importance. This paper is mainly dependent on the ideas extracted from a critical review done recently by a panel of experts for EU-INCO for evaluating water research projects with relevance to Integrated Water Resources Management (IWRM) approach done in the period 1994-2006 (FP4-FP6).

Key words: Policy research, research communities, ntegrated water resource management.

INTRODUCTION

Water is an essential driver of quality of life, health, food security and it is a pillar for economic development. The water sector involves much more than irrigation, water demand and supply, wastewater treatment, etc. It encompasses, in addition to its engineering and science aspects, political, social, environmental, economic and institutional dimensions. An example of its economic implications is that the production of one kilogram of grains consumes 1,000-4,000 liters of freshwater, food production already accounts for about 80% of freshwater use in developing countries and still these countries face the situation of food insecurity (Allan, 2001). In addition, the political dimension plays an important role in water sector, since the majority of people live in river basin shared by two or more nations. Therefore, much more is needed on the multidisciplinary and integrated nature of water sector and focus should be directed to these dimensions for more effective policy making (Allan, 2001; Gyawali et al., 2006).

Research is financed and undertaken to contribute to the progress of the human kind. Its efficiency is measured by the degree of its impact and mobilisation of its generated knowledge. Huge amount of work conducted by researchers does not have its proper and effective way to policymakers. Also, if the research results reach the policymakers, the impeded knowledge in these results is not properly mobilised. It is evident that there are inadequate and inefficient coordination, collaboration and communication between researchers and policy makers as well as with other social solidarities. In fact, challenges do not end with publishing research results; on the contrary, the real challenges start after this.

WATER SITUATION IN THE SOUTHERN AND EASTERN MEDITERRANEAN COUNTRIES AT A GLANCE

The Southern and Eastern Mediterranean countries (SEM) – figure 1, suffer from the least water availability per capita compared with any other region in the world (Ellysar et al., 2005). It has less than 1% of the world's freshwater resources and 5% of the world population. Water problems are exacerbated by pollution from human activities that negatively affects water quality and can further lower the available water quantities. These challenges will get worse in the future, as population increases, overexploitation of current water resources and pollution continues, and the corresponding demand for more freshwater continues to be on the rise.

Fig. 1 Map of Southern and Eastern Mediterranean Countries involved in the Report

The usually displayed trends have indicated that there is an approaching water crisis in SEM countries. It has been always emphasized that the main constraint to agricultural development of arid and semi-arid land in the Mediterranean will be the availability of water, rather than land. Although the physical availability of water to each country remains constant, the demand for it will increase steadily for the near future. The major challenge facing water planners and managers was and will be to balance demand and supply of water under these difficult conditions.

A summary of SEM countries water situation is shown in Table 1 below. The table shows clearly that six of the nine countries listed already face severe water stress, with levels often well below the redline figure of 1000 m3 per capita per year.

Table 1. Basic water data on SEM countries

Country	Population (million)	Land area (1000 km^2)	GNI per capita ($)	Agriculture % of GDP	Freshwater per capita (m^3/year)	Population with access to improved water services (%)
Morocco	28,238	446.3	1,190	15	1,062	82
Algeria	29,950	2,381.7	1,550	11	477	94
Tunisia	9,457	155.4	2,090	13	434	NA
Egypt	62,655	995.5	1,380	17	930	95
West Bank and Gaza Strip	2,839	NA	1,780	17	NA	NA
Jordan	4,740	88.9	1,630	2	148	96
Syria	15,711	183.8	970	NA	2,845	80
Lebanon	4,271	10.2	3,700	12	1,124	100

* Source: Adapted from Grover (2002) and based on the World Bank Atlas (2001). GNI: Gross National Income; GDP: Gross Domestic Product; NA: not available.

In addition to the obvious physical constraints, there are other factors leading to the exacerbation of the water crisis in SEM countries. The water scarcity is coupled, most of the time, with scarcity in management of this vital natural resource. Despite the tremendous efforts exerted by scientists and engineers in saving water by enhancing irrigation efficiency and increasing other non-conventional water resources, there are still indications that the water availability for nearly all sectors is becoming lower. The water use in agriculture is becoming much more each year despite all the water use efficiency measures.

In a study related to water demand management research activities in the Middle East and North African Countries (MENA), the results indicate that current research activities are significantly higher than the past activities. The results, as shown in table 2, indicate also that researchers are equally interested in technology development, policy and institutional issues.

In spite of the broad spectrum of research topics covered, there are still topics that receive less attention than others do. The following research gaps would be identified:

- Communication and information systems required to bring the message of proper water management to both end users and policy makers ;
- Assessment of the socioeconomic benefits and costs of different scenarios or systems for water allocation.

It is worth mentioning that the existence of research gaps in some areas does not mean that this should serve as guidelines for future research. Some gaps may indicate that there is no necessity to implement additional work as in the field of irrigation efficiency where we need the capital to mobilise the existing knowledge of research results.

Table 2. Distribution of water demand management research in SEM countries

Types of research	Past	Current	Future
Assessment and development of WDM policy and processes	45.4%	63.6%	45.4%
Development of WDM technologies	27.2%	72.7%	45.4%
Documentation of traditional and modern water management systems	22.7%	50%	45.4%
Improvement of intersectoral water allocation	27.2%	63.6%	54.5%
Development of financial management systems for improved WDM	9%	40.9%	54.5%
Improvement of intersectoral water allocation	27.2%	50%	45.4%
Development of alternative institutional designs for WDM	9%	59%	18.1%
Development of local water supplies to replace central supplies	27.2%	50%	63.6%

*Courtesy of Management of water demand in Africa and the Middle East, Current Practices and Future Needs, *sous la direction de David B. Brooks, Eglal Rached et Maurice Saade, 1997.*

The findings of this survey study[4] indicate that emphasis on appropriate water conservation policies should begin as soon as possible, especially in countries that are not self-sufficient in water.

It is difficult to set one single recipe to solve this exacerbating water scarcity problem due to the complexity and multidisciplinary nature of water sector. However, there are indications that we are facing evident shortcomings in some strongly relevant domains. Of these important domains ***is the translation and utilisation of water research results into practical and fruitful outcomes***. This is clearly manifested in the policy research area that should help in the formulation of water policies and strategies that is an integral part of each country comprehensive policies and strategies.

The following section will exhibit some strategic options necessary to activate the relationship between science and engineering outcomes with policymaking process within an integrated natural resources management vision.

General Background

Modernity Theory

An understanding of water resource management at the global and the local levels would be enhanced by being familiar with the trajectories and paradigms of water management because of the ideas and new technologies associated with modernity era. An important dimension of such analysis is also helpful in explaining why trajectories of investment and development have diverged between the North and the South at the start of late modernity in the North since the late 1970s (Allan, 2005). Water management has absorbed the driving ideas and new technologies associated with the modernity of the past two centuries. Water scientists and engineers solve problems and were able to be very competent in early modernity. Stakeholders represented in politicians, engineers, farmers and food consumers were all certain that the progressively larger withdrawals of water were good. This is accompanied by industrial modernity and in called the hydraulic mission.

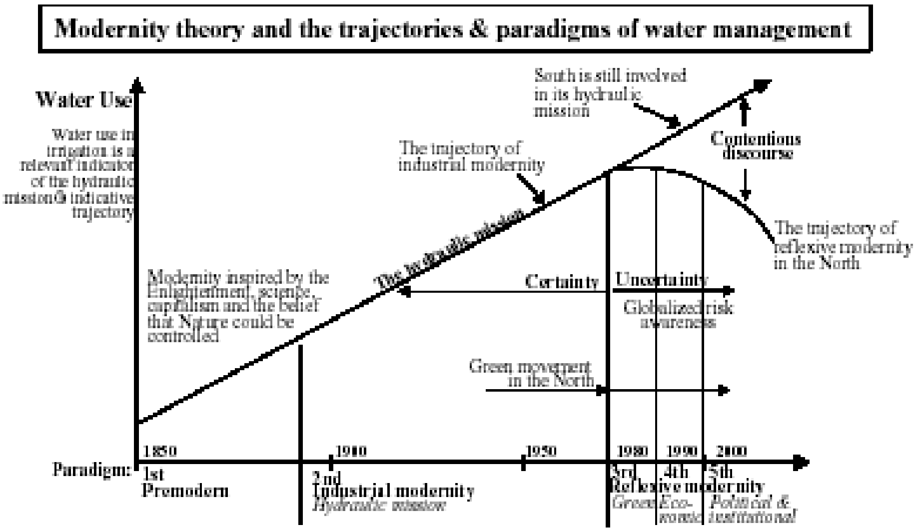

Fig. 2: Trajectories of freshwater use in the Northern and the Southern economies over the past two centuries (courtesy ref 2).

The constantly rising trajectory reflects the process of taking more and more water out of the environment to produce food in the agricultural sector. Before about 1980 ‘certainty’ prevailed that capturing more water for food and fibre production was sound. The messages raised by the green movement in the west and in the United States, shifted the emphasis of the water discourse from ‘certainty’ to ‘uncertainty’. This notion of uncertainty about the soundness of the hydraulic mission had gained such significance by the beginning of late modernity. Uncertainty became the dominant mindset underpinning water resource allocation in the North.

In the South, on the other hand, there remains a commitment to taking more water out of the environment. This is adopted in order to further increase the output of food to meet rising food demands, to avoid dependence on imports, and to increase the wealth of the respective economies as a whole. It is worth mentioning that the Southern economies achieved spectacular increases in production, by four and five times in the major grains, between 1961 and the end of century. This increase in the production resulted mainly from the following:

- increased freshwater use ;
- the expansion of the rain-fed area of crop production ;
- increased efficiencies in the use of land and water and
- the effective use of other inputs such as energy and fertilizers.

This general background about the water management paradigms is aiming at providing a perception about the tools with which it may be possible to address the problem of understanding and predicting water resource allocation and management and related policy-making processes. This background would establish theoretical linkages with culture, society and political economy being included as essential elements of a larger analytical framework. In addition, this linkage has proved to be an attractive intuitive explanation of how communities would react to resource scarcity (Allan, 2001).

Strategies to Converge Water Science and Engineering with Local and Regional Actions and Water Policies

Many strategic options would be implemented or adopted to converge the research dimension relevant to water science and engineering with local and regional actions and water policies. These strategic option are of multidisciplinary nature and not inclusive to the water sector personnel. The following are some important strategic options that would narrow the gap between water research outcomes and policymaking process:

Constructive Engagement – Integrated Water Resources Allocation and Management (CE-IWRM):

This strategic option is presented because IWRM has been criticised despite the fact that it is strongly adopted at the global and national levels. One important aspect of criticism is that IWRM in non-operational[6]. Another aspect of criticism is referred to the fact that IWRM does not help water managers understand the reasons for difficulties of IWRM being operational (Biswass et al., 2005).

For those working in the water sector as scientists, practitioners and educators, IWRM is perceived to be driven mainly by technical and economic fundamentals, enriched by a measure of increased environmental awareness. The problem with this understanding and with the international IWRM discourse, and its regional expressions, is that it has ignored the political dimension, although the notion of governance and related politics has been gaining a place.

A recent EU-Critical Review[2] indicates that IWRM could not be operationalised because it has not been adequately defined, and the definition of IWRM needs to be modified. This modification is required to make IWRM relevant and operational. It was found also necessary to comprehensively define some essential concepts like '*sustainability', 'integrated', and 'management'.*

Sustainability

There is a variety of definitions for sustainability. These definitions are dependent on the degree to which the concept is seen as limited to the environment, or a specific domain, or broadened to include the areas of social justice and other human activities. One of the most broadly accepted definitions was developed in 1987, when the World Commission on Environment and Development, agreed on a definition of sustainable development: *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*

The sustainability term is an essential component of any analysis of water policy. However, it can be misleading and have inefficient analysis if it is restricted to the water environment. An operational notion of sustainability is captured in the larger context of the sustainability of society, the economy as well as the maintenance of the environmental services provided by water in the environment. The concept of sustainability is very rich indeed, if this threefold context is adopted (Gyawali et al., 2006). Sustainability is a discursive outcome of the contending articulated concerns of society, those involved in the economy and those anxious about the status of the environment; therefore, its definition is a dynamic one.

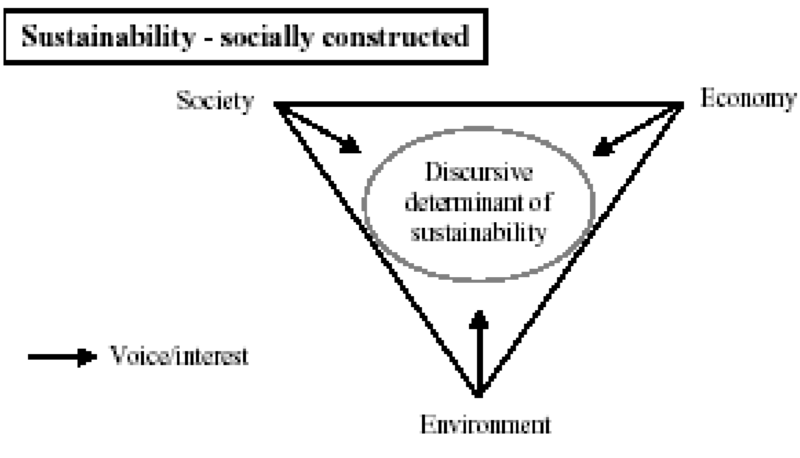

Fig. 3: The three dimensions of water sustainability – social, economic and environmental – and the central mediating role of discursive hydro-politics (Gyawalli et al., 2006).

Figure 4 illustrates how the different definitions of sustainability influence actual trajectories of water use that contrast with the economically and environmentally secure trajectory recommended by water scientists approaches.

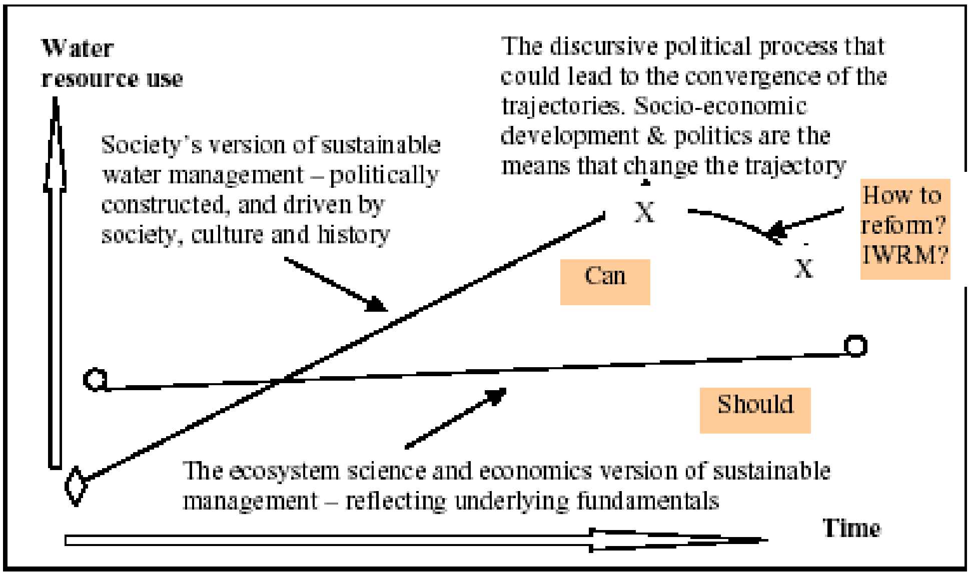

Fig. 4. Conceptualising the trajectory of water management determined by society, ecosystem scientists and economists – the lower trajectory. Convergence - shown as X-X -is achieved by getting the science into the political processes that determine use and policy (Gyawalli et al., 2006).

IWRM is composed of two dimensions: integration and management. *Integration* implies getting scientists and professionals from different fields to work together. Integrating the competing interests of water scientists, water professionals, of water consumers is very political indeed. *Management* is also political in the sense that within the rational implementation of a reform agenda in the water sector, there will be a need to *re-allocate* water between existing users. This is increasingly the case in a world where water scarcity has become the norm. IWRM, then would be a safer term if it is transformed to *IWRAM: «* Integrated Water Resources *Allocation* and Management ».

Water management would be strongly related to the framework of 'four ways of life' identified by Douglas (Douglas and Wildavsky, 1982). Thompson has shown the framework to be particularly relevant to the water sector (Thompson, 1988). He indicated that there are *three social solidarities* that shape the politics of water use and management:

-The institutions in the public sector -*hierarchism*- which are the dominant providers of water services and regulatory regimes ;

-The private sector firms and local *entrepreneurs* that provide some water services and a high proportion of construction capacity ;

-The *civil movement* bodies that advocate water related *environmental and human rights ethics* and play a social audit role.

-

It is important to note that the third solidarity can only deploy *voice*. The other two solidarities can deploy a wider range of instruments. Governments can tax, subsidise, legislate, regulate and provide employment and a welfare state. The private sector can provide services via markets and other contractual arrangements. It can also provide employment and promote its interests via various forms of advertising. The purpose of identifying these social solidarities is to establish their relevance to a sound and possibly an operational IWRM approach.

The capability to manage water and, more importantly, to reform the way water is managed reside in two social solidarities with different approaches (Fig. 5). For example, national water ministries and local government bodies provide *public sector finance, management and governance*. The second solidarity is the *private sector,* which uses the tools of the *market* to provide water services. The third solidarity, which is also of particular importance in the water sector, is *civil movement activists* who provide a voice for the impoverished consumers and the environment. *Civil movements – NGOs* and unions by their mobilisation of civil society bodies – have had a very significant impact - on how the value of water has changed in the past three decades.

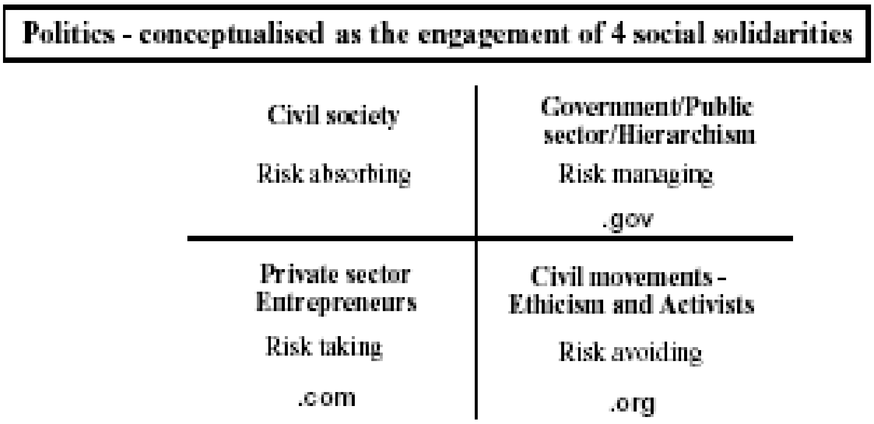

Fig. 5. Four Social Solidarities (Gyawalli et al., 2006).

« The importance of engaging the above perspectives or approaches in developing water allocation and management policies can be illustrated by considering how each social solidarity deals with *risk. Government departments* assume they can *manage risk.* The *private sector* tends to be *risk taking* – at least with respect to the interests of society and the protection of the water services of water. The third solidarity, sometimes identified as *ethicists*, is characterised by its adoption of principled positions. It *advocates risk avoiding* the maintenance of existing livelihoods that use large volumes of water » (Gyawalli et al., 2006).

To be operational and effective IWRM has to be *constructively engaged*. That is, IWRM practice must involve inputs from all social solidarities and must be gender sensitive. This analogy leads to coining the term Constructively Engaged Integrated Water Resources Allocation and Management – CE-IWRAM (Dixit et al., 2004).

« Water management and CE-IWRAM can take place in *humid* or *arid* environments, in economies *well endowed with freshwater and/or soil water* or not. They can also take place in *pre-modern* political economies with *little adaptive capacity* or in *late modern* political economies, which have the *adaptive capacity* to cope with water scarcity and with any other factor endowment deficits ».

The adoption of CE-IWRAM approach represents the extra mile that needs to be travelled to ensure that IWRM is operationalised, enables communication and achieves impact within shortened periods. Such constructive engagement offers the greatest chance of bridging the gap between the fundamentals of society and nature investigated by science and the perceptions of water actors in society, which are politically constructed and driven by culture, societal context and history.

The lack of CE-IWRAM often leads to the following results:

- fragmented institutional structures
- a sector-by-sector management approach and overlapping ;
- conflicting decision-making structures,
- upstream and downstream conflicting interests regarding riparian rights and access to water,
- diversion of public resources for private gain,
- Unpredictability in the application of laws, regulations and licensing practices, which impede markets.

Communication

Constructive engagement would be achieved by establishing an efficient and creative communication among social solidarities. Researchers are distributed among the three effective social solidarities of water management. Research is not a final goal in itself but is implemented to contribute to the prosperity of human being. The issue of communicating water research results is very critical in policy adoption and knowledge mobilisation « state-of-the-art research needs state-of-the-art communication and knowledge mobilisation strategies to achieve impact ». Research results should be widely and effectively communicated to policy-makers, to the technical community, to local water users and managers, to the education sector and to the private sector. The research should have impacts on capacity building, on the advancement of water management via innovative knowledge generation and its use to support solving problems.

Policymakers always want the right information, in the right form, at the right time. The right form depends on the policymakers' background and perspective. The right time, depends on the stage of the policy making process that can be divided into the following stages (Dixit et al., 2004).

- policy agenda development;
- specific objectives and policy options identification ;
- options evaluation ;
- recommendation advancement ;
- consensus building ;
- legislation set up ;
- policy implementation ;
- policy evaluation and impact assessment.

The following are extremely important aspects that should be taken into consideration to have the best chance for research outputs to find their way into the policy formulation process:

- Research results always written in a language very well appealing to other researchers but indigestible to policymakers. Most policymakers do not read lengthy research reports especially when written in a language with different groups in mind. The translation process for research result has to attract the attention of policy makers in addition to the simplification of displaying these results.
- The value of researches is implied in being inserted into the political process at the right time. To have the best chance for research outputs to find their way into the policy formulation process is to be inserted while this process is between stages one to four. Once research results lead to policy action, then researches have achieved their goals.
- « The 'container theory' of communication usually assumes ideal conditions: a sender packs the information he or she wants to convey into a container and passes it to a receiver who unpacks it and immediately understands the full content . Research results and the fundamental concepts behind them must be explained clearly and reinforced on a face-to-face basis with ample room for discussion.
- The other essential important approach to conveying research results to policy makers is via media. There is a natural interest of people and policy makers in particular, with issues raised by the media. The media makes different issues attaining high public profile that is of paramount importance to policymakers and parties. At the same time, the presentation of water issues in the media should be able to attract attention. This is another issue related to the professionalism of the mass media and the vision of technicians to make it booming.

Developing an effective means of communication entails the precise definition of the target audience and characteristics therein, as well as the change one is hoping to bring about through communication. What is the communication objective? Is it to bring about a change in knowledge, attitude or practice? Effective communication depends not only on what you are communicating, but also on an understanding of with whom you are communicating and for what purpose.

Most scientific and academic research centres are concerned with the number of publications in refereed journals without paying much attention of the impact of their researches even in one single report or study. If scientists have new knowledge, that could enhance the environmental services of water and its economically efficient use, they have to acquire new skills of communication.

Networking

Networking could be an effective approach to productive communication. It can develop an information system on water related matters that can be shared nationally and regionally. The main goals of networking are to achieve cooperation, coordination and collaboration through developing institutional framework to address the water relevant issues.

Networking is an important old tool for improving the flow of ideas and knowledge among researchers and policy makers utilising the development of electronic networking recently. There are many famous existing network dedicated primarily to water research in SEM countries like: Arab

Water Information Network (AWIN), The Centre for Environment and Development of the Arab Region and Europe Water Information Network (CEDARE), Network for Water and Sanitation International (NETWAS), Inter-Islamic Network on Water Resources Development and Management.

International Examples

Some of the developing countries have made a certain effort to develop enabling structures to allow the people's initiative to flourish. One such country is South Africa[2], which has a fairly comprehensive framework in place, at the central, state and local levels. Radical constitutional reform occurred in 1994, followed by a comprehensive, countrywide stakeholder engagement process that culminated in a new water law. These and other social and political changes in turn generated an unprecedented level of focused enquiry in the water sector. They have also spawned an extraordinary number of integrated, water-related, research initiatives on institutions, public participation and decision-making processes. Scientists of all stripes – modellers, ecologists, interpretive social scientists and scientists from the water sector and beyond - have had to respond to and cope with the priorities defined by the urgent needs of society. The option to remain un-involved in a comfortable core of familiar disciplinary science has simply not been possible.

Contributions by partner country scientists have helped to ensure that the current dynamic of South African water science has gained a high profile regionally and internationally. Amongst other local- and national-scale benefits, this co-operation has contributed to parallel processes of water law reform in southern African countries and helped to improve the management of shared (transboundary) river basins across the region.

Applied water management research in South Asia has also played a very important role in advancing our understanding of *constructively engaged IWRM.* The groups of interdisciplinary water research scientists coordinated by SACIwater and ISET [Boulder & South Asia] have made globally significant contributions by demonstrating the importance of the *constructively engaged* version of *integrated water resources management*. They have also researched deeply into the adaptive water managing strategies of communities in flood prone and drought prone regions. Their contributions are especially significant in confirming the role of economic processes beyond the watershed (SACIwaters, 2002).

Korea established an integrated water management system focused on water-utilization and flood control. This project will construct three water management systems:

•There will be a water management centre for the integrated management of water quantity, water quality, and electricity generation.

- A water management system will be set up to collect real-time information on the operations of water systems, and to make possible the linking and operation of dams.
- They will construct an operation system for the remote control operation of electricity generation facilities.

CONCLUDING REMARKS

The following main conclusion would be draw out of the above displayed sections:

1. Technical solutions alone cannot provide the increasing population of the region with safe water supply and proper environmental sanitation. The region needs to integrate the technical, institutional, managerial, social, and economic aspects of water-resources management. The new approach for sustainable water supply and sanitation depends on local involvement, solutions, and knowledge within an overall framework of water and natural resources planning.
2. Water scientists and engineers must recognise that their task should include learning how to communicate their science in order for their methods reveal to other stakeholders in society. Simultaneously, governments, private sector and civil society movements should seek to incorporate scientific results more systematically in their deliberation and decision making process to reach robust solutions.
3. Research should connect local knowledge, gender-aware socioeconomic development, culture and policy institutions and implementing bodies. Research should also focus on the systems beyond the watershed and the conventional concerns of water scientists and managers. It is in these wider systems that the major strategic solutions to water problems will be found
4. International water research should adopt the constructively engaged IWRAM approach and seek links to education, capacity building and innovation.

5. Interdisciplinary research in a constructively engaged mode should pay specific attention to strengthening human capital and implementation capacities and improve the enabling environment within Partner Countries. Bridging the gap between research into the fundamentals and the perceptions of water users and water policy-makers should be a research focus in its own right.

6. Communication and impact are very challenging and sensitive issues in the water management for sustainable development purposes. Effective communication of research must be a prime goal and essential component in the research log frame matrix. Indicators of successful communication and impact need to be identified with special emphasis on links to major societal constituencies, education, training and innovation.

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THE SCALING ISSUE IN WATER RESOURCES MANAGEMENT

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INTRODUCTION

The issue of scaling represents not only a scientific challenge but also a practical problem in water resources management and hydrological modeling. Models are scale specific because different processes are important at different scales. Hydrological modeling is being carried out at spatial scales ranging from point scale to global scale.

Since the early 1980's, a large number of models have been developed to describe the complex interactive physical, chemical and biological processes. Most of them were developed for research purposes but some have now entered into the management arena and are used as tools in the decision–making process by public authorities, industry, consultants and agriculture advisers.

Models are cost effective management tools since they are both cheaper and powerful. At best, they enable valuable insight into the workings of the complex natural soil system and allow the user to evaluate the likely impacts of alternative mitigation strategies while minimizing the need for extensive and expensive field experiments.

On contrast to physically based models, the conceptual models use empirical process descriptions. They have been developed to describe runoff generation and overall water balance but failed to provide details of water solute and energy flows and soil moisture dynamics. These models are applied at larger scales than the physically based models.

Processes description in hydrology is often studied at point scale. Modeling water and solute transport at catchment scale is complicated by the natural variability of the governing parameters.

Models are scale specific because:

1- different processes are important at different scales
2- The input data availability is reduced at larger scales.

One of the weaknesses of the first generation of simulation models of water and solute transport is that the soil was treated as macroscopically homogeneous. One frustrating issue facing hydrologists in dealing with the unsaturated zone both in terms of modeling & experiment is the overwhelming heterogeneity of the subsurface. One manifestation of the heterogeneity at local scale involves the preferential flows of water and chemicals through soil macropores and rock fractures.

On contrast to rocks, soil near surface processes such as shrinking-swelling, freeze-thaw, biological activity leading to earthworms and root channels and physical manipulation such as cultivation, can dynamically alter pathways leading to temporal variations in preferential flow processes. Such temporal variation tends to decrease with depth where fractured rocks also dominate.

Preferential flow is the accelerated movement of water, surface applied fertilizers, pesticides and pollutants into and through the unsaturated zone. Process based description of preferential flow invokes dual porosity models. Such models assume that the medium consists of two interacting pore regions. Accounting for heterogeneity and preferential flow is crucial in studies of agrochemical transport and in leaching saline soils.

Emerging issues: how to handle spatial heterogeneity, the existence or otherwise of natural or preferred time and space scales, and the linkages between scales of state variables, parameters and conceptualizations.

THE SCALE ISSUE

The natural focus of many hydrologists was to investigate specific processes such as unsaturated flow, overland flow, evaporation, etc. The outcome was verified against small scale experiments. Hydrological modeling has been carried out at spatial scales ranging from point scale to global scale. The importance of scale effects has been recognized by hydrologists, water resources managers, and other water practitioners. The unanswered questions are:

1- Do the mathematical descriptions often developed in laboratories or plot scale applied to catchment scale?

2- How can physical properties such as hydraulic conductivity measured at isolated points be used to accurately represent catchment scale water fluxes such as groundwater recharge or contaminant fluxes such as nitrate flows?

3- How can this spatial variability be incorporated in a model grid square and how is this affected by the size of the grid?

Hydrologists have made impressive gains in research leading to understanding and quantifying individual hydrological processes and in a variety of environments. However, theories of many processes such as infiltration, evaporation, overland flow, water, solute and sediment transport have been and continue to be developed at small scale. The record in implementing these theories towards the development of predictive models at much larger space and time scales has not been equally impressive. The extrapolation of theories of non-linear hydrological processes to larger scale natural systems such as basins, flood plains, wetlands continues to pose serious problems. New analytical formulations for atmosphere-soil-vegetation interactions and methods for their experimental verifications are urgently needed in regional water resources planning, water quality in large river basins, in validation of Global circulation model;s (GCM's) and in prediction and or interpretation of the hydrological impacts of global climate change.

At catchment scale, the hydrological processes combine and interact in a complex manner. The development of physically based catchment scale models provides a framework to represent the interaction of these processes at catchment scale. Applying scaling where several processes govern catchment flows and interact with each other, still represent a formidable challenge.

There is a need to discover hydrologic laws at catchment scales that represent more than a single process. However, it is recognized that different hydrological processes are dominant at different scales.

Although a clear picture is emerging about the nature and extent of the "scale problem", there is, as yet, no consensus on the solution to the problem. The need for continued and sustained research on scale issues is therefore self-evident.

The problem of scale may be differentiated as scale and scaling problems.

The scale problem: Different processes may dominate hydrological processes at different scales so that different theories and models may be appropriate at different scales.

The scaling problem: Denotes that processes description at one scale to be formally transferred to represent the hydrological response at a different scale. In other words, it is about development of a theory that would allow predictions at larger scale on the basis of small scale process information.

Due to the uniqueness of place, different points in the landscapes are characterized by different parameters such as slope, aspect, vegetation characteristics, soil physical, biological and chemical properties. These parameters are measurable but in practice this is a very difficult task to do, given the spatial and temporal variability. In reality, these parameters are measured at different and often incompatible scales and it is inconceivable that they will be measured everywhere in the landscape.

UPSCALING

Aggregation : Denotes that , small scale equations are applied at the small scale where they were derived and the outputs are aggregated to larger scale units. This allows the smaller scale parameters to be assigned directly from field data.

UpScaling : Process equations and associated parameters are modified or substituted when moving from the small scale to the larger scale. It can be conducted in three ways:

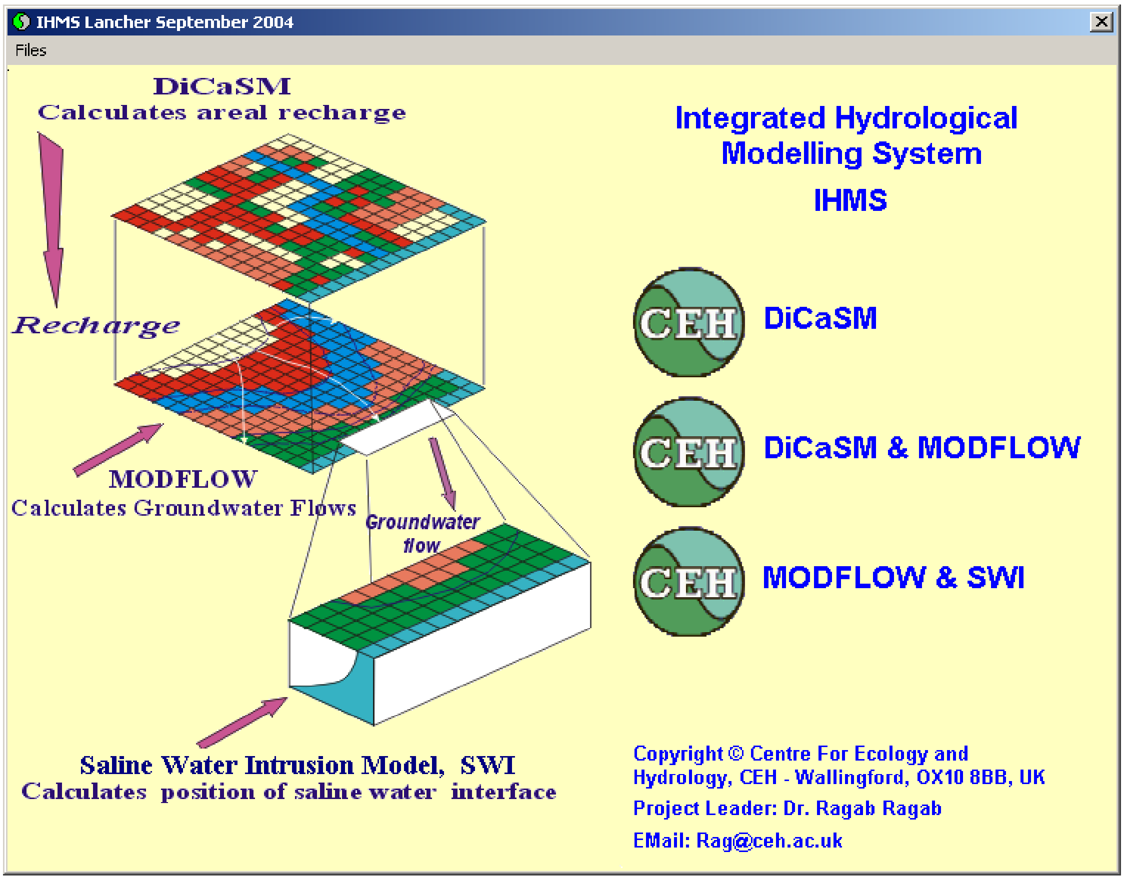
1- The small scale equations are assumed valid at larger scale without change. In this case the effective parameters are corresponding to the larger scale computational unit and produce bulk behaviour of heterogeneous medium. The estimation of parameters values in such case need to be done by calibration of key parameters.

2- The small scale equations are extended in a theoretical framework to account for spatial variability of small scale parameter over a larger scale. This is often carried out in a stochastic framework. Here it is possible to assess the large scale parameters directly from field data. However, effective parameters need to be assessed through calibration.

3- New equations are developed particularly for larger scale.

One of the major goals of the hydrological research is to extend our understanding of impact of changing scale on hydrological processes. Obviously there is a need to develop tools to properly treat these scale problems.

This paper will show some examples of scaling/downscaling or aggregation/ desegregation and how to deal with spatial variability at different scales. The examples are focused on water resources management: in urban areas, in rural areas using remote sensing and in coastal areas to quantify surface water, groundwater and sea water intrusion (see figure below) using a newly developed Integrated Hydrological Modelling System (IHMS) successfully tested on two catchments in Cyprus.



THE INTEGRATION OF COLLABORATIVE INDICATOR DEVELOPMENT IN WATER SAVING STRATEGIES AND POLICIES

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INTRODUCTION

Most of the Mediterranean countries are affected by more or less scarce water resources and periodical drought events with huge socio-economic and ecological impact on the societies. The reasons of situation of water scarcity are complex, including climate change, desertification, as well as expanded demand by different water user sectors. The total supply of water resources has to be distributed among different sectors of usage, namely the domestic, industrial and agricultural demand for water. It is stated for most of the Mediterranean countries that the main demand for water is cause from the agricultural sector (Araus, 2004). Moreover, the economic and social development in the Mediterranean countries is expected to cause a further increase in water demand for domestic and agricultural sectors and therewith a possible increase of scarcity problems and their respective impacts of threaten of economic and social development. In particular as water resources in the Mediterranean are expected to decrease within the next decades, due to climate change, the pollution of tributary rivers and the limited recycling and sewage systems for a growing urban population (IUCN, 2002; UNEP, 2004; GEO 2005).

The common strategies to overcome the scarcity problems are traditionally technological single sector (water) based approaches to increase the supply possibilities of water, particularly with dams, long distance water transport infrastructures, deep wells or other infrastructure solutions. This approach normally is characterized by top-down hierarchical and command and control management-systems and large investments. However, the approach is getting more and more to its limits. Exploiting new water resources and building the necessary infrastructure of these solutions is increasingly expensive (Rosegrant, Cai et al., 2002: 3) and therefore requires large-scale economic investments.

This may contradict the social and economic development efforts of many Mediterranean countries. Moreover, as water resources are limited or even scarce a further increase can not be fulfilled in many locations. Hence, the different sectors of use, including natural ecosystems, will compete for the scarce resources or are competing already. This can cause mayor conflicts within and between user sectors on the resource. This means the traditional single sector supply based approaches are causing one of the substantial problems for water resources management in the Mediterranean region as they not consider the continuously increasing demand for water and the underlying driving forces.

Hence, a new approach of water management is needed which consider the diverse range of resource-use features of water bodies, its interactions and driving forces to elaborate sustainable water resources management strategies. In the Mediterranean these approach in particular has to foster strategies and policies for water saving in the irrigated agriculture as most important water use sector. Central aspects of this approach are first the involvement of affected and interest stakeholder in the management process and second the use effective indicators, both to measure to resources and to evaluate the management actions, on which the management has to be based. By involving stakeholder in the management process of water resources and the implementation of water policies, these policies will gain higher acceptance by the relevant stakeholders, as the process is more transparent and the produce more trust of stakeholder in it. Hence, it is argued that water management policies are more effective and lead to more sustainable water management. The use of indicators as the second central aspect has to be build the basis of all management approaches, as it will provide the necessary information on what has to be managed and how. To provide these information indicators have to be applied and used by the involved actors (in this approach the interested stakeholders), will say, they have to be effective1 as well.

The presented study is mainly concentrating on these two latter aspects in the Mediterranean region. It reflects the actual approaches to water saving strategies in the region. Therefore it has investigated what is the current stage of water management policies in the Mediterranean regarding participation and indicator development, selection and use for water resource management. Coming from this, the study will derive the important role of a collaborative approach in indicator development or selection for Integrated Water Resource Management policy approaches as framework of effective water saving policies.

BACKGROUND

In recent discussions on water resource management the approach of integrated water resource management (IWRM) gets increased consideration. IWRM can be defined "as process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in equitable manner without compromising the sustainability of vital ecosystems." (GWP- TAC, 2000). Therewith the approach has the stated goal to integrate knowledge from different disciplines and relevant stakeholders about an environmental problem along the whole chain of causes and effects to provide useful information for decision-makers. Such a strategy is also requested by the international community since the early 1990 in several international agreements and conventions, such as the International Conference on Water (Mar del Plata), the Dublin conference and principles on water and environment (Solanes and Gonzalez-Villarreal, 1999), the Rio Summit in chapter 18 of the Agenda 21 (UNCED, 1993) and the documents of the four World Water Forums.

Following this approach the challenge for water management in the Mediterranean is to convert the management approach from a single sector supply based approach to an integrated water resource management strategy which is considering all different water use sectors, the different driving forces and impacts. Furthermore it should manage both the supply of water and the demand side. Hence, water can only be managed effectively if all the uses of the resource within the water body, by ecosystems and by human, both above and below ground, are considered as a coherent whole (IUCN, 2002:8). Thus, water saving strategies and therewith policies to implement the same become more evident. The aim is to overcome a managing approach of reacting to increased demand by increase the supply, but to reduce the demand and introduce water saving policies at all levels.

However, water management approaches always reflect the prevailing government policies and also the norms and values of the actors with in the sector (Hooper, 2005: 2). Therefore the involvement of all relevant stakeholders is essential for developing and implementing such an integrated strategy to water management and saving. Effectiveness of an indicator here is defined first by its application by stakeholder to assess and evaluate certain aspects of the system under evaluation targeted to incorporate local tacit knowledge, to raise awareness and to investigate the underlying norms and values as driving forces to derive appropriate management strategies. This can improve the effectiveness of implementation as the acceptance of measures is supposed to be higher by the actors. However, management approaches will not be successful and effective if the norms and values of the water user are not considered, as the actors will not follow the measures or, even more serious, will go in opposition to it.

The implementation of an effective integrated strategy and policy for water management and saving has also to be based on a comprehensive and integrated assessment of the water bodies. For a meaningful assessment in this sense, hence, all relevant components of the system have to be considered, like hydrological, geo-morphological, socio-economic and environmental issues. This request expert knowledge. By incorporating local tacit knowledge about the water body, the local circumstances can be obtained and the implementation will be more effective as it would be adapted to the specific local conditions.

Assessments are mostly based on indicators which can provide useful insights to the water resource system (stage, uses, vulnerability, etc.), its driving forces and impacts to derive effective management policies. The literature on management processes in general and water resource management in particular gives also evidence for the importance of using indicators in management processes. Indicators are defined as correlates depending on an interesting dimension of a system which is not measurable directly. They are providing insights to the system by reducing complexity, to assess (quantify and/or qualify) the interested issues and to describe a desired future stage of the system. However, indicators are never a complete and entire picture of the reality, which they should represent (Benninghaus, 1994). Therefore the use of indicators comes always with information lost, subjectivity and uncertainties. Nevertheless, indicators are seen as important instruments to enable a quantification and qualification of system aspects and therefore for evaluation.

Several indicator-sets for water management exist from different institutions, like UNEP, EU, Mediterranean initiatives or nation states. Also in particular for the agricultural sector many countries have developed and use indicators (comp. Bos, 1997; Molden, Sakthivadivel et al., 1998; Lorite, Mateos et al., 2004).

The aim of indicators in this regard is to provide the basis for the important first step of assessing the objective within a management process. However, as well in all other steps of the management cycle indicators are playing in important role (Kockler, 2005). According to literature of business administration, environmental science, and regional science the use of indicators in management processes have a central role in assessing the current state of the (water) system, to identify the problem(s) at stake, to derive actions fields, setting priorities and to evaluate progress and/or improvements in the system.

To ensure the adequacy of the provided picture of the system the indicators should measure the most important variables of the system. The selection of the same should be mainly driven by their relevance for the issue to assess. If an issue is identified the indicator which represents the best this issue should be selected. This selection or development process is mostly driven by scientists, a central authority, or other external sources with expert knowledge on the underlying system. By doing so indicators are supposed to provide rather objective and knowledge based measures of the reality. However, both the content of an issue (problem at stage) as well as the indicator itself which should represent this content might be rather controversial. Even the desirable future stage of the system might be controversial as well. Hence, the entire selection process is depending on normative implications and subjective perceptions based on personal norms, values and world views, but also and not at least on interests. Thus it can be judged that there is no value free indicator, but all serious indicator work is political because indicators mirror the perspectives, norms and values of the actor or group of actors (e.g. government, water user etc.) developing them. "Even with a solid scientific approach based on physical facts as well as systems theory and analysis, indicator cannot be defined without a significant amount of subjective choice“ (Bossel, 2001: 9). Hence Innes (1990) give the process of indicator development an important role in management processes and argues if indicators are defined as instruments for managing, this should not only consider their application, but also the development of the same. A meaningful and effective indicator-system should be focused to a clear purpose and reflect the norms and values of a community having a stake on the assessed system (Besleme and Mullin, 1997: 50). If this is not respected the resulting measures can be of limited use for the actors needs and/or be rejected by the actors. Hence, participation has also an important role in the development and selection of indicator-sets for water management and the implementation of water saving policies.

Experiences from Local Agenda 21 processes (e.g. Sustainable Seattle) and management processes of several common pool resources all over the world provide evidence for this hypothesis and show the advantages of a participatory approach in indicator development and selection.

These experiences raise evidence that a collaborative approach to develop indicator-sets together with relevant stakeholders can increase the quality and effectiveness of both, the indicator-sets themselves and the underlying management process (Kockler 2005; Besleme and Mullin 1997). With a collaborative approach indicator-sets will gain relevance for the stakeholders (e.g. water user, farmers) as they have contributed to the development and/or selection; indicators will be more transparent as stakeholder know how they were developed and selected; and the collaborative approach will give higher trust and acceptance to the management process as the stakeholder have a stake in it.

Following this argumentation, a collaborative approach of indicator development and selection for an integrated assessment will contributed substantially to a development and implementation of necessary water saving strategies and policies in the Mediterranean.

METHODS USED

The presented study investigated the state and possibilities of policies to participatory and integrated approaches of water management and the requested collaborative development and selection process of indicators for assessment of water systems. For the elaboration of the study a multiple approach was used which consists mainly of a broad literature analysis and of three field studies with interviews incorporating relevant stakeholders and experts in water management in the Mediterranean. The literature analysis consists first of all of an analysis of the already existing WASAMED documents and presentations elaborated in the cause of this project. Second, experiences from other European projects on (integrated) water management in the Mediterranean were incorporated, as well as a review of relevant scientific literature. The aim of the literature analysis was to get insights about water management in particular regarding institutional structures including the most relevant stakeholders, problems of water management and irrigation, and participation in the Mediterranean. Also a preliminary stakeholder analysis was done to be incorporated in the later field studies.

The field studies focused on three regions in the Mediterranean represented in the WASAMED network. Namely the surveys are work out in the Iberian peninsular (Spain and Portugal), in Morocco and in Turkey. Because of resource constrains it was necessary to concentrate on these regions, although other countries may differ from this selection in their specific approaches to water management. However, together the three field study regions seem to provide a comprehensive overview about the Mediterranean region. Furthermore for the same reason, it was in none of these regions possible to do an entire inventory of water management practices, but to concentrate on single water basins (Guadiana and Tajo in the Iberian peninsular; Tadla in Morocco and Harran plain in Turkey). However, the literature analysis gave evidence that the results of the field studies could be generalized to most of the 20 countries in the Mediterranean region. Within the field studies each region was visited. The field visit in Turkey occurred in summer 2005, Morocco were visited in autumn 2005 and the field visits at the Iberian Peninsular occurred in summer and autumn 2005 and spring 2006. Within each field visit semi-structured interviews with stakeholders, identified by the preliminary stakeholder analysis, were done. Guiding question in the interviews were the problem framing of the stakeholder regarding water use and management in agriculture, the problem framing regarding the water shed, perception of participation including cooperation and conflicts with other stakeholders, perceptions on indicators for irrigation and water management and the development / selection process of indicators. Furthermore, the interviews were aimed to provide insights to water management and participation which were not get from the literature review but also verifying the findings got from the literature review. The same aims were followed with another sort of interview with experts on water management, irrigation and participation in the Mediterranean region (or the investigated water sheds).

RESULTS AND DISCUSSION

From the literature analysis as well as from the interviews with experts and stakeholder in the three investigated water sheds it can be concluded, that participatory approaches in water management are foreseen theoretically and partly implemented in almost the entire Mediterranean region. However, the introduction to the proceedings of the 1st WASAMED workshop on Participatory Irrigation Management (Hamdy, Tuzun et al., 2004) showed that in many countries the development and management of at least the water supply infrastructure remains in the exclusive or at least main responsibility of government bodies. This observation is verified also by the field studies in the Mediterranean. Nevertheless, a tendency can be observed, that participatory approaches are getting increase recognition in the region. This is due to the requirements of the Water Framework Directive in Europe and due to reforms initiated by the World Bank in Northern Africa. To build Water User Associations (WUA) is the common approach of participation in water management. Farmers are participating in these associations and have therewith also a voice in water management. The Water User Associations are participating in different forms, from consultation to active involvement, in the water management processes on higher levels. In the most cases WUAs can distribute water that is allocated to them in their own responsibility to their members.

However, in all three field study regions participation is understood as participation of water users, i.e. irrigation associations, farmer association, domestic water supplier, and hydro-electric industry. Water users, however, are only one group of stakeholders affected by water management policies and strategies. There are other stakeholder groups which should be incorporated as well, like social groups, environmental groups, representatives of local communities and other parties having an interest in the water bodies or being affected by a certain water policy. From an institutional perspective in none of the water basins a participation of these other relevant and affected stakeholder is foreseen. This often results in the lacking discussion on the environmental and social costs of water management strategies and practices.

As well for Integrated Water Resource Management and for an effective implementation of necessary water saving strategies the participation of all relevant stakeholders is essential.

Generally spoken the restriction of participation to water users will not give incentive to incorporate environmental and social costs and develop appropriate strategies for water saving from the process. Water user will negotiate in the participatory process on the allocation of water, but not on reducing the total amount of water use, as they have a strong interest to use water for their purposes. Reducing the amount of water, i.e. water saving strategies, therewith is not in their interest. Of course, there are other important institutional aspects failing in giving incentives to water saving strategies, like low water pricing, promoting to grow inadequate and water demanding crops, etc. However, a serious participatory approach would provide somehow a balance to contradicting aspects to water saving strategies.

A second observation with respect to water management can be drawn from the field studies and interviews: Indicators for water management in general and for irrigation management (as important activity to water saving) in particular are not effectively used on the local level, i.e. by the stakeholders involved. Also other empirical studies in the Mediterranean imply that most of the indicators for water resource management are not effectively used or even unknown on the implementation level in the Mediterranean, i.e. by the WUA or farmer associations. However, this is not a problem only in the Mediterranean but can be observed in many other countries in the world. Water users are mainly interested in the amount of water allocated to them. In general they are not interested in quality aspects of water if it is not introduced from outside (law) to them or they are suffering from poor water quality. Hence, the use of indicators for integrated water management is not on the agenda of water users in the region. Therefore, one reason for this lack of effective usage of existing indicator sets might be again the missing consideration of affected stakeholders and the lacking incorporation of local tacit knowledge in the formulation of the specific policy and the selection or development of indicators. It is argued that the effectiveness of the indicators requires stakeholder (not only water user) participation during the development or selection of indicators. Through a participatory approach the knowledge and perspectives of the stakeholders can be incorporated into the development of indicator-sets for sustainable water use in agriculture and therewith the indicators can be perceived as relevant and useful. It is acknowledged that the indicator development requires the multiple concerns and, among others, stakeholder participation is considered as a principle during the development of indicators (Hardi and Zdan, 1997; Bell and Morse, 2004; Beratan, Kabala et al., 2004; McCool and Stankey, 2004). Nevertheless, the reasons for the lacking effective participation are multiple ranging from legal aspects in water laws to lacking education and knowledge on issues of water scarcity, its origins and driving forces.

In the interviews several times the institutional framework for water management was mentioned as the most important constrain to effective water saving strategies in the Mediterranean. As well as water laws and participation forms agricultural policies and subsidy systems for agricultural productions are not giving incentives to water saving strategies but the contrary.

CONCLUSION

To conclude the findings of the presented study it can be argued, that the implementation of water saving strategies and integrated water management policies is not yet been progressed in the Mediterranean. Even the European Mediterranean countries are lacking progress, although they have to implement the European Water Framework Directive (WFD).

Participatory approaches are developed and implemented with the Water User Associations. But participation of all relevant stakeholders (like required in the WFD) is often not even foreseen. This course also a lack in effective indicator use at the management levels, which is an evident precondition to water saving strategies. Furthermore, it can be concluded from the literature review and the field visits that still traditional supply-based management approaches predominate water management in the Mediterranean. Giving the reason for this lacks from the study findings, the can be argued that effective water saving policies in the framework of an integrated water management approach need an institutional change in the sense of an opening of participation processes to all relevant stakeholder. This can be reached relatively easy be allowing not only water users to participate in the water boards, but also other interested and affected stakeholders.

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COUNTRY REPORTS

GESTION DU PÉRIMÈTRE D'IRRIGATION DE LA MITIDJA OUEST TRANCHE 1 (ALGERIE)

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Résumé - En Algérie, le secteur de l'eau est confronté à la pression de plus en plus forte sur des ressources en eau limitées - surexploitées et vulnérables ce qui entraîne une baisse continue des disponibilités en eau par habitant, aux épisodes de sécheresse fréquents au cours des dernières années - ils constituent désormais un problème structurel à prendre en compte dans la gestion des ressources en eau. Un développement durable en Algérie passe obligatoirement par une durabilité des zones irriguées. Depuis des décennies, d'importants efforts de mobilisation des ressources en eau ont été réalisés par les pouvoirs publics. Libéralisation, désengagement de l'Etat, accroissement de la rareté de la ressource, recherche de compétitivité, changements de production et vieillissement des équipements publics ont conduit les producteurs à développer dans le pays, des stratégies de plus en plus individualistes. Des problèmes de durabilité au sens environnemental et économique se posent pour l'ensemble de ces systèmes irrigués. L'amélioration des efficiences et de l'économie de l'eau est aujourd'hui un objectif prioritaire. Pour faire face à cette situation, l'Office du Périmètre d'Irrigation de la plaine de la Mitidja a adopté une stratégie pour rationaliser et mieux valoriser l'usage de l'eau. Ainsi, sont prévues des opérations de réhabilitation et de renforcement de la maintenance afin de limiter les pertes en eau et d'améliorer le rendement des ouvrages hydrauliques d'une part, d'offrir un service de qualité aux usagers d'autre part. De même, sont programmées des incitations à une gestion de l'eau plus économe par l'introduction de nouvelles techniques d'irrigation, et des actions de sensibilisation pour impliquer davantage les agriculteurs. La plaine de la Mitidja située à proximité de la capitale Alger, se trouve face à une demande très forte en fruits et légumes et reste le plus important fournisseur de la région. Le climat, le sol et l'histoire offrent à cette plaine un potentiel agricole régional élevé.

Mots clés: périmètre d'irrigation, plaine de la Mitidja Ouest, efficience, économie de l'eau, gestion, Algérie.

INTRODUCTION

La plaine de la Mitidja est scindée en deux zones géographiques: le périmètre de la Mitidja Est et le périmètre de la Mitidja Ouest. Le périmètre irrigué de la Mitidja Ouest couvre une superficie de 8600 ha dans sa première tranche qui a été mise en eau en 1988. Aujourd'hui 86 % des exploitations sont des exploitations agricoles collectives et individuelles (EAC et EAI), c'est-à-dire que l'Etat reste le propriétaire de la terre. La question du statut foncier des exploitations interfère avec les investissements et le développement agricole dans cette région ou les terres privées sont minoritaires.

Sachant que cette zone était déjà traditionnellement irriguée en gravitaire à partir de puits et de forages individuels, l'Etat a réalisé un réseau public desservi à partir de barrages réservoirs et gérés par un office des périmètres irrigués (OPI), dans l'optique de préserver l'eau de la nappe tout en permettant le développement de l'agriculture irriguée sur la plaine

Néanmoins l'eau du réseau public ne représente qu'une faible partie de l'eau utilisée par les irrigants, vu le dysfonctionnement existant (sur les 8600 ha équipés, la superficie effectivement irriguée par le réseau n'a jamais dépassé 2800ha). De ce fait on assiste à une exploitation croissante et anarchique de l'eau souterraine avec des conséquences à la fois sur l'évolution de cette ressource aussi utilisée pour l'Alimentation en eau potable (notamment lors des périodes sèches) et sur les capacités de l'Office qui connaît des problèmes croissants. Dans ce contexte les agriculteurs adoptent des stratégies contrastées qui les conduisent soit à retenir la seule utilisation de l'eau du réseau public, soit à privilégier les forages individuels ou à utiliser des solutions mixtes.

La communication s'articule autour des aspects suivants :

Dans une première partie, les équipements hydro agricoles du périmètre de la Mitidja Ouest tranche 1 sont décrits. La deuxième partie expose la problématique de la ressource eau et la gestion du système d'irrigation du périmètre Mitidja Ouest tranche 1. La troisième partie est consacrée à la présentation du plan d'action de l'Office mis en oeuvre pour économiser l'eau : réhabilitation de certains secteurs, renouvellement de stations de pompage, renforcement de l'entretien. Ces mesures sont accompagnées d'efforts de vulgarisation et de formation des agriculteurs et des techniciens. Enfin des propositions de mesures et d'actions de l'économie de l'eau pour une gestion intégrée du périmètre sont proposées.

Aménagement hydro agricole du périmètre

Pour une exploitation plus économique de la terre fertile, située dans la Mitidja Ouest, dont la surface totale est de 23000 ha environ, un périmètre d'irrigation a été réalisé.

L'approvisionnement en eau se fait à partir de l'accumulation d'eau du barrage El Moustakbel sur l'oued Bouroumi, situé en amont du périmètre, dont la capacité de retenue est de 188 millions de m3. Un volume régularisé de 107 millions de m3 est obtenu par les apports propres du Bouroumi et les volumes dérivés du Harbil et de la Chiffa.

L'ensemble des ouvrages faisant l'objet du projet a pour but de capter et de conduire la quantité d'eau d'un débit de 13,85 m3/s nécessaire à l'irrigation des surfaces du périmètre.

Un barrage de prise avec une accumulation d'eau de 60000 m3 environ, situé à 15 km en aval du barrage El Moustakbel capte l'eau qui est dirigée vers le périmètre par un dalot en charge et le canal Rive droite (RD) d'un débit de 5,57 m3/s et rive Gauche (RG) d'un débit de 8,28 m3/s.

Le périmètre a été découpé en deux tranches :

-tranche 1 est desservie par le canal RD (fig. N°1)

-tranche 2 est desservie par le canal RG

La tranche 1 du périmètre d'irrigation de la Mitidja Ouest est située dans les Wilayas de Blida et Tipaza, à une distance de 55 km au Sud Ouest d'Alger et elle est limitée par :

-l'Oued Chiffa à l'Est

-l'Ouest Bouroumi à l'Ouest

-le piedmont de l'Atlas Blidéen au Sud

-l'Oued Bouroumi et oued djer au Nord

La surface équipée est de 8600 ha, la surface irriguée est de 7927 ha avec trois types d'assolement cultural :

-agrumiculture (2109 ha)

-une rotation maraîchère et une rotation cultures industrielles (1852 ha)

-une rotation maraîchère avec rotation cultures industrielles et une rotation fourragère (3966 ha)

La tranche 1 est alimentée par le canal Rive Droite qui dessert 03 secteurs (Table n°01):

le secteur sud alimenté par la station de pompage Mouzaia par le biais de l'adducteur n°2

le secteur Est alimenté gravitairement par la prise gravitaire n°1 (PG1) du canal RD par le biais de l'adducteur n°3

le secteur ouest alimenté gravitairement par la prise gravitaire n°2 (PG2) par le biais de l'adducteur n°1

Table 1. Répartition des surfaces de la tranche 1 et calage hydraulique des débits

Secteur	Surfaces en ha			Date de début d'exploitation	alimentation	Débit m3/s
	Géographique	équipée	irrigable			
Sud	2660	2490	2297	1988 (par pompage)	St.Pomp. Add 2	1.600
Ouest	3380	3410	2889	1992 (gravitaire)	PG2 Add. 1	1.529
Est	3210	2970	2741	1992 (gravitaire)	PG1 Add. 3	2.445
Totaux tranche 1	9250	8600	7927	-	-	5.570

La distribution de l'eau pour l'irrigation du périmètre se présente comme suit :

-trois adducteurs de diamètre de 1100 à 1500 m en tête, chacun alimente un secteur

-chaque adducteur alimente plusieurs branches de diamètre de 200 à 700 mm

-les départs des antennes se font à partir des branches avec un équipement des bornes, chaque antenne est équipée en prises hydrant pour l'irrigation d'un îlot type d'une surface moyenne de 18 ha.

Un aspect important de l'aménagement est le projet d'assainissement, drainage et pistes. La surface équipée par le réseau d'assainissement superficiel est de 8600 ha, y compris une zone de drainage de 600 ha. La fonction de l'ensemble de l'équipement de l'assainissement est l'évacuation rapide des eaux de pluie et des apports venant de bassins versants extérieurs au périmètre.

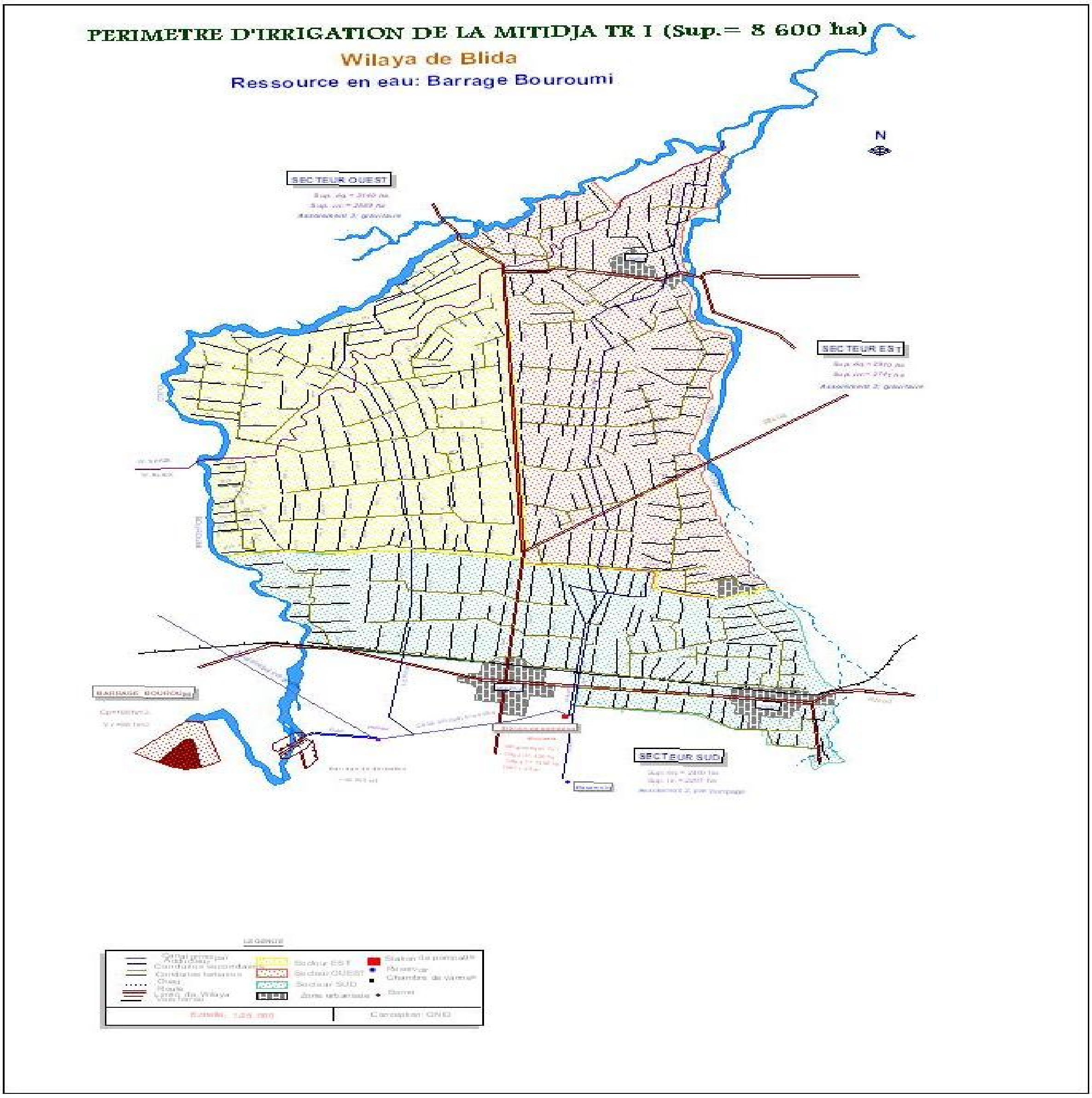

Fig. 1. Périmètre irrigué de la Mitidja (TR1)

Les ressources en eau

Le périmètre de la Mitidja Ouest (Tranche I) est caractérisé par un climat chaud et sec l'été, froid et humide l'hivers avec :

- Une saison pluvieuse de Novembre à Février.
- Une saison sèche de Juin à Septembre.

La pluviométrie inter- annuelle moyenne est de 667mm

Actuellement la seule ressource en eau provient du bassin versant de BOUROUMI et non pas de l'Oued Bouroumi, ceci contrairement à ce qui a été prévu dans l'étude BRLi ; à défaut des ressources prévus à savoir que :

- Le transfert d'eau de l'Oued CHIFF A n'est pas encore réalisé car les travaux sur ce dernier ne sont pas encore achevés,

- Les eaux de l'oued HARBIL sont contaminées par les déchets industriels et domestiques provenant de la wilaya de Médéa et de l'usine pharmaceutique (SAIDAL)

Ecart entre le volume théorique et le volume alloué et efficience

Tableau 2. Ecart entre le volume théorique et le volume alloué et efficience

Année	Volume théorique (Hm3)	Volume alloué (Hm3)	Ecart Vth - Vall (Hm3)	Taux %	Causes
1999	45.62	17.5	28.12	61.63	Indisponibilité d'eau au niveau du barrage
2000	45.62	7.00	38.62	84.66	Indisponibilité d'eau au niveau du barrage
2001	45.62	5.02	40.6	89.0	Indisponibilité d'eau au niveau du barrage
2002	45.62	0.00	45.62	100.00	Uniquement l'AEP d'Alger (plan d'urgence)
2003	45.62	20.00	25.62	56.16	Indisponibilité d'eau au niveau du barrage + AEP d'Alger
2004	45.62	10.00	35.62	78.07	Indisponibilité d'eau au niveau du barrage + AEP d'Alger

AEP : Alimentation en Eau Potable Source : OPIM

Suite de l'indisponibilité de la ressource en eau entre 1994& 1998, le volume théorique et le volume alloué sont évalués uniquement sur les cinq (05) dernières années (1999-2004).

On constate que, de 1999 à 2002, l'écart entre le volume théorique et le volume alloué progresse jusqu'à atteindre 100% en 2002. En 2003, l'écart se réduit (56,16%) puis se creuse en 2004 (78,07%).

Ces écarts s'expliquent, entre autres, par **l'indisponibilité** de la ressource en quantité suffisante au niveau du barrage d'EL MOUSTAQBAL. Cette indisponibilité d'eau au niveau du barrage est du à l'aléa climatique (sécheresse), particulièrement, et au fait que le bassin versant de l'Oued BOUROUMI reste la seule ressource en eau affectée à l'irrigation.

Cette situation a engendré une concurrence de plus en plus accrue avec les autres usagers de l'eau tels que l'AEP, car depuis l'année 2002, une partie des eaux du barrage ELMOUSTAQBAL est affectée à l'AEP d'ALGER via le transfert

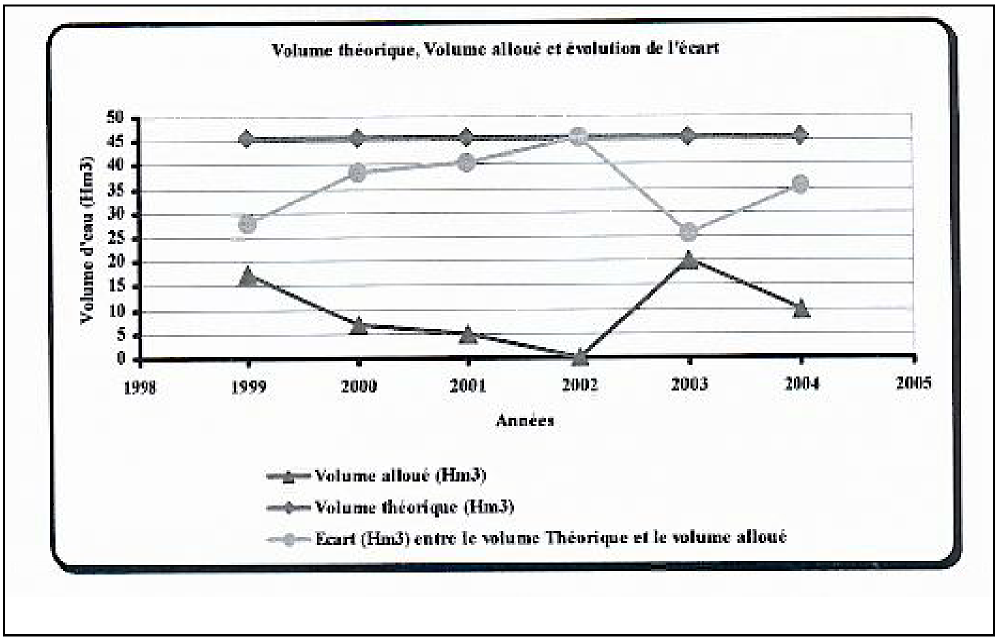

Fig. 2. Volume théorique, Volume alloué et évolution de l'écart

Les superficies irriguées et efficience du reseau

Tableau 3. Volumes lâchés, volumes distribués et superficies irriguées

Année	Volume lâché (Hm^3)	Volume distribué (Hm^3)	Superficie irriguée (ha)	Dotation réelle (m^3/ha)	Efficience du système (%)	Pertes d'eau	Observation
1999	15.5	7.61	1364.2	5578.36	49	51	Envasement du barrage de prise
2000	5.54	4.21	1350	3118.51	75	25	Manque de ressources en eau
2001	4.01	2.85	973.5	2927.58	71	29	Manque de ressources en eau
2002	0	0	0	-	-	-	Uniquement l'AEP d'Alger (plan d'urgence)
2003	7.77	6.1	1055.6	5778.7	78	22	
2004	9.33	5.62	1197.1	4694.67	60	40	Envasement du barrage de prise

Source : OPIM

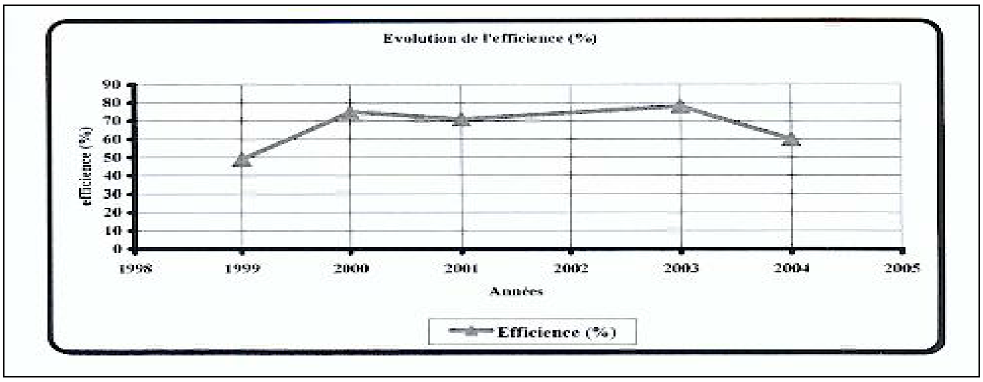

Fig. 3. Evolution de l'efficience

Il est à noter que l'Office du Périmètre d'Irrigation de la Mitidja Ouest ne dispose pas de moyens de comptage fiables au niveau de la mise en tête du réseau (barrage de prise) d'ou l'incapacité d'évaluer le volume mis en tête du réseau

On constate que l'efficience au cours des années 2000, 2001 et 2003 est proche à celle estimée, soit 81% (I). Ainsi, les pertes sont de l'ordre de 25% en moyenne.

L'efficience estimée se répartie comme suit :

- 0.9 (efficience du transport en rivière),
- 0.9 (efficience dans les réseaux de canaux et de canalisations),

En 1999 et 2004, la tendance constatée au cours des années 2000,2001 et 2003 (amélioration de l'efficience et réduction des pertes) s'inverse: l'efficience décroît de 78% à 60% et les pertes augmentent de 22% à 40%.

Les pertes les plus fortes en pourcentage se produisent des deux années ou les volumes lâchés sont les plus importants, ce qui s'explique probablement par la perte au niveau de l'ouvrage de prise par déversement du fait que le dalot envasé ne permet pas de prélever le débit arrivant par l'oued.

L'envasement rapide du barrage de prise, du dalot et des deux canaux (CPRD, CPRG) est du principalement au manque de ressources en eaux, ce qui explique que le barrage n'a jamais atteint son seuil normal de remplissage qui est de 188 Hm3. de plus ces eaux très chargées entraînent le dépôt de la vase le long de l'oued jusqu'à l'infrastructure.

Il faut aussi tenir compte des pompages illicites le long de l'oued Bouroumi, les volumes correspondants sont ajoutés aux pertes de parcours

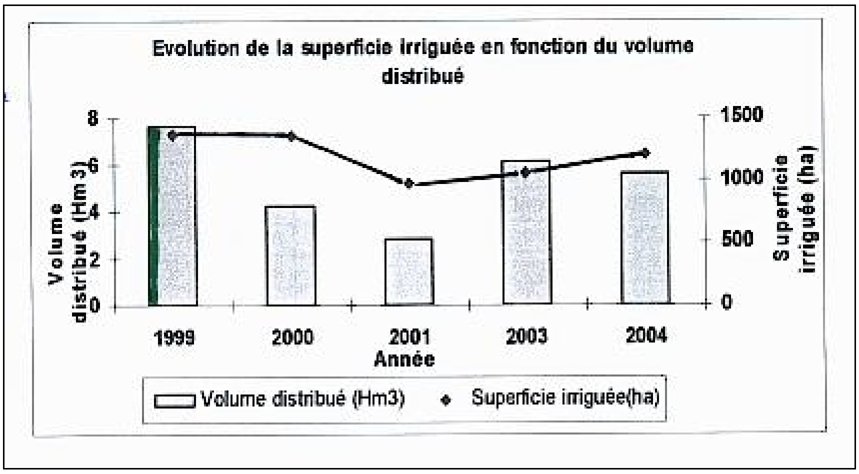

Fig. 4. Evolution de la superficie irriguée en fonction du volume distribué

On note que malgré l'augmentation du volume distribué au cours des années 2000, 2003 et 2004, les surfaces irriguées ont diminuées. Il semble que les variables, volume distribué et surface irriguée, ne sont pas liées.

Problématique de la gestion de l'eau d'irrigation et plan de modernisation du périmètre

Après une longue période de fonctionnement des équipements d'irrigation du périmètre Mitidja Ouest tranche 1 depuis sa mise en eau en 1988, des équipements se sont dégradés et leur rendement a diminué, – simultanément au déficit hydrique des années sèches.

A cet effet, l'OPI Mitidja a jugé utile d'entreprendre une stratégie d'amélioration en la matière et de procéder au préalable à un diagnostic du système d'irrigation de ce périmètre dans le but de déceler et d'analyser les défaillances en vue d'apporter les solutions requises pour améliorer les performances de l'infrastructure et des ouvrages dégradés, pallier les perturbations des opérations d'irrigation et les pertes d'eau qui s'y produisent et satisfaire l'exigence d'assurer un service d'eau de qualité aux usagers. Ces exigences s'inscrivent dans le cadre des orientations arrêtées à l'échelle nationale pour la modernisation du secteur de l'irrigation en Algérie.

Un plan d'action approprié a été élaboré par l'Office et ayant comme objectifs :

– augmenter les performances des systèmes d'irrigation du périmètre et garantir de la pérennité des équipements ;
– rationaliser l'usage de l'eau et optimiser la consommation d'énergie électrique ;
– améliorer la qualité du service de distribution de l'eau aux irrigants ;
– améliorer l'efficience de l'apport d'eau à la parcelle ;
– mieux valoriser les eaux d'irrigation ;
– augmenter les revenus des agriculteurs et le taux de recouvrement des redevances d'eau d'irrigation

Ce plan d'action porte sur trois axes d'intervention :

– améliorer des performances de l'infrastructure d'irrigation par le renforcement des opérations de maintenance et de réhabilitation des ouvrages et équipements d'irrigation ;
– optimiser l'application de l'eau à la parcelle et introduire de nouvelles techniques d'irrigation plus économes en eau ;
– renforcer l'encadrement et l'organisation des usagers et les sensibiliser à la nécessité d'une meilleure conduite de l'irrigation, plus efficiente.

En outre, le diagnostic de la tranche 1 du périmètre est devenu impératif en raison de la raréfaction des ressources en eau qui prend un caractère structurel, et de la demande en eau croissante du fait de la réalisation de la deuxième tranche de 15000 ha du périmètre irrigué et de la compétition accrue avec les autres secteurs en particulier l'AEP.

Devant ces conditions, une utilisation rationnelle des eaux d'irrigation et une gestion de plus en plus rigoureuse s'imposent.

Une étude de diagnostic des infrastructures hydrauliques du périmètre de la Mitidja ouest tranche 1 a été réalisé en 2005

Principaux résultats du diagnostic

Le périmètre de la Mitidja Ouest est relativement récent et par conséquent les infrastructures n'ont pas subi les atteintes du vieillissement des ouvrages que l'on rencontre sur d'autres périmètres. Cependant des conditions très défavorables de l'environnement ont été la cause d'une situation dégradée des ouvrages eux mêmes ou de leurs conditions d'exploitation. Ainsi la ressource en eau très insuffisante dès la mise en eau du périmètre (du au retard pris dans la construction des ouvrages de mobilisation et de transfert) a placé le gestionnaire (OPIM) dans une situation de faiblesse par rapport aux bénéficiaires (service de l'eau non assuré) et aux capacités financières du service (faibles recettes) De plus le périmètre a vécu une situation d'insécurité au cours de laquelle les ouvrages accessibles se sont dégradés rapidement (dégradations volontaires, manque d'entretien et initiatives individuelles préjudiciables)

Principales conclusions concernant les réseaux de conduites de distribution sous pression

- Un manque partiel, parfois total, de toutes les pièces hydromécaniques (toute nature confondue), particulièrement les compteurs d'eau et les purgeurs.
- Les systèmes de fermeture ou en d'autres termes de couverture des ouvrages de génie civil abritant les appareillages, endommagés ou même détruits, rendent ces ouvrages vulnérables aux vol d'eau, ou à d'autres inconvénients: lieu de dépôts de déchets et ordures. En outre, cette situation des ouvrages de protection des appareillages, fait que ces derniers ont disparus. Pour diminuer ces actes de vandalismes, les gestionnaires de l'office ont mis au point un nouveau système de sécurité aboutissant à fixer les dalles des chambres des vannes avec des barres métalliques.
- On constate que les soupapes qui se trouvent à l'intérieur des chambres de vannes évacuent près de 125 l/s, parfois plus, cela entraîne l'inondation des chambres ainsi que les ouvrages qui s'y trouvent, d'où la corrosion de ces derniers.
- La répartition des bornes et des vannes hydrants issue de l'ancien découpage des DAS (Domaine Agricole Socialiste) n'est plus adaptée au nouveau parcellaire des EAC (Exploitation Agricole Collective) et EAI (Exploitation Agricole Individuelle). Les gestionnaires de l'office proposent d'étudier la possibilité de remplacer les prises hydrants par des bornes de type A.

Selon l'étude, les prises- hydrants servent à brancher le système d'irrigation par aspersion, mais la plupart des agriculteurs qui trouvent ce système onéreux, irriguent traditionnellement (par gravité).

Cela a rendu ces prises hydrants inutiles et sont dans leur majorité sabotées ou enterrées par ces agriculteurs pour, malheureusement, gagner une petite superficie agricole.

Etat des canalisations enterrées

Le diagnostic a identifié quelques tronçons de conduites sur lesquelles on constate des casses et fuites répétées (conduites en amiante ciment et béton précontraint). Ces incidents localisés ne semble pas imputable aux conduites elles mêmes (corrosion ou qualité des matériaux) mais à des tronçons dans lesquels les conditions de pose étaient plus difficile. Il est donc proposé d'assurer le remplacement partiel des conduites sous la forme d'une campagne de réparation des casses et fuites.

Diagnostic des ouvrages de tête

Les ouvrages concernés et les principales conclusions du diagnostic pour chacun d'eux sont les suivantes de l'amont vers l'aval :

- le barrage de Moustaqbel: géré par l'ANBT (Agence Nationale des Barrages et des Transferts) avec l'ONID (Office National de l'Irrigation et du Drainage) comme utilisateur principal : Insuffisance des procédures de gestion concertée et des lachures de volumes au niveau du fonctionnement journalier: Communications insuffisante (ou absente entre les gestionnaires du barrage et l'unité de l'OPIM (office du Périmètre d'Irrigation de la Mitidja)
- La prise sur l'oued Bouroumi et les dalots : Ouvrage conçu pour une exploitation manuelle par un gardien: manoeuvre manuelle des vannes d'entrée et de dégravement. Ce fonctionnement n'a pas

donné satisfaction, l'automatisation est souhaitée. Dépôt de matériaux en amont du seuil, et au niveau de la prise

- Les prises gravitaires: dégradation des équipements existants (vanne, filtration automatique}, pas d'équipement de comptage des volumes
- La station de pompage de la Mitidja: diverses composantes de la station ne sont pas fonctionnelles ou sont dégradées, suite à un arrêt prolongé du fonctionnement de cet ouvrage

Un programme de travaux d'urgence est en cours de réalisation sur la base d'un contrat signé entre la DHW (Direction de l’Hydraulique de Wilaya) et l'OPIM, les propositions d'investissement sur ces ouvrages viennent donc en complément de ce programme

Programme d’intervention

Les ouvrages de tête tels que définis précédemment conditionnent le bon fonctionnement de l'ensemble du périmètre, les interventions à prévoir sur ces ouvrages sont donc proposées au court terme, et dans le prolongement de l'opération d'urgence en cours de réalisation

- Interventions de remise en état sur les ouvrages de distribution sur le périmètre : Le périmètre est homogène du point de vue des équipements, de la mise en valeur et des potentialités, on ne peut donc pas définir une zone géographique prioritaire par rapport à une autre.

* Le programme proposé est donc un programme pluriannuel à court terme sur l'ensemble du réseau. Les orientations de ce programme seront la réduction des pertes d'eau au cours des premières années et la remise en état des bornes et prises au rythme de l'évolution de la ressource en eau qui est faible actuellement, mais qui va s'accroître avec la mise des dérivations des oueds Chiffa puis Djer (horizon 5 ans).
* Programme particulier sur la mise en oeuvre du comptage individuel et de la réorganisation de la distribution: Cette action devra s'étaler sur le court et moyen terme et comporter plusieurs volets
* L'installation des compteurs en liaison avec les mesures techniques et institutionnelles.
* Réhabilitation de la borne à court terme
* Mise en place d'une concertation en vue de la création d'associations d'usagers par îlot pour une gestion participative.
* Elaboration d’un programme de suivi des efficiences au niveau de la parcelle et cela après la réhabilitation du réseau

Mode d'irrigation

- Lors des opérations de réhabilitation des bornes, Il sera tenu compte de la situation réelle des modes d'irrigation sur le périmètre: Les bornes utilisées comme bornes gravitaires seront équipées seulement de la vanne et du limiteur de débit, les bornes utilisées pour l'aspersion ou le goutte à goutte seront équipées de la vanne, du limiteur de débit et du régulateur de pression (protection du matériel à la parcelle contre les surpressions)
- Sensibilisation des agriculteurs et vulgarisation des techniques économes d’eau.

CONCLUSION

La mise en oeuvre du plan d’action d’économie d’eau présenté ci-dessus sera lancé la fin de l’année 2006. Cependant, la réussite parfaite de ce plan d’action d’économie et son aboutissement intégral ne peut aboutir sans une forte implication des agriculteurs, notamment par le renforcement de la mise en oeuvre de la gestion concertée et participative de l’irrigation. La gestion participative est complémentaire aux actions qui seront engagées par l’Office afin d’assurer une plus forte amélior ation de l’efficience du système d’irrigation et une harmonisation des différentes actions d’économie de l’eau sur le périmètre et garantir un service de l’eau de meilleure qualité.

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GESTION INTEGREE DES RESSOURCES EN EAU DANS LES BASSINS DU SOUSS MASSA

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INTODUCTION : PRESENTATION DE LA ZONE DU SOUSS MASSA

La zone du Souss Massa se trouve au centre du Maroc, elle s'étend sur une superficie de 12.000 km^2 répartie entre la plaine du Souss (4.150 km^2), la plaine du Massa (1.600 km^2) et des zones montagneuses du Haut et de l'Anti-Atlas (6.250 km^2).

Les ressources en sol de cette zone sont ventilées comme suit: 228.500 ha comme Superficie Agricole Utile (108.500 ha irrigables, 120.000 ha de terres bours), 580.300 ha de forêts et 391.200 ha de parcours et inculte.

Cette zone est caractérisée par un Climat de type semi-aride à subdésertique, mais le courant adoucissant de l'Océan Atlantique et la barrière montagneuse de l'Anti-Atlas constituent une protection contre l'influence désertique, favorisant ainsi la région. Les précipitations annuelles sont faibles et irrégulières: 200 mm/an en moyenne dans la plaine. Les températures sont modérées; La moyenne annuelle est d'environ 19°C, la moyenne des maxima atteint 27°C et des minima 11°C. En général, l'ensoleillement (3.000 heures de soleil par an) élevé et la douceur du climat font de la zone du Souss Massa l'une des premières régions primeuristes du pays.

Systèmes de production

Les réalisations des principales productions agricoles s'élèvent à 660.000 tonnes d'agrumes, 1.108.000 tonnes de productions maraîchères, 132.000 tonnes de bananes, soit respectivement 50 %, 20 % et 53 % de la production à l'échelle nationale.

Ces productions contribuent à l'approvisionnement des marchés intérieurs et extérieurs et permettent des rentrées appréciables de devises grâce à l'exportation des productions agrumicoles et maraîchères représentant respectivement 75 % et 55 % à l'échelle nationale.

Ressources en eau

Les ressources en eau superficielles sont constituées des principaux Oueds ci-après:
* Oued Souss et ses affluents dont les apports moyens annuels s'élèvent à 425 Mm3.
* Oued Massa: dont les apports moyens annuels sont de 138 Mm3.
* Oueds Tamri et Tamraght dont les apports moyens annuels sont de 75 Mm3.

Ces ressources en eau sont régularisées par les barrages, dont les deux plus importants (Youssef Ben Tachfine et Abdelmoumen) alimentent les périmètres publics irrigués (Massa et Issen), le troisième est constitué du complexe (Aoulouz/ Mokhtar Essoussi) ayant pour rôle la recharge de la nappe du Souss et l'apport d'un complément d'irrigation à la zone Sebt El Guerdane.

Le barrage Youssef Ben Tachfine d'une capacité de 303 Mm3, a été mis en service en 1973, il régularise 88 Mm3 par an, dont 85 pour l'agriculture et 3 pour l'Alimentation en Eau Potable.

Le barrage Abdelmoumen, sur l'Oued Issen, mis en service en 1981, a une capacité de 214 Mm3. Il régularise un volume de 80 Mm3 dont 70 pour l'agriculture et 10 Mm3 pour l'Alimentation en Eau Potable.

Le complexe Aoulouz/ Mokhtar Essoussi: Ce complexe est constitué du:
* Barrage Aoulouz d'une capacité de 108 Mm3, a pour rôle l'alimentation de la nappe du Souss.
* Barrage Mokhtar Essoussi d'une capacité de 50 Mm3, a pour rôle d'assurer un apport d'appoint de 45 Mm3 par an pour l'irrigation du périmètre Sebt El Guerdane.

Les ressources en eau souterraine sont constituées essentiellement par les nappes du Souss et du Chtouka.

La nappe du Souss: Son bassin hydrogéologique, limité au Nord par le Haut Atlas, au sud par l'Anti-Atlas et à l'Ouest par l'Océan Atlantique, s'étend sur une superficie de 4150 km2. Les apports sont de 400 Mm3.

La nappe des Chtoukas: De moindre importance, la nappe des Chtoukas, au sud-ouest de la plaine du Souss, s'étend sur une superficie de 1260 km2. Les apports moyens sont de 40 Mm3.

PROBLEMATIQUE DE L'EAU DANS LA ZONE DU SOUSS MASSA

Les ressources en eau superficielles deviennent de plus en plus insuffisantes pour satisfaire la demande exprimée. Le recours à l'exploitation des ressources en eaux souterraines a été toujours une pratique séculaire dans cette zone.

Les prélèvements d'eau souterraine ont dépassé les ressources renouvelables et ont conduit à un destockage des nappes du Souss Massa évalué en moyenne à 260 millions de mètre cube par an. Ce destockage s'est traduit par une baisse moyenne du niveau de la nappe de 0,5 à 2,5 mètre par an.

Pour faire face à cette problématique, un plan directeur du développement des ressources en eau dans les bassins du Souss Massa a été élaboré et approuvé lors de la 9eme session du Conseil Supérieur de l'Eau et du Climat. Ce plan vise entre autre le renforcement des ressources en eau (construction de barrages, recours aux eaux non conventionnelle..), et l'économie de l'eau reposant sur la gestion de la demande.

GESTION INTEGREE DES RESSOURCES EN EAU DANS SOUSS MASSA PROJET SIWM (SOUSS INTEGETED WATER MANAGEMENT)

Le principal objectif de SIWM est d'assister les partenaires du projet à créer un système de gestion intégrée des ressources en eau pour la région. L'approche utilisée est basée sur un système équitable, efficient et transparent pour renforcer les institutions locales à travers l'harmonisation des visions stratégiques variées par ces partenaires. Cette approche requiert une meilleure coordination, une planification conjointe et le développement et l'exécution de nouvelles politiques relatives à l'usage des ressources en eau.

Ce projet comprend trois composantes:

Etablissement d'institution et de politiques de gestion:

- Création et gestion d'une agence de bassin
- Elaboration de mécanismes pour un cadre interinstitutionnel et sa coordination
- Identification et réforme de politiques majeures de l'eau pour une gestion améliorée des ressources en eau

Mise en œuvre et dissémination de pratiques durables de gestion intégrée des ressources en eau:

Dans ce cadre six projets pilotes ont été identifiés et mis en œuvre par les différents partenaires

- PP 1: Développement d'un système de télémétrie pour la gestion intégrée des ressources en eau dans le Souss Massa

  L'objectif global de ce projet est d'établir un système intégré pour la gestion des ressources en eau dans les bassins du Souss Massa ce système comprend la collecte de données de base, leur transmission à partir des stations vers les sites centraux ainsi que les outils de stockages, d'analyse au niveau du site central de traitement de données.

  En agriculture ce système a été testé au niveau périmètre public d'une superficie de 400 ha. Il consiste en l'installation de matériels de mesure des volumes d'eau prélevés et distribués et des paramètres de fonctionnement des forages, de la station de mise en pression et des bornes d'irrigation. Ces données sont transmises à distance et automatiquement par lignes téléphonique ou GSM au niveau des postes de traitement de données.

  Ce système permet de maîtriser les volumes d'eau et suivre le fonctionnement des équipements à distance et d'alimenter l'observatoire interinstitutionnel.

  Des projets similaires ont été réalisés aux niveaux des équipements gérés par la Régie Autonome Multi Services et l'Agence du Bassin Hydraulique du Souss Massa.

• PP 2 : Inventaire des points de prélèvement et gestion de la nappe
Ce projet a consisté en la réalisation d'un inventaire des points de prélèvement d'eau, l'élaboration de la base de données correspondante et le développement de modèles hydrologiques.
• PP 3 : Mise en place d'un système d'information agricole pour l'économie de l'eau
L'objectif est de fournir aux partenaires un outil de promotion pour l'usage rationnel de l'eau à travers la création d'un système innovateur de communication. Ce système permet la diffusion auprès des agriculteurs des techniques et conseils pour l'économie de l'eau à usage agricole.
Il a consisté en l'installation d'une station météorologique dont les données sont transmises à distance vers le poste de traitement informatique et affichées au niveau de trois panneaux électroniques implantés dans des sites de production de primeurs.
Ce projet a permis la constitution de référentiels climatique et cultural.
• PP 4 : Conversion d'un système d'irrigation gravitaire en système goutte-à-goutte
L'objectif est d'aider les membres de l'association d'usagers de l'eau agricole retenue à améliorer l'efficience de l'eau dans le cadre de partenariat. Le projet sert de modèle à d'autres associations qui envisagent d'investir dans l'économie de l'eau.
Ce projet concerne la conversion en irrigation localisée de 223 ha irrigués initialement en gravitaire. La contribution de l'association a porté sur le creusement de deux nouveaux forages, creusement du bassin d'accumulation et l'équipement des parcelles en goutte à goutte.
• PP 5 : Inventaire des sources de pollution dans le bassin du Souss Massa
L'objectif principal de ce projet pilote est de dresser un état des lieux de la qualité de la ressource en eau et de connaître les principaux foyers de pollution en vue de les protéger.
• PP 6 : Harmonisation des outils d'aide à la prise de décision
L'objectif de l'harmonisatsation des outils d'aide à la prise de décision, est de développer des outils permettant d'encourager l'échange, de développer et de renforcer la collaboration pour adopter une compréhension commune de la gestion intégrée de l'eau dans le bassin du Souss Massa.
Dans ce cadre, il a été procédé l'élaboration d'un inventaire interactif intégré entre les différents partenaires permettant d'accéder au informations sur les partenaires, sur les ressources en eau (qualité, quantité et cartes thématiques) etc….

Gestion participative des ressources et implication des usagers de l'eau

• Renforcer la participation des associations, des ONG et des municipalités dans la gestion des ressources en eau;
• Accroître la sensibilisation du public au sens large et des groupes cibles de la région.

HARMONIZATION AND INTEGRATION OF WATER SAVING OPTIONS IN CYPRUS

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SUMMARY- For Cyprus, water is the most important resource and a prerequisite for progress. Its scarcity has acted as a limiting constraint for the development of agriculture and for other economic activities such as tourism. Irrigated land, accounts 35.100 hectares or 16,2% of the total area enumerated and 57% of the annual amount of water for irrigation purposes is provided mainly from Government Irrigation Schemes. In the Government schemes the sources of water used are surface water, groundwater and reclaimed water. As a rule, the water demand in the non- Government schemes is satisfied by groundwater. The scarcity of water together with the high cost associated with collecting and using the limited surface rain water for irrigation, has become real constraints for our irrigated agriculture. Because of this, particular emphasis is placed on the water use efficiency and modern irrigation technology. Modern irrigation systems have been used in Cyprus agriculture for the last 40 years. It is estimated that currently over 95% of the total irrigated land of the country is being served by modern irrigation methods. Recently, particular emphasis was laid on protected cultivation and more specific on cultivation of vegetables and flowers on substrates and soilless cultures (closed systems and open with minimum drainage). At the Agricultural Research Institute, the use of local materials i.e. perlite, mixtures of perlite with pomace, almond shells, pine bark etc. have been tried successfully. In this paper, results of the application of modern techniques, hydroponic cultures, re-circulation of irrigation water and nutrient solution in closed systems and control of the climatic conditions in the greenhouse are discussed. In making the supply meet the demand the Government policy has encouraged and adopted management measures as water rationing, increase of public awareness for water conservation measures and water pricing for improvements in the water use efficiencies. The main measures, as well as the new Government water policies, are discussed in this paper.

Keywords: water saving, water management, irrigation water, irrigation methods, water supply, water demand, water policies.

IRRIGATED AGRICULTURE

Cyprus is the third-largest island in the Mediterranean with an area of 9251 km^2 (925000 ha). Presently the agricultural land consists of 216000 ha. The irrigated land amounts to 35100 ha (16.2% of the total agricultural land - Agricultural Statistics 2002) with provision to be expanded. The irrigated agriculture in semi arid countries like Cyprus demands large amounts of water and faces the serious challenge to increase or at least sustain agricultural production while coping with less and/or lower quality water.

There is an increasing concern about the effective and efficient utilization of water for agriculture and water conservation in general. The promotion of effective water use and on farm water management, were identified as important contributions to the management strategy (Chimonides, 1995), needed to address problems of water scarcity and practicing intensive agriculture on environmentally sound grounds. Improving the water use efficiency at farmers level is the major contributor to increase food production and reverse the degradation of the environment or avoid irreversible environmental damage and allowed for sustainable irrigated agriculture (Papadopoulos, 1996). The overall target is to maximize positive impacts of irrigation and minimize potential environmental hazards. The interaction between agricultural production and the environment should be complementary rather than competitive for balanced development of both. In the same line, in scheduling irrigation it is also important to identify the critical periods (stages) during which plant water stress has the most pronounced effect on growth and yield of crops, since this is also directly related to the nutrients requirement by the crop (Chimonidou, 1996).

In the view of the above, Government decided to improve the situation by creating and strengthening with personnel and equipment the Water Use Section of the Department of Agriculture in 1960 and by applying the water Use Improvement Project in 1965 and water supply (Special measures) Low No. 35 of 1965. With the creation of the Agricultural Research Institute in 1965 experiments were carried out on basic concepts of soil-water plant relationships (Chimonides, 1995).

Irrigated crops (permanent, annual)

The percentage of water demand for permanent and annual crop is 59% and 41%, respectively. This accounts 95,8 MCM/year and 65,5 MCM/year.

From 35.100 hectares of irrigated crops, 19.100 refer to temporary crops, while 16.000 refer to permanent crops. The main irrigated temporary crops are vegetable and melons with 27,6%, followed by fodder crops with 12,8% and cereals with 11,4%. The main irrigated permanent crops are citrus with 15,3% followed by fresh fruits with 10,2%, olives and carobs with 9,4% and Vines with 7,1% (Agricultural Statistics, 2002).

Origin of irrigation water

A percentage of 57% of the annual amount of water for irrigation purposes is provided mainly from Government Irrigation Schemes. In the Government schemes the sources of water used are surface water, groundwater and reclaimed water. As a rule the water demand in the non- Government schemes is satisfied by groundwater.

- Surface Water: Although the capacity of all main dams is 273.6 MCM, the average annual amount of water available for use in 2006, is estimated to be about 112.5 MCM. During the dry year of 2005 the contribution to irrigation of all dams was 63 MCM while for 2006, is expected to be only 39.5 MCM. Out of the 112.5 MCM, 93 MCM are used within Government Projects, 14.5 MCM for domestic use (after treatment) and 5 MCM for ecological areas.
- Groundwater extraction is estimated to be about 127.4 MCM on an annual basis. Such figure does not mean the safe yield of the aquifers, which is much lower. From this amount, 100.4 MCM are used for agriculture (26 MCM are within the Government Irrigation Schemes and 74.4 MCM are outside the Government Schemes).
- Springs contribute very little, amounting to 3.5 MCM per year, for domestic use of the mountainous villages.
- Desalination units at present contribute up to 33.5 MCM per year.
- Treated sewage effluent: Presently, only about 3.5 MCM is used, from which 2 MCM for agriculture and the rest for landscape irrigation.

Methods of irrigation (surface, sprinkler, micro-irrigation)

Modern irrigation systems have been used in Cyprus agriculture for the last 30 years. Due to the relatively high installation cost the drip method was initially used for irrigation of high value crops, such as greenhouse vegetables and flowers. At a later stage the installation cost was reduced, and the use of drippers, minisprinklers and low capacity sprinklers was expanded for irrigating trees and field vegetables. Proper hydraulic design of the irrigation systems, offered free of charge by the Ministry, coupled by a subsidy of the installation cost, resulted in a rapid expansion of the new irrigation systems.

Farmers have extensively adopted modern irrigation systems. The new technology introduced is continuously being tested by the Agricultural Research Institute in order to evaluate the different systems under local conditions and select the appropriate irrigation method for each cultivation (Metochis and Eliades, 2002).

For densely spaced field vegetables like potatoes, carrots, beans, etc. the permanent low capacity sprinkler system is recommended for irrigation. In case, however, of limited financial resources the portable sprinkler system can be used instead, although it requires more labour.

Drip irrigation is the only applicable method for irrigation of row vegetables grown in greenhouses, low-tunnels and in the open field, spaced at a relatively great distance on the row and between rows. One nozzle is usually installed to deliver water to each plant. Among permanent plantations, drippers are mainly recommended for banana, grapes and several other crops, like aromatic plants. Generally, unless there is a particular problem, drippers with larger nozzle opening are preferred, because they are not easily blocked by impurities, therefore, they require less filtering and they are characterized by higher uniformity in flow.

For irrigation of permanent tree plantations both drippers and minisprinklers can be successfully used. No differences have been observed concerning crop development and production; therefore, the choice of the irrigation method depends on several other factors. Minisprinklers are generally preferred and are more widely used for irrigation of trees, mainly due to lower installation cost. Moreover, as nozzle opening is relatively large they are not easily blocked by impurities present in the irrigation water.

The introduction of modern irrigation systems in Cyprus resulted in the expansion of irrigated agriculture, increase of water use efficiency and production, and improvement of yield quality. Continuous testing of new technology and instrumentation is always required, however, for further improvement of the design and management of the systems.

It is estimated that currently over 95% of the total irrigated land of the country is being served by modern irrigation methods. With the improved irrigation systems and the scheduling of irrigation based on experimental work of the Agricultural Research Institute, the overall water use efficiency at farmers level is above 80%.

PROTECTED CULTIVATION

In most Mediterranean countries the problem of an adequate water supply to meet the present and future demands of irrigated agriculture is very important. Water supply must be used in the most efficient way especially in countries where water is scarce, of high cost and in most cases of poor quality.

The irrigated area by crop, the percentage of water use by crop as well as the value of production for the irrigated crops (producer's price), are presented in Figures 1,2 and 3. The area under protected cultivation represents only the 1% of the total area, uses the minimum quantity of water and gives the highest return/income compared to the rest of the irrigated cultivations. The greenhouse cultivations represent the most profitable crops per volume of water (m^3). This is a very important consideration in countries of the Mediterranean region since water is the limiting factor in agricultural production (Chimonidou, 2000).

The scarcity of water, together with the high cost associated with collecting and using the limited rain water for irrigation, has become a real constraint for our irrigated agriculture. Because of this, alternative water resources, innovative approaches and new technologies are sought to help solve the problem. Development of more efficient irrigation methods to save water, better utilization of marginal quality water, and the turn to intensive irrigated agriculture, protected cultivation and soilless culture are promising alternative and innovative approaches (Chimonidou, 2000).

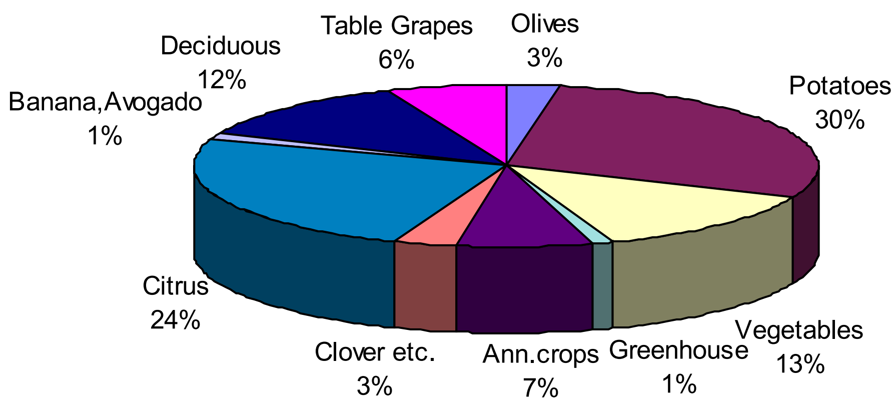

Fig.1: Irrigated area by Crop (35100 ha)

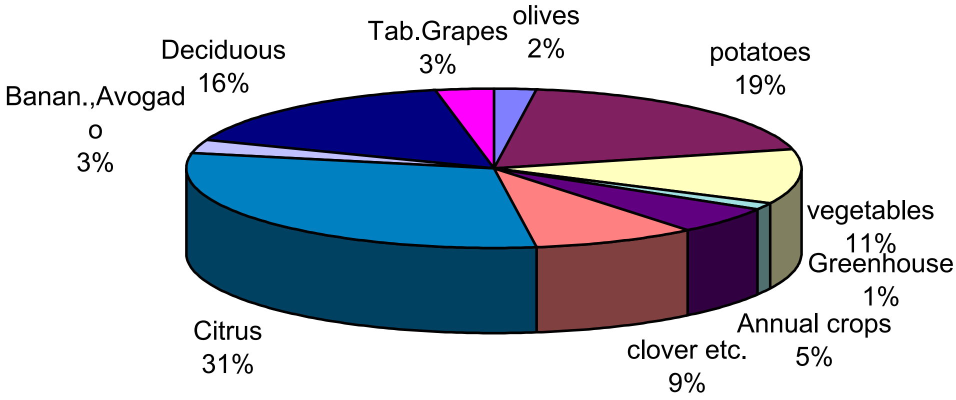

Fig.2: Water use by Crop

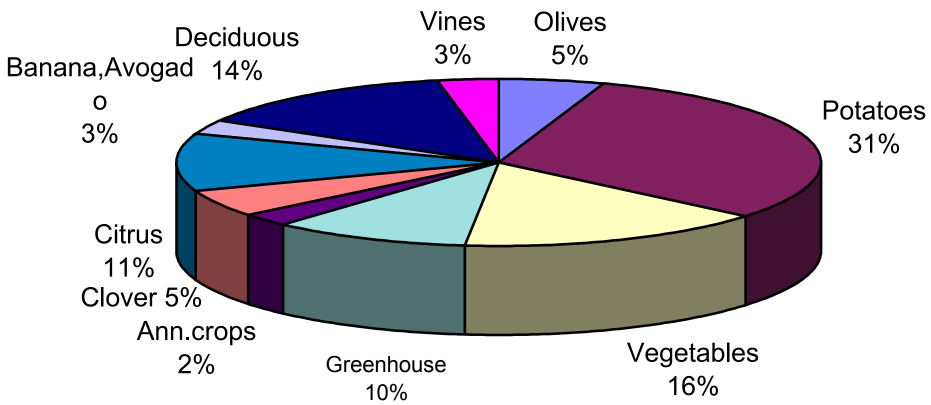

Fig.3: Value of Production for irrigated Crops (Producer's price)

SOILLESS CULTURE

Recently, particular attention was given in soilless cultivation and the area under soilless culture is rapidly expanding. There are various reasons for changing from soil growth to soilless cultivation:

- Higher water use efficiency.
- Increase of yields. For fruit (i.e. strawberries) and vegetable on substrate, yields can be increased by 10-15% and for flowers by more than 30-40%.
- Disinfecting. The use of methyl-bromide is harmful to the environment and restricted by the government. Steaming the soil is expensive. By using substrates disinfecting is avoided. Steaming and reusing the substrate is also less expensive than steaming the soil.
- Energy-saving. For warming up the root system less energy is needed when growing on substrate, compared to growing in the soil. There is also less risk of too high relative humidity

when warming up the root system in a greenhouse where screens are used. The energy used per unit of product is also less, because the yields per m^2 of area increase. Moreover, decreasing the number of working paths, results in a better use of space.

- Growth control. Growth of crops on substrates can be controlled better. This not only improves the quantity, but also the quality of the product.
- Improving labor conditions. The change to soilless culture opens the possibility to bring the crop to the workers, instead of the workers having to go to the crop. Hence, the position of the crop can be adapted to be comfortable to work with.
- Avoiding hazardous amounts of harmful compound in vegetables. The risk of contaminating land with undesirable elements has increased considerably in recent years. By applying soilless culture, vegetables will not contain these elements in high concentrations and risk for man of taking harmful amounts of these elements is avoided.
- Avoiding of soil born diseases and better aeration of the roots especially in countries like Cyprus with heavy clay soil conditions.
- Avoiding cultural practices (i.e. digging, weed control, etc).
- Saving of water and fertilizers from deep penetration and surface flow out.
- Use of areas that the soil conditions are not suitable for cultivation.

Experimental work at ARI

Cultivation of Roses on substrates

A joint programme between the Agricultural University of Athens - Greece and the Agricultural Research Institute of Nicosia - Cyprus (2001-2004), aimed at studying the development and photosynthetic activity of roses cultivated in four different substrates and two irrigation regimes.

Roses cv "Eurored" were cultivated on four different substrates in a heated greenhouse at the ARI using local materials i.e. perlite 100%, mixtures of perlite 50% with pomace 50%, perlite 50% with almond shells 50% and almond shells 50% with pine bark 50%. The two irrigation regimes applied, were 800ml (6 times/day X 2 min) and 530ml (4 times/day X 2 min). The pH and the EC were kept constant at the levels of 6,5 and 1,7-1,8 DS/m respectively. Drainage for both cases was only 5%. The photosynthetic rate, stomatal conductance, CO2 concentration and transpiration rate of the rose plants were measured, as well as the total productivity and quality characteristics (stem length, fresh weight) of the roses produced.

Results on the relation between the stomatal conductance and the % of moisture of the substrate showed that when the percentage of moisture of the substrate reached the lower price of 2,7%, the stomatal conductance reached the maximum value of 8 sec/cm. The minimum value of stomatal conductance (3,8 sec/cm) was obtained when the value of moisture content was 11,5%.

Effect of irrigation and substrates on the production

Concerning the interaction between substrate and irrigation level, higher production was recorded with the roses growing on the substrate of pine bark 50% and almond shells 50% irrigated with the reduced irrigation level followed by the substrate of perlite 50% and pomace 50% irrespective of irrigation level. However, no significant differences were recorded concerning the quality characteristics and the roses produced under all treatments were marketable with mean stem length between 75-97 cm.

Irrigation level irrespective of substrate did not have any significant effect on the quality or quantity of the roses produced. On the contrary, the effect of the substrate was pronounced and higher productivity was recorded in the substrate of pine bark 50% and almond shells 50%, followed by the substrate of perlite 50% and pomace 50%. Significant differences were observed also on the weight of the flower stems of the roses produced on the substrate of pine bark 50% and almond shells 50%.

Physiological Activities

No significant differences were observed concerning the photosynthetic rate, the stomatal conductance, the CO2 concentration and the transpiration rate under the four substrates and the two level of irrigation. Differences on the value of the parameter Fv/Fm under the different treatments were not statistically significant and under the obtained values, plants did not suffer from dysfunction of their photosynthesis centers and photosynthesis ability of the leaves.

During the three years duration of the programme, result of rose cultivation for intensity of luminous radiation PAR 500 μmol m^{-2} s^{-1} but also for lower intensity of luminous radiation, PAR 75-90 μmol m^{-2} s^{-1}, showed that the photosynthesis rate, the stomatal conductance, the CO_2 concentration in the intercellular spaces and the transpiration rate, did not show statistically significant differences between substrate and irrigation level. It seems that the lower irrigation level did not create conditions of water stress and did not affect negatively the physiological activities of the rose plants. Concluding remarks showed that the local substrates could be used successfully as substrates for the rose cultivation in the region.

Cultivation of Lysianthus (Eustoma grandiflorum) in substrates

Experiments on Lysianthus were conducted during the 2001-2004 at the Agricultural Research Institute and at Zygi Experimental Station, aiming at higher productivity and year-round production.

The productivity and quality characteristics of *Eustoma grandiflorum* on two substrates and under two irrigation regimes were evaluated. The substrates used were perlite 70% plus coco 30% and perlite 50% plus pomace 50%. The irrigation was performed using drippers of 4l/h and the irrigation intervals were: 6 times x 2 min (800 ml/ day) and 4 times x 2 min (530ml/ day = reduction 33%). The pH and the EC were kept constant at the levels of 6,5 and 1,7-1,8 DS/m respectively. Drainage for both cases was only 5%. Results showed that no significant differences existed between the different substrates or the stressed and not stressed plants with respect to total productivity (number of stems) or the quality characteristics (number of flower buds, stem length and fresh weight) of *Lysianthus*. Vase life of the plants was not affected by the cultivation in different substrates. On the contrary, the plants under the low level of irrigation lasted more days in vase with or without preservative (Chimonidou et al., 2003).

Modern Irrigation Technology

Modern irrigation technology has moved very rapidly from an experimental technique to a commercially significant method of irrigation. The ability to carefully control water application not only offers improved efficiency in the use of an increasingly scarce natural resource for agriculture, but also opens the door to new and more efficient ways to manage fertilizers and other agricultural chemicals.

Recent innovations designed to adapt drip irrigation to different conditions include moving units, simplified bubbler systems, and the promotion of spitters or micro sprinklers rather than drippers. Perhaps the most significant trend has been towards greater control and automation of the frequency and amount of water application, using programmable computer-based systems and including such devices as sequential metering valves and sensors to monitor weather and soil moisture variables. More recently, new drip-irrigation systems have been introduced for use with wastewater in both agricultural and garden settings. The rubber tubes of these pipes have a labyrinth “toothed” water passage, which facilitates superior filtration. Chemigation and particularly fertigation are yet other developments of major importance (Papadopoulos, 1996).

HYDROPONIC SYSTEMS

The open system for soilless culture is at present the most favoured commercially in Cyprus due to its simplicity, mainly in managing the nutrient solution.

Pollution of the environment (underground water), waste of fertilizers and water are though only some of the problems faced in open hydroponic systems. The leachate is usually collected in a reservoir and is used for the fertigation of open cultures or greenhouse cultivations in the soil. This results in approximately 30 % loss of fertilizers and water from the system.

For this reason ARI started a research program in order to develop a locally adopted closed hydroponic system, using locally available inert substrates, like crashed gravel produced in a copper mine in Cyprus. The leachate from the substrates is collected in a tank and is recirculated after being sterilized passing through a UV lamp. The EC and pH of the water are regulated using an automatic fertilizer-mixing unit as by the open system. The water consumption of a good managed closed system is reduced to the evapotranspiration level of the plants. The system requires water of very good quality that is difficult to find in Cyprus. At the coastal areas where greenhouse cultivation has developed due to the favourable climatic conditions, the ground water salinity ranges from 1.5 to 4 dS/m, whilst the salinity of water coming from dams is around 1 dS/m. The fresh water supplied to the closed system can be therefore rainwater collected from the greenhouses or water treated by a small reverse osmosis unit. Thus the need for replacing the nutrient solution due to the increasing concentration of chlorides and sodium is minimized. The experiments are carried out at the ARI research station at Zygi on tomato cultivation (Polycarpou and Hadjiantonis 2004).

In addition, an open system using a mixture of locally available organic materials with perlite or peat moss as substrate is being studied in floriculture. In this “zero loss” system, the nutrient solution is supplied to the plants, planted in big boxes (substrate volume 15 liters/plant), in such a quantity that leaching just starts. In this way the water and fertilizer loss from the system is minimal. The salts are pushed by the irrigation water away from the root zone and are accumulated in the outer volume of the substrate not affecting the growth of the plants.

In designing and operating such a closed hydroponic system the following main parameters are to be considered:

- Crop related matters such as the life span of the crop, the water and nutrient requirements (recipe),
- and the cultural practices needed.
-
- Method for fertilizer mixing and supply of irrigation water (Using simple volumetric fertilizer injectors or automatic fertilizer mixing units).
- Use of locally available inert substrates like perlite, coarse sand, crashed gravel vs. imported inert materials like rock wool.
- Climate Control in Greenhouses, like monitoring the aerial climate requirements (temperature, relative humidity, light, CO_2, etc), the root zone requirements (root temperature and O_2 supply in the root zone) and improving the PAR transmission of covering materials and lowering their NIR transmission.

Due to the advantages of the closed hydroponic system compared to the open one, ARI is investing a lot of effort in optimizing its parameters, simplifying its operation and training the growers in its effective management and utilization (Polycarpou and Hadjiantonis 2004).

WATER RESOURCES ASSESSMENT AND WATER POLICY

Water Supply

The maximum quantity of water, for calculating its availability for planning purposes, is the mean annual long term precipitation that is 513 mm (1987-2000) times the area that is 9250 Km^2. It corresponds for the whole island to approximately 4600 million cubic meters (MCM) of water per year. More than 80% of this returns to the atmosphere through evapotranspiration. Only the remaining 20% i.e., about 900 MCM can be considered as the actual water available for use. From this, 600 MCM is surface water and the rest i.e., 300 MCM, flows into the aquifers. The above are estimates of 1970 and refer to the whole island. They are based on rainfall-runoff and groundwater hydrology relationships of past years. Since then, rainfall has decreased considerably, more than 13%. Consequently there is a marked decline of the surface and groundwater sources. It is estimated, that the reduction may be as high as 30 to 40%. A reassessment of both the surface and subsurface hydrology is urgently needed, for meaningful planning and management of the water resources of the island (Socratous 2003).

The drastic reduction of the water supply couple with the concurrent increase of the demand for water have brought about the full utilization and even overuse of the available traditional water sources, i.e. groundwater and surface water. Groundwater is reliable, clean and cheap when compared to other sources. The result is that all aquifers in Cyprus are today exploited beyond their safe yield, which is estimated at 230 MCM per year. The excess pumping over natural recharge is in the order of 40 MCM per year. The result is sea intrusion into most of the coastal aquifers. The Government of Cyprus embarked in 1960, the first year of its independence, into an ambitious program of tapping the surface waters that used to be lost into the sea. This program was in essence a comprehensive water resources program that was produced in 1967 to 1970 with the technical help of the United Nations Development Programme. Thanks to this program the storage capacity of surface reservoirs has reached 304,5 MCM from a mere 6,1 MCM in 1960. The yield of these reservoirs is about 130-150 MCM/year. This value is now seldomly reached because of the decline in rainfall and hence of runoff (Socratous 2003).

Now, as the conventional water sources are reaching saturation in their development the Government is planning the use of treated sewage as the additional main source for water supply for agriculture and the use of desalination water for domestic purposes.

The first large sewage treatment plant in the Government controlled areas started operation in Limassol in summer of 1995. Sewage treatment plants are now under design or construction in all the major cities and sensitive mountain villages of Cyprus. All municipal sewage treatment plants have provisions for tertiary treatment. Projections estimate that the volume of reclaimed sewage effluent will increase to 25 MCM by the year 2020.

Desalination of seawater was first introduced in Cyprus on a large scale basis, on the 1st of April 1997, with the operation of the 20 000 m3/day reverse osmosis Dhekelia plant. Due to the drought prevailing at the time the plant was soon expanded to 40 000 m3/day. The plant operates on a Build, Own, Operate, Transfer (BOOT) basis and the desalinated water is presently sold to the Government, at source, at a varying unit price which is about £0,54/m3. A new seawater desalination plant, of 51 667 m3/day nominal capacity, has been constructed next to the Larnaca airport. It started normal operation in February 2001. This too, is a reverse osmosis BOOT type plant. The cost of the water from this plant is only £0,43/m3. However, the present tragic situation demands the construction of another 30 000 to 40 000 m3/day seawater desalination plants. In this way the domestic water demand for water will not any more be dependent on the vagaries of the weather.

Other, tertiary or exotic sources of water supply, such as, importation of water from abroad, artificial rainfall, undersea fresh water tapping, underground deep drilling and evaporation suppression from water surfaces are not economically justifiable and/or risky and unreliable (Socratous 2003).

Water Demand

Domestic use and irrigation are the two main sectors of water demand. The total water consumption in the Government controlled areas in 1994 a year having no appreciable water supply restrictions was 235 MCM, of which 55 MCM was for the domestic sector. The industrial and tourist demand were 6 and 11 percent respectively of the total domestic consumption. Gross and net consumption of water was 220 l.p.c.d. and 140 l.p.c.d. respectively. This compares well with consumption in most European countries. As the tourist industry seeks new forms of recreation e.g. golf facilities, the water demand for recreation will be increasing. It is conservatively estimated that the domestic water demand will rise to 100 MCM in 2020. Irrigation water use in 2005 in the Government controlled areas totalled to 182 MCM i.e., 77% of the total water demand. More than half of this amount was supplied from Government water works. The demand for irrigation water will increase to 225 MCM by 2015. Demand for irrigation water is expected to remain stable thereafter.

Water Management

In making the supply meet the demand the Government policy has encouraged and adopted such management measures as water rationing, increase of public awareness for water conservation measures and water pricing for improvements in the water use efficiencies.

Water rationing has been extensively applied in an attempt to curtail the demand in periods of drought. This has allowed the authorities in the last year to reduce the water by 20% of the normal demand for domestic purposes and by 67 percent for irrigation purposes. Water conservation measures include subsidies for use of inferior quality groundwater or the treatment of the gray water from households for the flashing of toilets and irrigation of house gardens in the cities. Furthermore the campaign for raising the “water awareness” of the public towards water conservation proved to be successful. Now, water pricing is an integral part of the Government policy on water. Water for municipal including industrial, commercial and tourist purposes is sold at full cost, while irrigation water is heavily subsidized by as much as 77 percent. The Governments´ policy towards agriculture is very generous and this has contributed to the selection of non-efficient cropping patterns and even to the wastage of water. It should be noted that in the last six years the water tariff for the domestic sector does not reflect the full cost as is formed with the recent introduction of the comparatively expensive desalinated water. The subsidy is as high as 34 percent. The present price of the water to agriculture and domestic sector is 6.5 c/m3 and 33,5 c/m3 respectively (Socratous 2003).

For 2006, Cyprus Government has decided to curtail the water supplied for irrigation both for permanent and annual crops as well as for glasshouses and clover. The above decision was taken, taking into consideration the needs for irrigation as well as to preserve water reserves in case of possible drought next year. The measures to be taken for summer 2006 are as follows:

- Water supply for covering 50% of permanent crops demands in order to keep them alive except for the district of Pafos where water reserves are enough to cover 75% of crop demands, keeping reserves for next year as well.

2) Water supply for covering 20% of seasonal crops demands in all regions, except the district of Pafos where water reserves are enough to cover 75% of crop demands. In addition, at Famagusta district, water will be supplied in order to cover water demands of subjected crops, as well as water demands of early potatoes.

3) Water supply for covering 50% of water demands of crops in greenhouses. Water will be enough to cover the demands of one crop instead of two, which is the usual method.

Tables 1, shows the water balance and water reserved in dams in 2005/06, after the application of the above measures.

In addition to the above, the Ministry of Agriculture, Natural Resources and Environment have announced measures for saving drinking water, such as subsidizing the excavation of private drills for irrigation and other domestic purposes, promote the installation of domestic water recycle systems and initiate campaigns for public awareness.

Table 1. Water Balance and Water Reserved in Dams for the years 2005/06

	Water Sources	MCM
Water reserves in dams on 1/1/2005		189.0
Plus	Water flow in dams	47.0
	Desalinization units	30.0
	Drills	16.0
	Recycled water	3.5
Less	Watering	-73.0
	Irrigation	-63.0
	Evaporation, losses, enrichment	-21.5
Water reserves in dams on 1/1/2006		128.2
Plus	Water flow in dams	16.3
	Desalinization units	25.5
	Drills	15.8
	Recycled water	3.5
Less	Watering	-73.0
	Irrigation	-39.5
	Evaporation, losses, enrichment	-16.3
Water reserves in dams on 1/1/2007		60.5

New Water Policy

It is apparent, by a simple comparison of the supply and demand, that the current water situation is not sustainable. The recent droughts of 1989/91 and 1995/2006 demonstrate quite convincingly how critical the water situation may become. A new water policy is warranted that will bring about sustainability. The new water policy should include the following specific measures.

a. Secure additional sources of supply
b. Ensure efficient use of available water
c. Modify the current irrigation water allocation matrix
d. Built up strategic water reserves
e. Maintain and enhance the quality of water

f. Introduce new effective/efficient management procedures through the establishment of a Water Entity

These measures should be holistically applied. Each measure compliments the other.

The basic water policy of the Government is the production of desalinised sea water, the use of non-conventional sources such as the use of recycled water for irrigation, recharge and amenity purposes, the desalting of brackish water, the efficient use of available water including the better use of pricing and water conservation measures, the harmonisation with the European acquis, the protection, preservation and improvement of the water quality, the introduction of new effective management procedures through the establishment of a Water Entity and the development of the remaining existing water resources with the construction of dams until 2015.

CONCLUSIONS

Water is by far the most precious resource in Cyprus. The quality of life and almost all economic activities depend upon the presence of an economic water supply. The present water situation is not sustainable in spite of the impressive development of the conventional surface water sources in the last four decades. Much has been done but still a lot remains to be done in the realm of water resources development and management. A new approach is presented that ensures sustainability of the water sector of the island.

The targets of this new plan are summarized below:

a. The relief of the domestic sector from the vagaries of the weather
b. The increase of water tariffs for all uses
c. The use of recycled water for amenity purposes and irrigation
d. The formation of underground strategic reserves
e. The reduction of horizontal expansion of irrigation
f. The changing of the cropping pattern to less water demanding crops
g. The preservation and further enhancement of the water quality
h. The formation of a Water Entity

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COUNTRY PAPER ON HARMONIZATION AND INTEGRATION OF WATER SAVING OPTIONS IN EGYPT

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INTRODUCTION

The rising demands for water and the rapid increase of the population make Egypt facing strong pressures with respect to the country's limited water availability. Water resources in Egypt are fixed to the country's share of Nile water and minor amounts of rainfall and groundwater. The rising demands of water have made it mandatory to improve the irrigation system performance and increase water use efficiency in the face of future water shortages and likely water crisis.

Water is one of the most important inputs of the economic development. Size, type, location of socio-economic developments depends on the nature, quantity, quality, and location of the available water resources. The less the water resources are, and the more the demand is, the more valuable water is. This is the case in Egypt, where rainfall is rare and desert covers most of the country area, except for a narrow strip of cultivated land and urban areas along the Nile river course and Delta. The quota of Egypt from the Nile River, which represents the main source of water, hasn't changed since 1959. The Nile River in Egypt has played great role in Egypt's civilization, which lasted more than seven thousands years where the Egyptians, throughout the history, exerted great efforts to efficiently utilize the Nile water.

Increased pressure on the available water resources, such as increased urbanization and intensification of agricultural development, would result in adverse impacts namely water quality and pollution issues. Competition between water uses such as agricultural, drinking water supply are increasing and needs should have unique measures to be balanced. Such developments and changes will have impacts on the decisions of water management and use. Therefore, performance of water delivery systems, particularly irrigation systems, needs to be well defined and assessed under these current or expected stressed conditions. Improvement of irrigation system performance is not only achieved by technical interventions, but more important, by reform in the institutional framework that enhance the effectiveness and efficiency of system management, operation and, maintenance. Enhancing farmers and private sector participation in operation and maintenance of the irrigation system is now being adopted as policy by the Egyptian Ministry of Water Resources and Irrigation.

Late in 1996, the Ministry of Water Resources and Irrigation formulated a water policy program to assist the ministry identifying, evaluating, and implementing policy adjustments and institutional reforms that would lead to improved water use in agriculture. Over the last three years, the ministry's water policy program has swiftly taken on a life of its own. Specialized teams assemble to address key issues, examine constraints, and review the feasibility, merits, and costs of various strategies. Workshops, focus groups, and surveys solicit the opinions and encourage the participation of private sector, farmers, and other stakeholders in policy formulation. The issues examined are diverse and complex, ranging from legislative reform and measures to protect water quality to increased private sector involvement in water management of Egypt's irrigation system.

This paper highlights the efforts exerted towards improving the water use efficiency through harmonization and integration of the water saving options and the promotion of water saving policies and guidelines.

IMPROVEMENT OF ON FARM WATER Improvement of On-Farm Water Management Practices

On-Farm water management practices could be improved through the integration and harmonization of different water saving options and techniques.

Land leveling

The main objectives of land leveling are given attention to:

- Achieve water application uniformity in the field to avoid having areas of water logging and others of water stress. Uniformity of water application will thus contribute to increased crop production.
- Water losses could be minimized through reducing farm water run-off.

In Egypt, land leveling, particularly laser leveling is practiced on a large scale in either by the governmental, public and/or private sector. The very pronounced example is that applied in sugarcane fields where the government is subsidizing the laser leveling in these fields by about 50% of its cost. Another type of this land leveling is that being implemented in rice cultivation areas, where leveling is done under water by a wooden beam using animal traction. This is to minimize the water infiltration and losses by percolation through the soil profile.

Maintenance and Operation of Field Ditches

Field ditches (Mesqa and Merwa) are operated and maintained by farmers. They are cleaned manually under the supervision of the agricultural administration extensions. Due to the importance of having these ditches capable of conveying water to the fields, the government had started a project for improving these ditches. This project aimed to build new and/or improve field ditches (Merwa) to reduce/prevent water losses.

Crop Diversity

Due to the fact that water varies in terms of its quantity and quality along the canal system, and that the soil characteristics and climate conditions vary over the different water management zones, the agricultural practices are consequently affected by such varying conditions. Selection of crops to be grown over these zones has to be considered. In Upper Egypt, the government encouraged growing sugarcane, while establishing considerable number of sugar factories. In Northern Delta where lands are affected by high water table and increased salinity in irrigation water, rice crop is the most dominant crop over there as it can resist relatively saline water.

Irrigation Improvement Project

Improvement of tertiary canals (mesqas) constitutes the major part of improving irrigation performance. It includes replacement of the existing system with improved ones. The old system is usually earthern and low level ditch with non-organized water withdrawals through multiple pumping/lifting points along its length. Two types were recommended for improving the old system, open elevated mesqa and buried low-pressure pipe. Elevated one is an open ditch, but lined and elevated. Normal water level in the elevated mesqa was set to permit gravity flow to fields at 15 cm above the field level. Alternatives for elevated mesqa include a rectangular concrete cast-in place section and pre-cast concrete “J” section. Low pressure PVC pipeline mesqa is another option for replacing the old mesqa. It is set at approximately one meter below grade and are provided with risers at spacing of 100 meters. Such types of mesqas, elevated or pipe line, are intended to reduce the seepage of water to minimum. The end of mesqa is closed to prevent water losses to drains.

The stated primary goal of the Irrigation Improvement Project (IIP) is to increase water use efficiency and agricultural productivity in Egypt’s old lands. Increasing water use efficiency is used in a broad sense with a connotation of improving irrigation water management rather than in the sense of the traditional definitions of water use efficiency. This is to be accomplished by implementing a series of interventions at the irrigation delivery system and on-farm levels, designed to remove irrigation related constraints to increased agricultural production, and considering a full range of technical, economic, environmental and social factors impacting irrigation water management.

The IIP package includes a combination of physical and institutional improvements to the main irrigation delivery system and the farm level irrigation delivery and application systems. These improvements include renovation and improvement of branch and distributary canals, downstream water level control, conversion from rotational flow to continuous flow, mesqa improvements, organization of farmers into water users associations, and water management technical assistance through the Irrigation Advisory Service (IAS).

There were dramatic improvements in mesqa conveyance efficiencies before and after IIP improvements. Conveyance efficiencies appear to increase from an average of around 60-65% to around 90-95% as a result of improvements. These “local water savings” are translated into improved adequacy of the farm level water supply and reduced water quality degradation.

While it appears that water delivery efficiencies and distribution uniformities along the canals and mesqas have improved significantly as a result of IIP, on-farm water application efficiencies have not been equally improved. IIP efforts have been paid to demonstrations of precision land leveling on demonstration fields in each command area. The implementation of a full package of on-farm water management improvements can be expected to gradually result in additional “local water savings”. The improved control and management of water in the delivery system resulting from IIP offers the mechanism to capture and distribute these savings locally in the system. Reduced on-farm irrigation losses can also be expected to result in less water quality degradation. In addition, improved on-farm water management contributes to increased crop yields and crop quality.

The primary expected benefit of IIP, contributing in large part to the economic and financial feasibility of the improvements, the increased agricultural productivity. This was expected to occur primarily from yield increases and secondarily from productivity improvements on previously fallow or partially fallow lands. Limited yield data have been collected for some crops in some command areas. IIP yield monitoring data show an increased wheat yields ranging from 0-35%, increased alfa-alfa yields of 8-10%, increased cotton yields of 7-15%, increased rice yields up to 18%, and increased maize yields of 16-30%.

Gated and perforated pipe system for sugarcane fields

Sugarcane is considered one of the high-consumptive water crops in Egypt. Investigations and trails of assessment of water application to sugar cane and field water losses showed that there are significant water losses resulting from using the traditional basin irrigation. Therefore, Ministry of Water Resources and Irrigation in collaboration with the Ministry of Agriculture and Land Reclamation initiated a program for improvement of on-farm water management in sugarcane fields. The program has been implemented in several pilot areas in Upper Egypt. The program included a package of improvements such as laser land leveling, introduction of improved irrigation system (gated pipes), widening spaces between furrows, and balancing fertilizer requirements. Monitoring programs have shown increase in yield up to 25%. In addition, irrigation application losses were dropped down greatly, which means increasing applied water efficiency. Water requirements of sugarcane at the field are expected to reach 8000 m^3/feddans/year compared to a figure of 12000 m^3/feddans/year used in the traditional irrigation practices. Therefore, the government has decided to extend the applications of the improved surface irrigation system to private farms in other sugarcane areas.

Short Duration Rice Varieties

Since liberalization of farmer choice of cropping patterns, the number of feddans on which rice is grown has almost doubled, from about 800,000 feddan in 1988 to 1.56 million feddans in 1997, replacing cotton and maize in the summer season. Early indicators suggest even greater rice increase was planned by farmers in 1998. The rapid increase in rice cultivation has resulted from increasing its profitability relative to other crops and rotations, as well as other factors.

The drastic increase in water use in rice cultivation is putting added pressure on water supplies, and threatens to undermine the availability of water for the “new lands”. Further, the capacity constraints on certain canals in the system coupled with expanding rice cultivation prevent enough water from being delivered to newly reclaimed land at the tails of the canals. On the other hand, Egyptian farmers are among the fore front of the world in productivity per unit of land for both rice and sugar cane. Reducing rice cultivation will result in significant losses to farmers and, perhaps, to the Egyptian economy as a whole.

The Field Crop Research Institute of the Ministry of Agriculture and Land Reclamation has devoted several years in developing short season varieties of rice which allow reduced water application and consumption and ensure high productivity levels. The efforts have been quite successful. At least three varieties of rice have been produced to shorten the cultivation period from normal 160 days (Giza 171) to 120 or 125 days (Giza 177 and Sakha 102, 103, and 104) in experimental farms. Sakha 101 and Giza 178 reduce the cultivation period to 140 and 135 days, respectively. Giza 178 is more salt-tolerant than the other short duration varieties. In those same experimental trials, the short duration varieties produced yields higher than the longer duration varieties. In fact, over the past years, increase in rice cultivation has been devoted to these short duration varieties. In 1997, about 14% of rice grown was short duration varieties, and in 1998, about 50%was short duration varieties.

Sprinkler/Drip Irrigation

In new areas in the fringes of the Nile Delta and Valley, modernized irrigation (sprinkler or drip) is being applied due to the fact that the soil is characterized by relatively higher permeability. The present area under modern irrigation system is about 6% of the total irrigated area. Modernized irrigation is now becoming a must, (by law) in the newly reclaimed land in Egypt.

Harmonization and Integration of Water Saving Options

The different water saving options could be integrated and harmonized to save water on the farm level, through the different options:

- Leveling the farm land,
- Lining the farm ditches and mesqas or using pipelines in place of the earth ditches,
- Cultivating crops which are suitable to the climate of the area where the evapotranspiration is low,
- Using gated pipes in the areas where sugarcane is cultivated,
- Using sprinkler/drip irrigation in the newly reclaimed land,
- Cultivate short duration rice varieties,
- Maintain the field ditches, and enhance farmer's involvement,
- Continues flow and night irrigation, and
- Establish water users associations and private sector participation.

IMPROVEMENT OF THE WATER DISTRIBUTION SYSTEM

Improved Water Delivery System

To achieve on-time water deliveries, Egypt started a national program on improving the main delivery system (branch canals). This involved improvement of the main delivery system through:

- Rehabilitation of water structures along these canals such as intakes, cross regulators and tail escapes to minimize water losses from canal.
- Replacement of the old control structures with new ones with radial gates to provide automatic control for the downstream water levels to cope with farmers demand and abstraction.
- Remodeling the canal cross-section to improve the canal hydraulic characteristics and conveyance efficiency, and to ensure bringing the cross section back to the standards of the original design. The remodeled cross section was made to allow for water storage during the non-irrigation times, particularly during night time.
- Turn-outs and off takes are also planned to be installed along the branch canals such as facilities at the head of each mesqa, pumps, pump stands, and pump sumps. Energy dissipation basins are also constructed at the head of each mesqa.

Telemetry Systems

To improve water management and irrigation system performance, a telemetry system was installed on more than 800 locations on the irrigation network. This system enables collecting real-time data and information on water flow every two hours. It utilizes a volumetric basis for water allocation and distribution. The remote sites transmit the measurements information either directly or indirectly to the sub-master stations at the directorate level. This is where the water management decisions are made based on the data received. The directorate engineer thus has access to data from all remote sites area of responsibility regardless of the technology used to transmit them.

Drainage Water Reuse

Since the large-scale of field sub-surface tile drainage was started in the late 1960s, a well-designed and well-constructed agricultural drainage system has been operating in the Delta. Numbers of main drains and branch or lower-order drains collect and transport drainage flows from the south to the north of the Delta plain. More than forty lifting pump stations and twenty two main reuse mixing stations are in operation in the 22 drain catchments of the Delta region. Presently an annual amount of about 4 milliard m^3 drainage water reuse is made available through the official drainage reuse program.

The monitoring program revealed that the average annual drainage reuse amount has increased from 3 milliard m^3 of 1984-1990 to 4 milliard m^3 of 1991-1996. The official reuse levels in the East and West Delta regions have almost remained constant in the past decade. It took about a decade to obtain 1 milliard m^3 reuse expansion in the Delta, mainly from the increased reuse in the Middle Delta region in the 1990s.

The practically achievable reuse pumping potential in the Delta will be 9.6 milliard m^3 per year, which is 5.3 milliard m^3 more than the 1995-96 reuse level of 4.3 milliard m^3. This 5.3 milliard m^3 additional reuse pumping potential could be achieved by capturing all the drain water with salinity concentration below 2250 ppm, except for unacceptably polluted drain water.

Efforts to recapture drain water salinity levels higher than 2250 ppm will not be efficient and meaningful, since the incremental capture after that salinity level will be limited to 0.2-0.3 milliard m^3. The only way to achieve more reuse beyond the 9.6 milliard m^3 reuse potential is to remove and/or treat the municipal and industrial wastes according to health standards and make the water available in the Bahr Bagar drain (East Delta) and several other polluted drains reusable (according to health standards).

One of the options and potentials for reducing pollution constraints in drains is by adopting intermediate reuse. Intermediate reuse will be supplementary to, but not a replacement for, the current main reuse system. The technical merits of intermediate reuse are the capturing of the good quality drain water before it gets mixed with poor quality drainage water and replacing unofficial reuse at the canal tail, where canal deliveries are in short supply.

One of the recommended policies is to restrict unofficial drainage pumping in the areas where major reuse projects exist. This is to secure the drain water availability for the miga reclamation projects, which are already in operation. The action should be seen as an effort to reallocate water resources for a broader national development interest.

Over the next decades, the reuse of drain water may remain as the first supply augmentation measure due to its easy handling and low cost. In the long-run with less drain water volume and increasing salinity concentration, the potential for expanding reuse, or even continuing the current reuse level, may be limited.

Cropping Systems and Water Requirements

A comparison of crop yields between old lands and new land soils shows that some tree fruit yields were as high in the new lands as in the old lands. Most vegetable crop yields were lower on small farms in the new lands, but higher yields were reported for some crops such as tomatoes, with considerable variation among crops. Soybean yields were higher in the new lands.

Experiences of successful farmers indicate that oil seed crops, have an advantage in sandy lands. Part of that advantage is due to soil properties and part is due to fewer diseases. Most fruits and vegetable crops can do as well or better on the new lands compared to old lands, when managed properly. Currently most cereal crops (wheat, maize, etc.) seem to be less productive on the sandy soils, but this is based on varieties, which have been bred for old lands. Even with available varieties, high grain yields are reported on some large farms.

Water use efficiency is a critical issue for Egypt as a whole and should be for individual farmers. However, very little information is available on amount of water actually applied per feddan of individual crops in the absence of technical information in farmer lands on yield/water relationships for various crops.

Given the higher cost of water in most of the new lands, farmers have a greater incentive to improve efficiency, but because of lack of information on crop/water relationship and difficulties, small farmers having modern systems, many have reverted to flood system even in sandy soils. In view of the generally low yields of many crops on new lands, it is likely that water use efficiency (yield / m^3 of water) on small farms is low, and perhaps lower than efficiency in old lands. However, there is evidence of some very high levels of output per unit of water, for example, in drip systems in general, and in protected vegetable production in particular.

Land use intensity is often quite high in both new and old lands. Current intensity (number of crops per year per unit of land area) is about 1.7 for small farmers in new lands and about 2.0 in old lands. Climatic conditions in Egypt permit a cropping intensity of non permanent crops of two or more in new lands. Small farmers use over 90 percent of their land for cropping. Larger farmers leave a larger part idle especially in summer when water delivery costs are higher and water shortages are experienced.

The main objectives of the agricultural strategy are to increase agricultural productivity per unit of land and water, through more efficient use of these limited resources. Modern irrigation system along with suitable technology would provide significant benefits in improving crop yield and quality, reducing cost of production and improving environmental benefits, while minimizing environmental impact.

On the other hand, improved design and practice methods for surface systems (Border strips, Basin irrigation, level-Basin and furrow irrigation systems) have proved to be more appropriate and efficient and less expensive than pressure systems. Proper irrigation scheduling and a uniform distribution of water in the effective root-zone for sugar cane are foreseen for increasing water use efficiency. Precision land leveling using laser technology is recommended for improving water application efficiency in surface and non-pressurized irrigation. Meanwhile, the introduction of sprinkler and micro-irrigation (localized) methods to Egyptian agriculture raises debates about the amount of water requirements, water losses, effect on soil characteristics, salinity problems, and the feasibility of the different methods under different farming systems.

Precision land leveling using laser technique has improved water application efficiency for cotton, wheat, barely, and sugar crops. It reduced the applied irrigation water by about 33%, in the same time the crop yield increased by 21%. It is also reported that land leveling on clay loam soils resulted in an increase of 28% in corn yield and about 30% water saving compared with the unleveled field in the same site. Sugar cane yield increase with about 46% in addition to a 28% irrigation water reduction due to land leveling.

Conjunctive Use of Surface Water and Groundwater

As Egypt has limited water resources, the dependence on surface water only in the future to cover the increasing demands will not be adequate. Conjunctive use of surface and groundwater resources to support increased irrigation demands is identified as one of the principle means of raising agricultural production. The pressure upon existing water resources will become more intensive in the future to satisfy the increasing demands. Improper management and poor practice connected with intensive use of groundwater lead to serious problems such as depletion of the resource due to high extractions or water logging due to the rise in the water table from the aquifer recharge. Conjunctive planning and development of surface and groundwater resources results in maximum utilization of the limited water resources, greater yields, and economic returns compared to the separate use of the resources.

Automation

One of the objectives of irrigation system improvement is to increase the reliability of irrigation water supply to meet the water demand more efficiently and effectively. Water supply that meets demand could be either on rotational or continuous flow. Continuous supply requires stable water levels in the main and secondary canals. The gate hoisting mechanism on the canal control structures are operated manually. This causes difficulties to adjust gate openings in response to rapidly changing demand. As a result, there was often too much or too little flow in the canal. Fluctuation of water levels in the canal would promote bank instability and unreliable supply to the secondary canals. To resolve this issue, the government initiated certain programs and pilots to introduce automated operation of water structures. Three projects have been implemented in Egypt, and mainly including two major parts of automation; (1) replacement of manually operated mechanical hoists with electrically powered and motorized gates and (2) install of programmable controllers at each regulator and adding remote control and monitoring system. The projects were implemented in:

- Serry canal automation system in El-Menya governorate
- Bahr Saghir in Dakahlia governorate
- Improved water delivery system on Bahr Yousef in Beni Suif and El-Fayoum governorates.

Harmonization and Integration of the Different Water Saving Options

Different water saving options could be integrated and harmonized to save water in the water distribution system through the following mechanisms:

- Improving the water delivery system,
- Using the Telemetry system to improve the system of real-time information and management,
- Reuse the drainage water to increase water use efficiency,
- Conjunctive use of surface water and groundwater,
- Using optimal crop pattern,
- Automation of the irrigation structures.

IMPROVED RESERVOIR MANAGEMENT

Forecasting Project

As known, Nile River is the main water source for Egypt. Numerous studies were carried out to predict the river inflows to Lake Nasser upstream the High Aswan Dam (HAD). Therefore, reliable monitoring, forecasting, and simulation of hydrological and meteorological processes occurring in the River Nile basin are considered to be of paramount importance for optimal planning and management of Nile water. For this reason, Egypt's National Forecast Center has been established and staffed by trained hydrologists and meteorologists with the following objectives:

- Primary data distribution system for real time acquisition, primary processing, quality control, display, storage, and automatic transfer of satellite infrared, water vapor, and visible raw image for Nile Basin.
- A meteorological data distribution system for receiving Real-time raw meteorological data from network of synoptic stations located in the Nile Basin.
- A computer system for data processing, forecasting, and simulation of hydrological and meteorological process in the Nile Basin.
- A comprehensive Nile Basin hydro-meteorological and hydroclimatic database and retrieval system.

The resulting forecast-control and decision support system together with water management models allow for more efficient operation of the HAD for a reliable water supply and maximum hydropower production.

Rehabilitation of Grand Barrages (Diversion Dams)

Egypt has an ambitious program for rehabilitation of the grand barrages along the Nile to improve its performance to meet the different water requirements. Esna barrage was replaced in 1995 and have been equipped with a hydropower station. The Nagaa Hammadi barrage are being replaced for improving water control and to provide better navigation conditions. It will be also equipped with a hydropower station.

Harmonization and Integration of Water Saving Options

Water saving options could be integrated and harmonized through the reservoirs and barrages by the followings:

- Using the forecasting project and the forecasting techniques to better manage the reservoir of High Aswan Dam, and
- Rehabilitate the old barrage to improve their effectiveness in managing the Egypt's water resources along the Nile and consequently saving water.

ORGANIZATIONAL AND REGULATORY FRAMEWORK

The performance of irrigation system significantly depends on the capacity of the organization that manages and distributes water. Poor performance of irrigation schemes can often be traced back to inappropriate organizational structures. Organization structure is defined as the empowerment and delegation of responsibilities and the clarification of the line of command between positions inside of an organization and between organizations. The water management organizations are mainly governmental ones. Involvement of water users in decision-making is becoming crucial, particularly the rising water demand will soon exceed the available limited water resources. Therefore, there will be an essential need for institutional reform and involvement of water users in decision making and planning so as to manage the available water resources in an efficient and equitable way.

Participation and Establishment of Water User Associations

Water User Associations (WUA) is a private organization owned, controlled and operated by member users for their benefits in improving water delivery, water use and other organizational efforts related to water for increasing their production possibilities.

Within the context of institutional reform in irrigation water sector, establishing Water Users Associations allows farmers to perform activities which are more difficult, or impossible, for them to do individually. These associations perform functions which allow the farmers the capability of managing parts of the irrigation system more effectively by providing the following services:

- Administering the irrigation system under their authority;
- Providing a mechanism whereby the government interacts meaningfully with the farmers; and
- Providing a means whereby the farmers can make decisions concerning problems of irrigation.

In terms of administering the irrigation system, a WUA can mobilize local resources to reduce the costs of managing the system for the government. A WUA can provide the procedures and mechanisms whereby the canals and other tertiary channels are cleaned, maintained, and operated on a schedule. In addition, such associations can act as arbiters to local conflicts in the area. Since there is a need for the government to interact with the farmers, the WUA can act as the conduit for such interaction. Through the association, various extension programs can operate. Such organization can also serve as a means to channel the needs and desires of farmers to those government agencies best equipped to meet them. They can provide such services by acting as a communication channel between the government and the farmers.

Integrated Water Management District

The smallest management unit of the Ministry of Water Resources and Irrigation (MWRI) structure is the district; irrigation district and drainage district, where engineers are in direct contact with users. This level of management is the most important level to have innovations for improvement of performance of water allocation and management. MWRI is now implementing the integrated water management concept in a number of pilot districts. In order to cope with this concept, reorganization at the district level is carried out and the new organizations are called Integrated Water Management Districts (IWMD), which integrate all MWRI activities in each district. The objectives of such policy were viewed as follows:

- Devolution of operation and maintenance responsibilities and decision-making to the local MWRI entities at the district level.
- Integrate the different water resources within the district into the district water budget and allocation programs. These water resources would include canal water, drainage water, groundwater, rainfall, etc.
- Involvement of water users and non-governmental organizations in water management decision-making at the district level.

Hence, it is expected that the IWMD will have an important role in water allocation and water saving. The IWMD will be responsible for scheduling, through consultation with water users (represented by water users associations) the pre-set quota of water for the district.

Irrigation Advisory Service (IAS)

Irrigation Advisory Service (IAS) activities started in 1989. In 1999, a ministerial decree was issued to establish a Central Directorate for Irrigation Advisory Service (CDIAS) with two general directorates in Upper and Lower Egypt. According to this decree, the following objectives are mandated:

- Help water users associations improve water distribution
- Improve water use practices
- Help farmers in building strong and sustainable water users associations either on private Mesqas or branch canal

IAS proved to be essential for the Ministry efforts to establish water users organizations at the Mesqa or branch canal levels.

Modification of Laws

The Egyptians, since a long time ago have set legislations and laws to regulate the Nile water and control water use. These laws changed from time to time according to the hydrology conditions of the river and the political and institutional development experienced by the country. Legislations generally deal with several main issues such as: flood protection, flow regulation and water distribution; protection of water resources from waste and pollution and protection of the river banks, canals and drains; and management of the water system in general. These issues are governed by three major laws; law 48 of 1983, law 12 of 1984, and law 4 of 1994. Law 48 of 1982 governs the discharge of wastes into the Nile and its waterways and sets standards for the quality of these discharge effluents. The law outlines the responsibilities of MWRI and the other concerned ministries. Although the law is comprehensive, some of the details need careful review particularly those dealing with the required standards of effluents. Law 4 of 1994, concerning environmental protection in general, gives the Ministry of Environment increased powers and duties. Efforts have been conducted to coordinate the implementation of law 48 and law 4 to achieve efficient management of water quality and protection of irrigation water.

Law 12/1984 and its supplementary Law 213/1994 define the use and management of public and private irrigation/drainage system structures; including main canals, feeders, and drains. They also provide legal frame for the use and maintenance of public and private canals, and specify arrangements for cost recovery in irrigation and drainage works. Law 12 regulates the use of groundwater and agricultural drainage water and legislates other factors such as protection against flooding, navigation and coastal protection. Penalties for violation of the Laws and by-Laws are also specified. Modification of these laws to enhance water users participation in the operation and maintenance of the irrigation system is being in process of finalization.

Institutional Reform

Ministry of Water Resources and Irrigation is currently formulating a comprehensive program for restructuring the ministry's functions at different levels in order to strengthen the decentralization and participation process. The main goal of this restructuring is to move towards the integrated water resources management (IWRM) that is recently acknowledged as the best tool of improving water use efficiency and irrigation performance. Therefore, an institutional reform unit (IRU) has been established. The basic strategies of this unit are:

- Involvement of private sector in irrigation activities
- Support decentralization and participation process of decision making
- Conduct awareness program for dissemination of IRU concepts within ministry's sectors and entities.
- Ensure capacity building and information availability.

Conducting Public Awareness Campaigns

During the last years, The Ministry of Water Resources and Irrigation took a bold step in introducing a new approach to its programs. The Water Communication Unit (WCU) was established in July 1995, and is responsible for designing and implementing a participatory communication program to support the Ministry's goals of increasing the understanding of the general public that Egypt has a limited water supply and it will become more limited in the future; and there is a need to change water users behaviors to conserve water and prevent its pollution. The WCU enables the Ministry to more effectively communicate with people and at the same time to better listen to public. The Ministry communication strategy mainly consists of three phases:

- Building the general awareness of the Egyptian public that there is a limited water supply and it will become more limited in the future;
- Strengthening Ministry field staff to work with local groups to support the introduction of water conservation and pollution programs and practices;
- The implementation of campaigns using mass media and interpersonal channels of communication which focus on changing water users behaviors in terms of water conservation and pollution prevention. The communication campaigns are expected to continue for many years addressing continued awareness and behavioral change subjects.

Since the establishment of WCU, different awareness campaigns have been conducted and a lot of communication materials have been produced to increase the awareness of the water users to conserve water and use it efficiently.

Harmonization and Integration of Water Saving Options

Water saving options through the introduction of the organizational and regulatory framework and institutional vision / strategy and action plan, that would develop and enhance the following:

- Establishment of water users associations,
- Establishment of integrated water management districts,
- Strengthen the role of Irrigation Advisory Service,
- Modification of the old Laws
- Continuing the institutional reform, and
- Conducting an awareness campaigns.

CONCLUSION

Different water saving options have been considered and integrated to present the optimal water savings and productivity on the farm level, the water distribution system level, and on the organizational and regulatory framework level. Integrating and harmonizing all the water saving options of the previous highlighted levels will result in an optimal water saving and management on the national level.

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CONVENTION AND PROMOTION OF WATER SAVING POLICIES AND GUIDELINES

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SUMMARY - The annual precipitation as a total in Greece is adequate. Water imbalance is often observed, due to temporal and spatial variations, especially in summer months when there is an increased demand for water. Many water saving aspects for increasing the quantity and improving the quality of limited water resources are described. Coordinated actions to promote water resources management and an integrated and effective planning are given.
Key words: water saving, limited water resources, water resource management

INTRODUCTION

Greece has a population of about 11,000,000 and occupies an area of 131,962 Km^2. The cultivated area is 34,962 Km^2 and the irrigated land occupies 14,305 Km^2 with crops, vegetables, trees and vines to cover 65.1%, 24.2%, 7.9%, and 2.8% respectively. The annual precipitation ranges from 400 mm in Athens and Cyclades islands to more than 1500 mm in the high mountainous areas with values of 700 mm in Eastern Greece and 1000-1200 mm in Western Greece and the Ionian islands. (National Statistical Service of Greece, 2001). The annual water consumption was estimated at 8,200 hm^3/year, most of which been used in agriculture (83%), whereas the domestic, industrial and other uses are 13%, 2% and 2% respectively. The increase demand for water cannot always be met despite adequate precipitation. Water balance is often experienced, especially in the coastal and southeastern regions, due to the spatial and temporal variations of precipitation and as a result of the increase water demand during the summer period as well as the high cost of transporting water. The water problem remains at the gates and there is great need for harmonization and application the water saving techniques and strategies.

WATER SAVING ASPECTS

Many water saving efforts have made in Greece to improve the use and management of water resources. Some of these efforts are given in brief below.

Increasing the drip irrigation systems

The irrigated land covers an area of 1,430,000 ha and irrigation of water is done by surface irrigation (19%), sprinkler irrigation (50.6%) and drip irrigation (30.4%). The general trends in the existing public networks (Fig. 1) and private networks (Fig. 2) are to gradually abandon the surface irrigation systems giving place to sprinkler and especially to drip irrigation techniques with higher application efficiencies than the former.

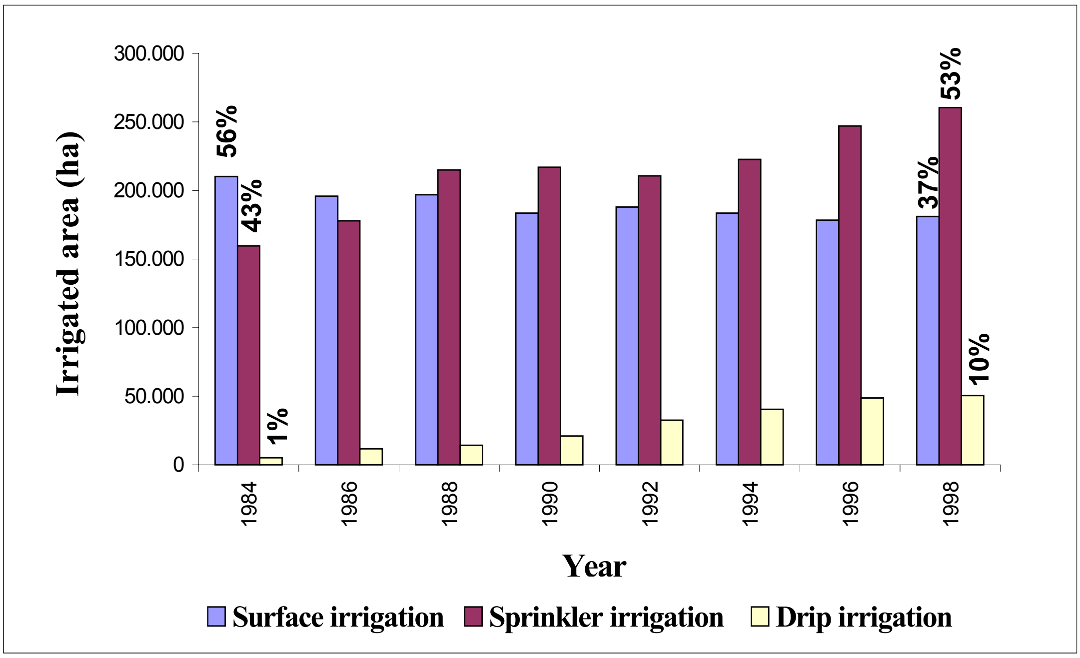

Fig. 1. The trends of irrigation techniques used in public networks

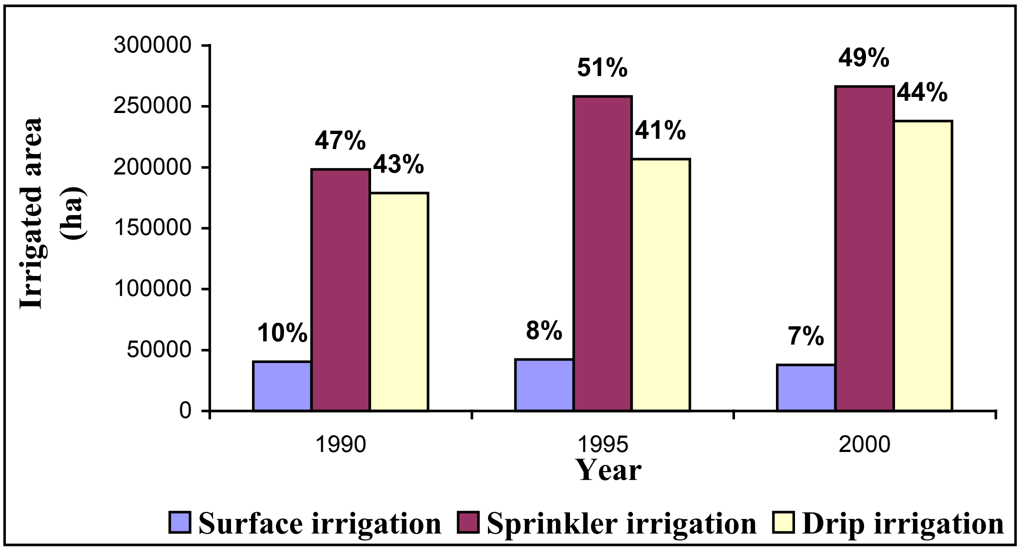

Fig. 2. The trends of irrigation methods used in private networks.

Additionally, the conveyance of irrigation water tends to be made by more efficient ways using pipelines instead of surface flow (Figs. 3 and 4).

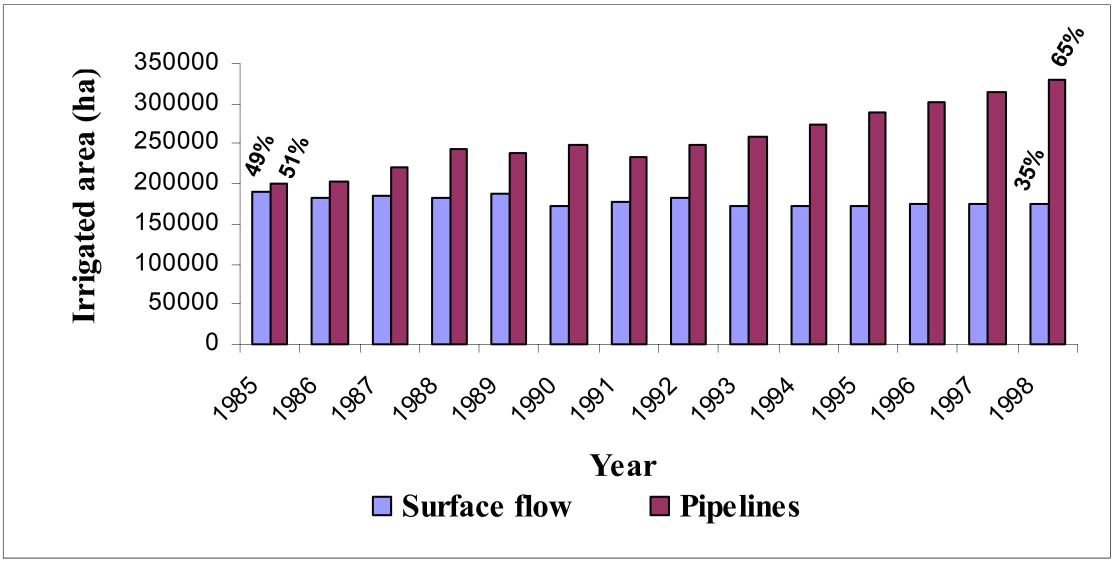

Fig 3. Conveyance of irrigation water in public networks.

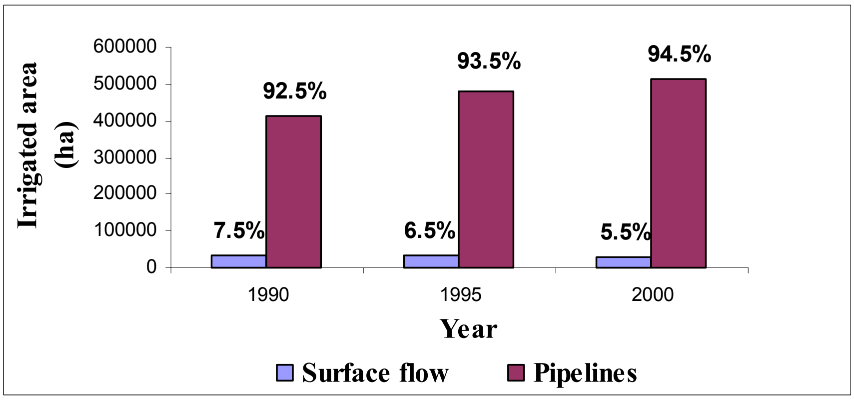

Fig. 4. Conveyance of irrigation water in private networks.

Increase the water use efficiency in irrigation networks.

The water application efficiencies for surface, sprinkler and drip irrigations are 75%, 85% and 90% respectively. Furthermore the water conveyance and distribution efficiencies are 70%, 85% and 95% for transportation of water with earthen, concrete channels and pipelines respectively (Ministry of Agriculture, Land Reclamation Service, 1991). These data must have been changed by now, by increasing some units.

In Greece the total water use efficiency is estimated to 60%, as the actual water use was 6,833 Km^3 and the maximum calculated crop water requirements reached the value of 4,089 Km^3 (Tsanis, 1996). More specifically in public networks, water and energy consumptions are generally increased as a result of considerable water losses in the course of water conveyance from the source up to the final application in the field. Consumptions about 10,000 m^3/ha are usual. Data from relevant research pointed out that the effective (actual) needs of the crops do not exceed the 5,000 m^3/ha. Therefore, losses exceed 50% (SCP-GERSAR / Hydrosystem, 1997). A lot of canals in the network for surface irrigation earthen, although this situation is being improved. However, there are cases where water shortage has positively activated the involved users and losses have been reduced to the normal range of 15-20% (Organization of Development of the West Crete, 1998).

Water saving practices at farm level

There are several practices to save water

- Storage water in farm reservoirs
- Destroy the weeds by mechanical (cultivation) or chemical (herbicides) ways.
- Covering of the cultivated soil surface with plant residues (mulch).
- Using minimum tillage techniques.
- In order to prevent surface runoff and to increase the soil moisture, different types of terraces (stone-walled and earthen) have been constructed from ancient times up to now in hilly and mountainous farms of central and south part of the country as well as in many islands. The main cultivars are olive trees and grapes.

Water saving in irrigation districts or regions

- Construction of dams
- Construction off-stream water reservoirs.

These structures refer to whole regions and large investments are needed.

Water saving techniques related to water harvesting

The techniques related to the water harvesting in Greece can be divided into the following categories.

- Structures which harvest runoff from ground surfaces. These are micro catchments (contour earth bands) constructed for irrigation of olive trees.
- Structures which harvest the rain from the roofs and ground surfaces and deposit water in rain-water tanks of a capacity 50-500 m^3, for domestic use and vegetable production in Aegean islands and Crete.
- Techniques which collect discharge by diversion the ephemeral water sources and spreading within irrigation channels for olive trees (Amfissa).

Recharging the degraded aquifers

During the last decades, in some Mediterranean countries attempts have been made to recharge mainly coastal degraded aquifers in order to increase water tables. In Greece, recharging has been applied in Argos region in East Peloponnesus with very good results. Recharge takes place during winter when there is enough rainfall. Following this technique the water quantity of the aquifers is increased as well as the quality of ameliorated groundwater is improved. Such plants cannot be made by individual farmers as large investments are needed.

Non-conventional water use

An alternative plan for saving water could include use of non-conventional water resources such as the reclaimed wastewater originating from the wastewater treatment plants. This alternative water use may provide sufficient water for irrigation, in order to prevent water shortage as well as intrusion of the pollution loads to the sea, rivers and lakes.

Greece has complied with the EU 271/91 directive on urban wastewater treatment. Thus in the year 2002 more than 350 Municipal Wastewater Treatment Plants (MWTP) could serve about 65% of the country's population (Angelakis et. al. 2002). As a member of EU, it was required to connect all agglomerations at sensitive areas with population more than 2000 to MWTP, by the end of 2005 (Tsagarakis,et. al. 2004).

Use of desalination water

Desalination systems based on renewable energy were used in some islands of Aegean Sea. While agriculture provides the living basis for most of the rural population, tourism carries hopes for significantly increasing wealth and employment in the island. Therefore the water competition between the two sectors increases the demand of water. Using desalination water initiative will help overcome this water competition.

Affecting the water balance

The total annual precipitation as it can be seen in Table 1, is estimated to be 116,689 hm^3 with 50.9% to be lost by evaporation, 31.9% by runoff and only 17.2% is infiltrated into soils (Ministry of Development, 2002).

Table 7. Water balance per water district (hm^3).

Water district	Precipitation	Evaporation	Internal runoff (rainfall infiltration)	Runoff
1. W. Peloponnesus	8031	3614	1285	3132
2. N. Peloponnesus	6404	2824	1661	1918
3. E. Peloponnesus	6563	3290	1847	1426
4. W. Central Greece	14340	5450	3825	5065
5. Epirus	17046	6818	4290	5938
6. Attica	1642	1150	241	251
7. E. Central Greece	9516	5257	1695	2564
8. Thessaly	10426	6255	973	3202
9. W. Macedonia	10470	5654	1239	3578
10. Central Macedonia	6068	3034	428	2606
11. E. Macedonia	4917	2722	524	1671
12. Thrace	8574	5325	530	2719
13. Crete	7500	4874	1068	1558
14. Aegean Islands	5192	3104	527	1562
Total	116689 *(100%)*	59371 *(50,90%)*	20133 *(17,20%)*	37190 *(31,90%)*

Any attempt to increase the infiltrated water into the soil, reduces the runoff of water and positively affects the water balance. This can be done by applying the following measures:

- Application of appropriate agricultural practices in the slopping cultivated areas in order to minimize runoff of rainfall, i.e. plowing according to the contour lines, cultivation in zones, using minimum tillage techniques, leaving mulch on the soil surface, etc.
- Low rock dams in winter water courses in order to slow down the rain flow and increase infiltration time.
- Measures to avoid forest fires.

The combination of these techniques and plans affects the water balance, especially in regions like eastern-south Greece and islands, where people are needed to increase “saved water” yields.

Application of rational agricultural practices

The application of appropriate agricultural practices by the farmers provides a lot of benefits by protecting the land from soil erosion and the ground water from chemical pollution. Fertilizers must be rationally applied, especially nitrates that affect the quality of the environment by polluting the ground waters. Agrochemicals must be used with a sparing hand and administrative measures must be applied in order to avoid the chemical degradation of groundwaters.

BENEFITS OF WATER SAVING OPTIONS. PROPOSITIONS ON MEASURES

Water saving requires coordinated actions in order to promote water resources management through an integrated and effective planning framework.

1) A reasonable quantity of water can be saved by replacing the old surface irrigation systems with drip irrigation ones. This policy can be improved by subsidizing the purchase and establishment of drip irrigation systems.

2) The increase of water use efficiency can be achieved by applying the following measures:

a) Training of young farmers in water management techniques.

b) Pricing of irrigation water in public networks is based on the size of the parcel. Farmers should pay on water volume consumption basis, instead.

3) Constructing dams and off-stream water reservoirs as well as recharging of coastal aquifers projects need large investments. Nevertheless, by converting a dry or degraded land to irrigated one the family income is increased by more than 70% as well as the employment at a rate of 20% in the perimeter of the project district. In addition a reduction in labor cost was observed as a result of automations (Naftemporiki Newspaper, 2004).

4) The effluents can be used to irrigate crops, forestry, amenities and for industrial needs. Thus the freshwater that is currently used for irrigation can be saved by 3.2%.

5) Desalination water can be used in some Cyclades islands in order to overcome the competition between the vital economic sectors of agriculture and tourism.

6) Encouraging and subsidizing any measure or technique that affects positively the water balance.

7) Administrative measures must be applied in order to avoid the environmental degradation of ground waters from nitrates, herbicides, fungicides and pesticides as well as of forests from fires.

The possible water saving opportunities in Greece can be obtained mainly from:

- The reuse of effluents from Waste Water Treatment Plants by 3.2% of current total use of freshwater.
- The reduction of water losses in the irrigation networks by 10% to 50% of the water used for agriculture.
- The different water saving options by an inestimable proportion.

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AGRICULTURE AND IRRIGATION WATER POLICIES TOWARD IMPROVED WATER CONSERVATION IN JORDAN

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SUMMARY - The paper addresses the water situation in Jordan in term of supply and demand management as well as policy formulation and implementation in irrigation and irrigated agriculture. Specific policies has been formulated to ensure sustainability of irrigated agriculture, optimal utilization of water resources, maximizing water efficiencies and optimization economic return of unit volume of water.
The policies of Ministry of Water and irrigation and the policy of the Ministry of Agriculture have been translated into action plans and projects. It seems that these projects are being harmonized by both entities to meet the objective goal aiming at water saving in the agricultural sector. The level of policy implementation in both sectors is satisfactory although additional efforts are needed in term of human resources development and training of farmers. The papers present some projects and success cases in promoting water saving and increasing efficiencies and water productivity.
Key words: Agricultural policy, Irrigation water policy, Policy formulation and implementation, Water policy analysis, Irrigation efficiency, Policy harmonization.

INTRODUCTION

Jordan is classified among few countries of the world with limited water resources where demands are far exceeding supplies. The scarcity of water has been a key part of the life of people where they have developed mechanism and norms to cope with the problem translated into rationing, limiting irrigated areas, water conservation and deficit irrigation. These conditions are aggravated as a result of reduced supplies, population growth, occurrence of drought, complexity of water resources management and water allocation policy. Under these conditions and due to water allocation policy, agriculture is the residual claimer of water. Priority in water allocation is first given for domestic use including tourism demand, then to the industrial sector and the remaining is allocated to agriculture. However, agriculture may receive additional water through reclaimed wastewater or recycled drainage water. By the year 2020, the volume of unconventional water used for agriculture is estimated to be about 40% (240 MCM) of allocated water to irrigation. On the other hand, agricultural areas irrigated with groundwater are being threaten due to control of pumping or plans to divert it to other sectors as the need is growing for additional supplies for domestic, industrial and tourist purposes. The hope in the future water supplies is limited and if available it will be expensive to use for agriculture because it would relay on desalinated water or imported water from neighboring countries.

The challenges facing irrigated agriculture in Jordan with respect to water availability are becoming chronic and complex due to a diversity of reasons; mainly:

1. Limited amounts of allocated water to the agricultural sector due to increasing uses by other sectors.
2. Low water efficiency and high water losses in the water system.
3. Shortage of available funds for water development and conservation
4. Lack of extension services and transfer of research results.
5. Unfavorable social habits and attitude toward water saving due to poor public awareness programs.
6. Lack of tools of public policy required to change attitude of stakeholder.

The above conditions leave no option expects to use water efficiency by improving water use efficiency and increasing its productivity. These options for a country, like Jordan, has bee given the highest priorities by the government through different policies and strategies that has been adopted by the Ministry of Water and irrigation and the Ministry of Agriculture.

This paper discusses various policies adopted by Jordan in the agricultural and water sectors that promote the efficient use of water is agriculture. Water saving is the main object of these polices, strategies and action plans. The paper discusses also policy formulation in achieving the above objective in forms of projects and action plans aiming at water saving, improving efficiency and increasing water productivity. This requires that a combination of technology, education and extension services be integrated in an effective policy and regulatory framework.

OVERVIEW

The total land area of Jordan is about 88,778 square kilometers (km^2) while the area of water bodies is approximated at 482 km^2 that includes the Jordanian part of the Dead Sea and the Gulf of Aqaba (DOS, 2004). About 91% of the land area is semi desert with rainfall amount of less than 200 mm. The range land area of annual rainfall between 200 to 300 represents about 5% of the country while the forest area that are found on the mountains and steep rocky areas comprise only 1%.

In general, only 4% of the total area of Jordan can be put into cultivation through rainfed agriculture in years of sufficient rainfall. The actual cropped area varies from year to year. It was 306,000 ha in 2000 compared to 380,000 ha in 1992. Areas developed for irrigated agriculture amounts to approximately 76,000 ha. Of this total, 33,000 ha are in the Jordan Valley and the southern Ghors which are primary developed by the Government. The rest of the irrigated area of about 43,000 ha has been developed by the private sector in the plateau and the Badia regions depending mainly on groundwater.

According to last census of 2004, the population of Jordan has reached 5.35 million people (DOS, 2004). Comparing this figure with that of the previous census of 4.18 million people in 1994 shows that the population growth during the last ten years has reached 2.5%. Before 1994, the population was growing at 3.4% rate due to three population influxes in 1948, 1967 and 1990. About 80% of the population is located in urban areas concentrated in the governorates of Amman, Zarqa and Irbid; all of which are water deficit areas and depend on water importation from other areas. Although the current population growth rate are relatively low and are expected to decline, due to education, birth spacing and the cost of decent living; the population will continue to place an enormous pressure on water resources.

WATER SUPPLY SITUATION

Jordan is classified among few countries of the world with limited water resources and it is one of the lowest on a per capita basis. The renewable water resources per capita are falling as a result of population growth and are projected to fall from less than 160 m^3 /capita/year at present to about 90 m^3/cap/year by 2025, putting Jordan in the category of an absolute water shortage. The scarcity of water in Jordan is the single most important constrain to the country growth and development because water is not only considered a factor for food production but a very crucial factor of health, survival and social and economical development. As a result of scarcity, the demands and uses of water are far exceeding renewable supply. The deficit is made up by the unsustainable use of groundwater through overdrawing of highland and desert aquifers, resulting in lowered water table in many basins and declining water quality in some. In addition to that, the deficit is overcome also by supply rationing to the domestic and the agricultural sectors.

Water resources consist of surface and ground water, with reclaimed wastewater being used at an increasing scale for irrigation. Water desalination has also become an optional source where 40 million cubic meters (MCM) are presently produced from over 10 desalination plants for domestic supply and about 9 MCM for irrigation. Renewable water resources vary from 785 to 840 MCM per annum, including 280 MCM of groundwater and 505 to 560 MCM of potentially exploitable surface water. An additional amount of 143 MCM is estimated to be available from the non renewable aquifers. The volume of effluent from the different wastewater treatment plants was estimated to range from 75 to 80 MCM in the year 2004.

WATER DEMAND ON JORDAN

Water uses vary from year to year depending on the available surface water supply which is decreasing due to upstream uses and climatic fluctuations. According to available water supplies, a total of 520 MCM in 2003 were used in agriculture (representing about 63.5 % of the total water use); the domestic sector consumed 270 MCM (32.5 %); industry share was only 36 MCM (4 %).

The municipal water demand is growing rapidly faster than the population growth but due to system capacity and limited supply, the actual demand has never been met. The total amount that have been supplied to municipal uses in 2004 reached 270 MCM which indicated that the annual per capita share of water for domestic uses was only 50 m^3/capita/year. This low amount averages a daily supply of 137 liter/capita/day. To overcome the shortage and gap between supply and demand, water consumption is rationed by rotating supplies and providing intermittent services during most of the dry months.

Most of the industrial allocated water is consumed by two major industries, namely; phosphate and potash production. These industries and many others are located outside of cities limits and therefore they secure their water supplies either by using surface water like the Arab Potash company or by drilling their own private wells as the case of the phosphate company. The government is selling surface water to industry and imposing a resources tax of 0.15 JD/m^3 for groundwater. For industries that receive water from the domestic network distribution system, water price is 1.0 JD/m^3.

Irrigated agriculture in Jordan falls under two categories in term of management and source of water. In the highlands, privately managed individual farms are irrigated by groundwater from private wells. The publicly managed irrigation system in the Jordan Valley uses surface water of the Yarmouk River and side wadis as well as reclaimed wastewater.

Expansion of both systems has been rapid in the last 30 years. Highland irrigation expanded from 3,000 ha in 1976 to an estimated 43,000 ha in 2004 which uses mainly groundwater as a source of irrigation including 6,000 ha that are irrigated by the fossil non-renewable groundwater in Disi and Mudawwara areas for the production of cereals, vegetables and fruits.

Irrigation in the Jordan Valley and Southern Ghors have been developed by the Jordan Valley Authority (JVA) which covers 23,000 ha under full irrigation in the Jordan Valley plus 6,000 ha in southern part of the Valley that are restricted by water availability to winter use only. In addition, there are about 3,000 ha that are irrigated with groundwater using private wells.

In the Southern Ghors, south the Dead Sea, about 5,000 to 7,000 ha are irrigated using the base flow of southern wadis and release of the southern dams. As such the total irrigated area in the Jordan Valley and Southern Ghors is estimated at 33,000 ha and about 43,000 in the highland and the desert; totaling 72,000 ha as the irrigated area in Jordan.

WATER MANAGEMENT

In Jordan, there are three public agencies responsible for the management of water resources. The Ministry of Water and irrigation (MWI) is responsible of water resources policy and strategy development, water resources planning, research and development, information systems, procuring financial resources. The two agencies, namely; the Water Authority of Jordan (WAJ) and the Jordan Valley Authority (JVA) are executing bodies; they are under the umbrella of MWI and the Minister of MWI heads their boards of Directors. WAJ is responsible for providing water and sewage services throughout Jordan and for water resources management while JVA responsibilities cover the development of Jordan Rift Valley, including water resources, primarily for agriculture in the Jordan Valley and southern Ghors. JVA is also in charge of managing the scheme in the Valley and all dams and reservoirs feeding JRV. The Ministry of Agriculture has a small role in irrigation management confined to on-farm irrigation extension services and research and technology transfer through its research arm (NCARTT). The Ministry of Environment monitors the quality of surface water in natural environment and the quality of industrial wastewater discharged to the ecosystems to meet its mandate in conserving the environmental elements from pollution.

Up to 1996, management of the water sector had been characterized by short term planning focusing on increasing water supply, fragmented short-term policy and overlapping responsibilities between the three agencies (MWI, WAJ and JVA). In addition, there was no coordination between MWI and other ministries like the Ministry of Agriculture (MoA). For example, the responsibilities on up-land irrigation and on-farm irrigation management are vague and lost between MWI and MoA. Also, there has not been any significant coordination between MWI and the Ministry of Environment as well as other entities in Jordan. However, according to ESCWA report (2004), Jordan is one of the few countries in the Middle East that applies the integrated water resources management.

FORMULATING OF WATER AND AGRICULTURAL POLICIES

Prior to 1990, management of water resources was based on crises management principles. Every summer, rural and urban populations are faced with fresh water shortage which results in rationing of water distribution. The situation with the agricultural sector is similar and even severs in drought year. As a result of that, there was an urgent need to formulate a national water policy taking into account all issues related to the water resources and their uses and management. This need was supported strongly by the World Bank, FAO and other donor agencies as well as by other donating governments.

Early work on water policy development programs started in Jordan in 1995 which was initiated by MWI with support from US-AID project (WQIP) and GTZ. The first phase of the program included establishing a water policy committee, chaired by the General Secretary of MWI composed of a team of experts who represent the full range of prospective and interest in the water sector in Jordan. The core of the water policy committee numbered roughly 25 was drawn from Jordanian and international experts representing the senior staff of MWI, private sector, the academic community and members from other government agencies. The committee members reviewed previous policies adopted earlier in the country such as those of the Ministry of Agriculture, Ministry of Planning and the Higher Council for Science and technology. Relevant literature, including water policy review papers adopted by the World Bank, FAO and other countries were identified, analyzed and synthesized. The committee identified 22 policy issues which were grouped under six categories; water resources and supply management, demand management, allocating priorities, water quality, investment in the water sector, and institutional and legal aspects. Each one of the 22 issues was developed into a brief policy profile. The profile was used to assist the policy team in ranking the issues and concluding a policy statement, strategies and action plans.

In 1997, a National Water Strategy was approved by the government. The strategy stresses the need for improved water resources management with particular emphasis on the sustainability of present and future uses. Special care was given to protect Jordan’s water resources against pollution, quality degradation, and depletion. Furthermore, MWI was supposed to sustain the highest practical efficiency in the conveyance, distribution, and application and use of water resources. In addition, MWI was expected to adopt a dual approach of demand management and supply management, with tools of advanced technology being increasingly utilized to enhance the resource management capabilities.

The Water Strategy ensures that the rightful shares of the Kingdom’s shared water resources shall be defended and protected through bilateral and multilateral contacts, negotiations, and agreements. Water and wastewater projects associated with regional peace processes, including the scheme for the development of the Jordan Rift Valley, shall be accorded special attention for construction, operation and maintenance. Due respect will be given to the provisions of international law as applicable to water sharing, protection and conservation, and those applicable to territorial waters. Bilateral and multi-lateral co-operation with neighboring states shall be pursued, and regional co-operation shall be advocated.

The strategy defines the long-term goals that the government of Jordan seeks to achieve in the water sector. The Ministry plans was to formulate certain policies that would help achieve these goals. Up to now, the Ministry has prepared and published the following four policies:

1. Groundwater management policy;
2. Irrigation policy;
3. Wastewater management policy and
4. Water utility policy.

Agricultural Policies

After the economic depression in the 1980s and the resulting 1988 economic crises, the government of Jordan took strong measures by implementing a long-term structural adjustment process. As a result, many substantial and far-reaching changes in the overall economic and sectorial policies have been made. Since the agricultural sector was the largest contributors to the government’s subsidy expenditure, therefore, it was among the first sector for reform in the early 1990s. There was an urgent need to formulate a comprehensive agricultural policy which would be an integral part of the overall policies for the economical development especially in rural areas. The agricultural policy, which has taken the government approval in 1996, would be an integral part of the comprehensive social and economic policy of Jordan considering the following criteria:

Efficiency

- Development and optimal use of available natural and agricultural resources.
- The application of concepts of economic efficiency and comparative advantage in utilizing these resources.

Sustainability

- Effective management and conservation of natural resources used in agricultural production especially soil, water and natural vegetation to ensure long-term sustained agricultural production.
- Ensuring that measure aimed at the promotion of agricultural development must be sustainable in the long run and must not become a continuous burden on the government budget.
- Development of the necessary legal and institutional framework within the public and private sectors, to provide stability as well as a favorable investment environment, with the aim of strengthening agricultural development.
- Assuring a continuous supply of food that is adequate in terms of quality and quantity.

Equity

- Achieving social and economic equity between agriculture and other economic sectors, and also within the agricultural sector itself.
- Providing equal social and economic opportunities to all participants in agricultural activities, especially to those engaged in agricultural production, and in particular to small farmers who depend on agriculture as their main source of income.
- Increasing the income of framers and agricultural workers to equitable levels, and improving their standard of living accordingly.

Objectives

- To increase the degree of Jordan's self-reliance in food
- To manage and utilize the available agricultural production inputs, in particular; water, land, capital and labor, in an economically efficient manner, while preserving the environment and ensuring the sustainability of agricultural production in the long-term.
- To increase the profitability of the agricultural sectors as well as standards of living for farmers and agricultural workers.
- To orient the production of food and other agricultural commodities to meet demand of the domestic, regional and international markets and to ensure that such production is competitive in quality and price.
- To maximize the value added to the gross domestic product (GDP) of Jordan's agriculture sector, particularly that of agribusiness.
- To promote the export of agricultural and livestock products, and help improve the national balance of trade.
- To attain social and economic equity between the agricultural and other sectors of economy and also within the various parts of the agricultural sector itself.
- To achieve integration of agribusiness among Arab countries, and promote cooperation between countries of the region in the area of production and trade of food and agricultural commodities, ensuring balanced to all countries concerned.

Challenges and Approach

The Government is determined to achieve the above-mentioned objectives by putting in place adequate economic, legislative and institutional framework to support rural change and transformation in the agricultural sector and to enable the sector to cope with the challenges and problems facing development. The following principles and general approaches are intended to provide the appropriate environment that will enable the sector to grow:

- Creating a favorable environment to ensure a freely functioning marketplace including the necessary regulatory and monitoring framework, while encouraging private agribusiness to play a major role in agricultural development.
- Strengthening the implementation of government policies supporting agricultural production and rural development, and making the necessary policy adjustments whenever needed.
- Providing the necessary institutional support and services in areas where the private sector is unable to provide them, including the infrastructure needed for sustained agricultural development, as well as information and other basic services.
- Encouraging the effective participation of individuals and target groups in agricultural policy formulation and in decision-making processes, and also ensuring their participation in the implementation of various programs and activities.
- Integrating agricultural policy into, and ensuring that it is in line with other general and specific government polices.
- Defining agricultural development as the core of the integrated development of Jordan's rural areas.

Irrigation Water Policy

The Irrigation Water Policy (MWI, 1998) was also approved by the Council of Ministers in 1998. The policy addresses irrigation water including agricultural use, resource management, technology transfer, water quality, and efficiency, but does not address or extend to irrigated agriculture. Many provisions of this policy already are in practice. Specific policy statements address**:**

- *Sustainability of Irrigated Agriculture* (e.g., existing areas shall be accorded the chances for sustainability; protection of ground water resources takes priority over sustainability of agriculture; coordination with Ministry of Agriculture)
- *Resource Development and Use* (e.g., use of wastewater; use of rainfall for crop production)
- *Technology Transfer* (e.g., higher agricultural yields; modern advanced irrigation technologies; pressurized pipelines; genetically engineered plant varieties)
- *Farm Water Management* (e.g., night application of irrigation water; automation of farm irrigation networks; monitoring of soil moisture; crop water requirements for micro-climatic zones)
- *Irrigation Water Quality* (e.g., monitoring at sources, conveyances, and distribution network; improving wastewater quality to allow unrestricted irrigation; testing of soil salinity).
- *Management and Administration* (e.g., JVA responsible for operation and maintenance of irrigation facilities from source (e.g., reservoir, river, spring) to farm gate; use of piped irrigation networks; metering of water at the farm turn-out; participatory irrigation management)
- *Water Pricing* (e.g., irrigation water managed as an economic commodity; water price to cover at least operation and maintenance costs and as possible capital costs; differential prices for different water quality)
- *Regulation and Controls* (e.g., discourage crops with high water uses through economic and market forces)

Irrigated Agricultural Policy

In order to exploit the growth potential of irrigated agriculture, Jordan will continue an outward-oriented market strategy based on economic opportunities and incentives, and on strengthening its institutional capacity to increase and diversify horticultural exports to reach beyond, emerging Middle Eastern markets. Thus, Jordan will re-establish a clear comparative advantage for its horticultural products for domestic and regional markets. Production for export will be part of a long-term strategy, taking advantage of the new export opportunities related by the recent economic and political developments at regional and international levels. Effective research and extension will play a significant role supporting dynamic and sustainable irrigated agricultural production.

The limited availability of irrigation water is the most severe constraints to the growth of the sector. It is thus imperative that policies geared towards improving the efficiency of water utilization receive the highest priority. Government policies and strategies in this area will aim at achieving the following:

Optimal Utilization of Water Resources: In order to achieve the objective of efficient and sustainable utilization of Jordan's available resources, the Government will adopt the following specific policy: *Maximizing the efficiency of water storage, conveyance, distribution and on-farm application*.

Government policies in this area are intended to produce substantial saving and to reduce the current shortages of irrigation water. This will require the joint effort and investment of both the Government and the farmers involved, particularly in the following areas:

- Developing suitable water storage structure both on and off-farm in order to minimize evaporation and seepage losses.
- Converting the open-canal conveyance and distribution systems to closed-pipe systems in the Jordan Rift Valley and the highlands.
- Replacing existing surface basin or furrow irrigation by drip systems.
- Designing and implementing irrigation projects jointly between the public and private sectors.
- Pricing publicly developed and managed water to reflect the importance and scarcity of water in Jordan.

To implement the above-mentioned policies, the Government will adopt the following strategies:

- Strengthening all overlapping issues and responsibilities shared between ministries and other public-sector institutions concerned, regarding the management of the country's water resources to ensure compliance in their work.
- Strengthening the national capacity for the generation and dissemination of technical information on water-saving technologies.
- Defining crop-water requirements in the various agro-climatic zones to ration the use of irrigation water.
- Upgrading the management capacity of manpower involved in water distribution.
- Furthering public awareness regarding the efficient use of water, water quality, and the conservation of watersheds.
- Exempting materials required for the local manufacturing of water-saving technologies from import duties.

Maximal Efficiency of Water Use in Irrigation: The maximization of net economic returns on each cubic meter of water used in irrigation will mean that the production of crops with high water-consumption will be limited, in particular if their gross margins per cubic meter are comparatively small. This assumes that protective policy measures for such crops are removed. Appropriate pricing and market mechanisms will ensure that crops with high net returns per cubic meter of water, and which are in demand in both domestic and export market, will be given priority by farmers. The following measures will be implemented in pursuing this policy:

- Adopting water –management plan for the Jordan Valley on the basis of water requirements of crops in order to assure the availability of irrigation water to crops with high economic returns. Such a plan would reflect the economic value and the relative scarcity of irrigation water in the different seasons.
- Developing water crop regimes that maximize the net value of output per cubic meter of water.
- Promoting the use of technologies that maintain soil fertility and acceptable water quality.
- Safeguarding soil and water from contamination due to drainage water carrying undesirable chemical residues, and from misuse of fertilizers and pesticides.
- Steering applied research to define water requirement and performance various crops in the different agro-climatic zones, their economic returns on water input, quality requirements for main crops and the effect of varying water quality on crop yields.

Quality and Quantity of Recycled Water and Groundwater: The policies to be actively undertaken in this regard relate particularly to proper treatment when recycling water and to special measures for the preservation of the quality of groundwater. The Government will implement the following measures in pursuing these policies:

- Enforcing regulation for monitoring recharge of groundwater aquifers and groundwater extraction

- Enforcing regulations for the licensing of deep groundwater wells in cropped areas.
- Protecting the watersheds of major aquifers to ensure the sustainability of water recharge in terms of quantity and quality.
- Monitoring the quality of surface and groundwater resources as well as irrigated soils to prevent any deterioration, and to remove the source of pollutants.
- Monitoring salinity and pollution levels, in particular in the effluent of wastewater treatment plants, and minimizing salinity through improvement of treatment methods, or by mixing such effluent with fresh water to meet Jordanian standards for treated wastewater.
- Enforcing environmental impact assessment of all development projects and programs affecting the nation's water resources, in particular dams and wastewater treatment plants.

Securing Investment in Irrigated Agriculture: In order to maximize net returns on producer investment in irrigated agriculture, to reduce the various risks faced by producers, and to minimize production and marketing costs, the Government will implement the following measures:

- Render market information available to producers and exports.
- Facilitate the organization of a balanced supply and demand for commodities produced and marketed in Jordan and for export, to minimize potential losses to farmers arising from market price fluctuations
- Encourage farmers' and exporters' organization to assume responsibility for improving the marketing of Jordanian produce, including the development of new markets and new crops in demand in these markets.
- Enforce legislation concerning technical standards for agricultural products, and grading and packing regulations.
- Strengthen the generation and dissemination of technical information on pest and pesticide risks, and the potential misuse of agricultural inputs.
- Enhance post-harvest technical services for fruit, vegetables and other crops, including pesticides monitoring and residue analysis, and provide information on quality control standards, packing specifications, and the pre-cooling and handling of fresh horticultural produce.
- Orient research and technology transfer towards production and market oriented priority programs, with farmers participating in the decision making process for resources allocation and program priorities. The outlay of financial resources for this research will be at levels ensuring adequate efficiency, and should reach a target of not less than two percent of the total value added to irrigated crops. Such measures are equally applicable to other market oriented production systems (in particular, export oriented production systems).

POLICY ANALYSIS

Under the current water policy directive, agriculture is the residual claimer of water. Priority in water allocation is first given for domestic uses, then to the industrial sector, including tourism, and remaining is allocated to agriculture. Agriculture may receive additional water through reclaimed wastewater or recycled drainage water. Long term plans to increase the capacity of use of reclaimed wastewater are in place and it is expected by 2020, that the volume of treated wastewater to agriculture will reach about 240 MCM. This will represent about 40% of allocated water to irrigation.

By 2020, the per capita share of water can reach 90 m^3/capita/year including wastewater. The maximum amounts of 890 MCM that may be allocated for agriculture may contribute to about 15% of the country's self-sufficiency on food. Additional 15-20% comes from rainfed areas, will put Jordan food self-sufficiency at 30-35% level. The irrigation water policy of MWI and the irrigated agriculture policy of MoA are in agreement in terms of sustainable use of water resources, irrigation water management and irrigation water quality. Price and cost recovery policy of irrigation water is set only by JVA because it is responsible for delivery and tariffs collections. As a matter of fact, the role of MoA is irrigation water policy is limited to extension and public awareness and research as well as regulation and it has no power in policy implementation. Protection the interest of the farmers and the agricultural community are among the mandates of the Ministry of Agriculture. Therefore, it is not expected that MoA take a part in the pricing and water allocation policies as it would be set by MWI. Unless the Ministry of Agriculture is given a legislative role in irrigated agriculture in water delivery and scheduling since its role in improving on-farm irrigation efficiency role will be limited to extension and research.

In the upland, there is a direct link between groundwater management and irrigated agriculture policies. Reducing the abstraction level of renewable aquifer to the sustainable rate (safe yield) will have a direct impact on irrigated agriculture in the upland. The action plan to implement groundwater policy requires reduction of 122 MCM by 2020 and transferring 100 MCM (65 MCM of them already are used in Agriculture) from the non- renewable Disi basin to Amman for drinking purposes. This action will reduce irrigated area in the upland by about 20,000-25,000 ha leaving areas irrigated by groundwater to only 15,000 ha. It is anticipated that this reduction will be replaced by the reclaimed wastewater either for direct use or artificial recharge. These conditions will require adjusting the cropping pattern to those suitable for this kind of water such as fodder, industrial crops or wood trees. The policy of gradual reduction of ground water abstraction to its safe yield will be of course being on the expense of agriculture.

In the Jordan valley, the situation will be similar where there will be a transfer of about 135 MCM of fresh water to the upland cities in trade of wastewater. This action requires special soil and water management and the introduction of restricted agriculture. Such changes in water allocation and uses in the upland and the Jordan Valley will have a direct impact on the kinds of crops and thus on food security. Shifting to fodder or maize cultivation as animal feed might change the trade balance in milk and red meat.

Historically, food security and self reliance were the main two items put on the top agenda in the formulation and implementation of the successive development plans. Increasing wheat and livestock production was the two priority item in achieving the above goal. In doing so, the government in 1994, leased land in the southern desert of Jordan, and issued groundwater abstraction licenses to private companies in order to grow wheat and fodder crops. The area that was leased exceeded 60,000 ha. Wheat and fodder production under sprinkler irrigation continued for few years during which the government was the main buyer of grain at subsidized prices. Even with input subsidized (Water, land, seeds…), these companies shifted to the cultivation of fruit trees and vegetables, the objective of food security were not achieved.

Self-reliance on food has been fluctuating since then and as usual reflecting the climatic conditions or rainfall amounts and distribution. The severe decline in the agricultural sector which has begun in 1994 has not been corrected through government interaction. On the country, agriculture has been always under criticism due to its low contribution to the national GDP and high demand for water. The problem was further aggravated by the three year successive drought (1998-2001). The issues of food security were almost ignored after imposing the trade liberalization policy, eliminating the protection of agricultural products and abolishing the direct support to farmers and animals growers.

The issue of self-reliance on food has been considered on the agricultural agenda and is being addresses by the water policy and the agricultural policy charter. The first objective of the agricultural policy is to increase the degree of Jordan's self-reliance in food while the water policy calls for stability for irrigated agriculture. These objectives have not been translated into a specific policy statement or strategic measures and work plan until recently in the development of a national agricultural strategy. A set of programs including development was proposed to increase the degree of self-reliance on food.

POLICY IMPLEMENTATION

In this section, discussion concerning the stages of the implementation process is presented. Discussion will also consider adjustment measures and interactions that could overcome problems associated with implementation.

The Irrigation Water Policy Implementation: The irrigation policy addresses irrigation water including agricultural use, resource management, technology transfer, water quality, and efficiency, but does not address or extend to irrigated agriculture. Many provisions of this policy already are in practice. Specific policy statements address: sustainability of irrigated agriculture, resource development and use, technology transfer, farm water management, irrigation water quality, management and administration, water pricing and regulation and controls.

In implementing the irrigation water policy*,* Both MoA and JVA address the irrigation water policy as mean to improve irrigation water management, in term of improving irrigation efficiencies and water use efficiency as measurable indicators.

On the sustainability of irrigated agriculture provision, the policy ensures that protection of groundwater resources takes priority of sustainability of agriculture. Progress in these issues is still very slow. The policy encourages coordination between MoA and MAI, but such coordination has not been materialized. On resource development and use, the progress is very slow and is confined to treated wastewater reuse. On technology transfer, farmers, private sectors and universities are ahead of government is using modern tools and technology transfer in irrigated agriculture. The process of adopting technology transfer is slow. An indicator for success requires baseline survey every five years. Two baseline survey conducted by Shatanawi et al (1986 and 1994) indicating a slow progress in this regards. However, a significant progress has been achieved since then with the implementation of many USAID supported projects such as IAS and Kafa'a. The number of farm that has converted from surface irrigation to high tech micro irrigation has jumped from 32% in 1985 to 68% in 2003. On management and administration, almost all irrigation distribution systems have been converted to pressurized pipe network. Water delivery to farm is under control through metering of water at the farm turn-out.

On water pricing, the objectives of the provision of water pricing policy are based on the assumption that irrigation water prices should cover operation and maintenance cost and as possible capital cost and should be used as an incentive to improve on-farm irrigation efficiency. The price of irrigation water in the Jordan valley was dramatically restructured so that it is ranging from 8 to 35 fils (1 fils = 0.001 JD) per cubic meter. The average operation and maintenance cost (O&M), which are estimated to range from 25 to 28 fils per cubic meter, is covered. Subsidies to producers on irrigation water have been virtually eliminated by 1998 compared to about 670,000 JD in 1993 (JVA, 2001).

Prices of Irrigation Water in the Jordan Valley according to Block Tariff.

User class (Block)	Water Consumed Per month in m^3	Water costing Fils/m^3
1	0-1000	8
2	1001-2000	12
3	2001-3000	20
4	>3000	35

It is believed that the new water pricing structure has helped to improve irrigation efficiency in the Jordan Valley. Irrigation efficiency in the valley is rising reaching 70% in 2000 compared to 57 in 1994 (Shatanawi, 1995).

A study (FORWARD, 1999) was submitted to JVA recommending a differential pricing structure according to water quality. This study is based on crop response to water quality model. JVA is in the process of putting this recommendation into the implementation stage in the area of the central Jordan Valley where the quality of water poses an issue.

As for irrigation in the upland, MWI has concluded an agreement with the farmers to put charges on groundwater withdrawal exceeding 150,000 m^3/year. This limit is applied to all groundwater users regardless the area and the productivity of the wells. Such policy however, could not be fair for large ownership with high productive wells. On the contrary, it will encourage small farmers with wells of less than 100 m^3/hr yield to increase their pumping rate. Price restructuring is required to take farm holding and well productivity into consideration. Such arrangement has been materialized by issuing the ground water protection by-law of 2002 (Law 88 of 2002).

Wastewater Management Policy Implementation: The Wastewater Management Policy (MWI, 1998) addresses the management of wastewaters as a water resource including development, management, collection and treatment, reuse, and standards and regulations. Specific policy statements address: resource development, resource management, wastewater collection and treatment, reuse of treated effluent and sludge and pricing.

Wastewater is undertaking massive efforts in the development of master plan for the construction of wastewater treatment plants with provision of reuse to cover about 85% of the population by 2020. Planned activities should be able to treat about 280 MCM compared to about 80 MCM that are being treated as of 2003. The number of treatment plant that are completed and in operation has reached 19 treatment plants. Improving the plant efficiency and the quality of the effluent to meet the Jordanian standard for reuse is an objective to be achieved during the implementation of the master plan. Along with that, legislation and standards has been drafted to cover the legal and administrative aspect of treatment and reuse. A new standards and guidelines for reuse of treated effluent was completed and approved by the Department of Standards and Specification. Finally it was published as standard No 201 of 2003.

Treated wastewater is considered an integral plant of renewable water resources and is counted in the water budget. New treatment plants and the expansion of old plants will be operated by the private sector on BOO or BOT basis. There will be a price of effluent to cover the operation and maintenance cost.

Groundwater Management Policy Implementation: The main provision of groundwater management policy included development, protection, management and reduction of abstraction rate to the safe yield. Efforts in assessment of sustainable yield and further exploitation process are going one. New well field were developed (Corridor well fields for example) to augment domestic water supply. In this regards, MWI has established a unit for protection of recharges where the By-law in this regards has been completed. It appears that integrated watershed management approach has not been considered a priority area by MWI or MoA.

The policy calls for gradual reduction of abstraction rate to the renewable safe yield by 2010. No. progress in this regards, has been made.

The Water Sector Review Report (World bank, 1997) recommended reduction in groundwater abstractions and improved water quality monitoring of groundwater. Irrigation use of Disi fossil groundwater was to be reduced. The possibility of a resource tax on resources mined in excess of licenses was to be studied. Some of these recommendations have been achieved responding to the policy where about 90% of wells were metered , charges for excess abstraction have been agreed upon by the farmers and MWI, WAJ took the monitoring responsibility, and a groundwater management program has been launched.

Government policy calls for a massive reduction in abstraction by highlands pumpers. The bulk of the projected reduction in abstraction of renewable groundwater, by 86 MCM/year until 2010 and by a further 36 MCM/year until 2020, will have to come from reduced abstraction for Highland agriculture. If this reduction does not materialize, there is a risk completely losing some aquifers due to almost irreversible Salinization of the groundwater stocks. Continued effort at metering, ensuring operational performance of meters, and enforcement of licensed quantities, volumetric tariffs, together with stakeholder participation should be the thrust forward. Lessons from the Zarqa basin project on socio-economic strategies with respect to agricultural users should be incorporated into a medium term program of action.

Efforts in low enforcement against illegal wells and enforcement of licensed rate of abstraction are not encouraging. Desalinization of brackish water are at early stages where few farmers are using reverse osmosis techniques to desalinize saline marginal groundwater and use it for irrigation.

ACTION PLANS AND PROJECTS

Implementing the water and agricultural policies in Jordan was coordinated by respected authorities putting them in modules and priority order. The implementation measures were translated into project and action plans that are put in the pipeline of implementation. The level of implementation depends on allocation from the general budget and the support of donors such as the World Bank, UNDP, FAO, USAID, GTZ and other bilateral donors. There are several projects that have addressed water management and conservation issue in the irrigated areas of Jordan. These projects, action plans and measures range from research and development, improving extension services, training, public awareness to direct support to farmers in term of financial assistant, loans or revolving funds. This section provides brief description of some projects including duration and implementing agency.

Description of Projects

1. Water Quality and Conservation Project (WQCP): In this project a base line diagnostic study was conducted in the Jordan valley to determine the on-farm irrigation efficiency.
2. Irrigation Advisory Services (IAS): This project provides services to farmers by evaluation the performance of their micro irrigation systems and advising on measures to improve their efficiencies.
3. Water Efficiency and Public Information for Action (WEPIA): The project aim at improving water use efficiency at all level including the irrigation sector by launching public awareness campaigns and training programs. It has also encouraged the use of water saving devices at the household and farm levels. It addressed wide range of stakeholder from school pupils to teachers, educators, housewives, decision makers and farmers.
4. Skill Enhancement Project: In job training course was provided to official of the Ministries of Water and irrigation, Agriculture and Environment by the University of Jordan to improve their skill in water management and irrigation extension services.
5. Research Projects by Universities; There are several research projects carried our by different universities. The University of Jordan is carrying out several project funded by European

Commission. Three of these projects are oriented to irrigation; WASAMED is a thematic network aiming at compiling information and technologies for promoting water saving in Agriculture. IRRIMED is aimed at designing and improved management tools for water-limited irrigation; while DIMAS deals with applying reduced amount of irrigation water without comprising yield significantly.

6. Sustainable use of Reclaimed Wastewater: There are several projects experimenting on the use of reclaimed water for sustainable and marketable agriculture carried out by GTZ, USAID, JICA, and the Arab Fund.

7. Improving System Delivery Performance: This project is carried out by the Agricultural Mission of the French Embassy aiming at creating best condition to improve the hydraulic and performance of the pressurized distribution network. The mission is also working on introducing precision irrigation by the use of soil moisture sensors and automated water scheduling.

8. Educational and Informational Program to Improve Irrigation Water Use Efficiency (KAFA'A): This project is funded by USAID and is designed to increase water productivity of the precious and limited water resources used in the agricultural sector. The project team is working with partnership with different stakeholder to tackle the problem from multiple directions in order to increase the economic yield of used water. This is achieved by different means such as changing cropping pattern and implementing new technology to control water use. The project achievement so far can be summarized in the following points (i) production of extension leaflets, (ii) improving on-farm irrigation management through community revolving grants, (iii) establishing high quality extension services, (iv) Promoting policies to improve irrigation water use efficiency, and (v) introducing modern and high irrigation technology in the field demonstration farms.

CONCLUSIONS

The Government of Jordan has realized that reform, economic adjustment, planning and development have to be streamlined into general framework and translated into different sectorial policies including agriculture, food security and water. The water and the agriculture sectors were the main candidates for reform because they are the basic elements for economical development and food security. In this regards, water and agriculture policies were formulated in the mid 1990s to avoid the fragmented approach of crises management. The irrigation water policy of the MWI and the irrigated agriculture policy of the MoA have put general framework for managing the limited irrigation water more efficiency and in a sustainable manner that ensure highest economical return per cubic meter of water. It has been noticed that coordination between MWI and MoA is still lacking in the irrigation sector although their respective policies call for full coordination. The lack of cooperation in implementing these policies is clear when it come to channel or provides support to research and development. It appears that the private sector and the Universities are far head in implementation of these policies. Both ministries depends in implementing their polices on external support provided by different agencies and bi lateral donors. Most of the action plans and projects are carried out for short term while lacking sustainability.

However, there are several success cases in the implementation of the irrigation water policy toward water saving can be summarized as:

1. The implementation of the water pricing policy as an incentive for improving on farm irrigation efficiency and water productivity was very successful.

2. The involvement of the private sector in water distribution in form of management contract has improved system performance and reduce unaccounted for losses at an annual rate of 5-7%.

3. Appropriate pricing and market mechanisms policy has encouraged farmers to grow crops with high net returns per cubic meter of water and which are in demand for domestic and export market.

4. Formulation of the National Strategy for Agricultural Development as a tool for agricultural policy implementation is a successful case and is considered as a first step toward implementation. The main reason of success is the involvement of the target groups, individual, farmers and decision makers in the process of strategy formulation.

5. The policy of enhancing resources development is a challenging issue for MWI, so that treated wastewater development project has taken priority in the Ministry investment plans.

6. The policy of reuse of wastewater for agriculture is taking priority to guarantee that effluent meets WHO and FAO guideline. In this regards new standard and guideline on reclaimed wastewater reuse has been drafted and approved.

7. The policy of encouraging private sector participation has resulted into fruitful results. Agribusiness farming are introducing the most advanced technology in water management and saving.

8. The policy of skill enhancement and human resources development has made sustainable changes in people attitude toward water saving.

9. The provision of international cooperation has attracted many international and bilateral donors to concentrate on stakeholder involvement and partnership to increase the economic yield of water.

10. Satisfactory public awareness attitude has been created as a result of intensive public awareness campaigns.

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NCARTT POLICY IN WATER SAVING

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INTRODUCTION

A National Center for Agricultural Research and Technology Transfer (NCARTT) is a research and technology transfer organizations work for agriculture development and optimizing water resources utilization in Jordan. NCARTT was established in 1994 to supervise, coordinate and implement applied agricultural research and technology transfer across the Kingdom. In 1996, a National Strategy for Agricultural Research and Technology Transfer was adopted.

In consistent with the national agricultural development goals and polices, a realistic national agricultural research strategy for Jordan's national agricultural research and technology transfer system was developed. This strategy for NCARTT was developed with the support of ISNAR, and ICARDA. Additional advisory support was also provided by USAID. The methodology utilized in developing and formulating the national agricultural research strategy for Jordan was based upon the approach used by ISNAR. This approach included a review and analysis the agricultural sector, and analysis of the constraints to agricultural development, an assessment of the national agricultural research and technology transfer system, and appraisal of the future environment in which agriculture will have to operate, and the formulation of an agricultural strategy.

NCARTT consists of a main headquarter and six regional centers. The center operates 12 Research Stations (Map 1) representing different agro-ecological conditions in Jordan. Water and irrigation activities are carried out under the Water Management and Environment Program and cover the following area of interest:

- Optimal utilization and management of traditional available water resources;
- Optimal utilization of non-conventional water resources (treated wastewater and saline water);
- Study the effect of supplementary irrigation on improvement and sustainability of agricultural production under rainfed conditions.
- Introduction of appropriate water harvesting and spreading techniques (s) in areas of 100-300mm annual rainfall.
- Minimize the environmental degradation through conducting the following research activities:
    - Impact of using treated wastewater and saline water for irrigation on soils, plants and water resources.
    - Impact of using fertilizers and pesticides on the environment.
    - Effect of using plastic sheets and Poly-ethylene pipes on the environment.

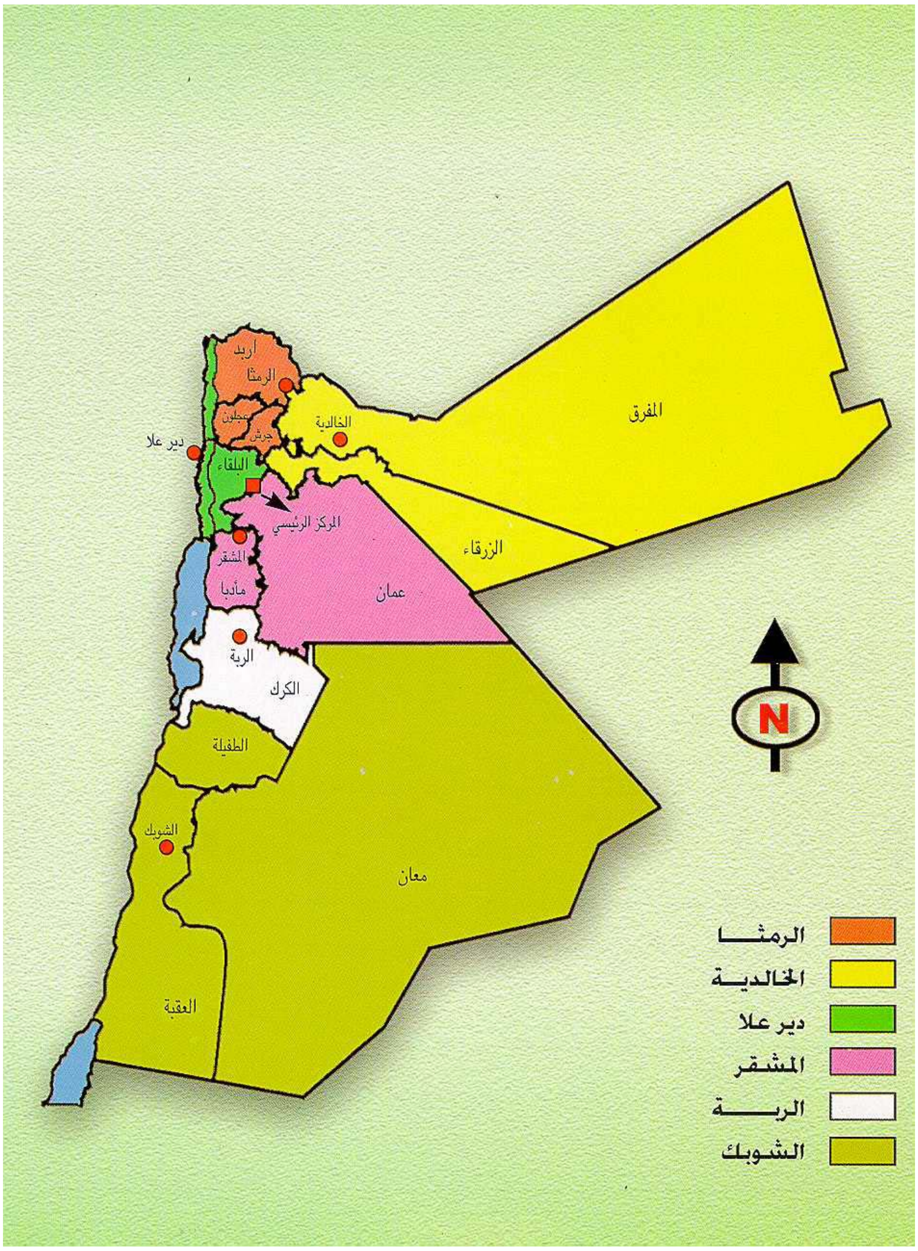

Fig. 1: NCARTT regional centers distributed in Jordan

NCARTT RESPONSIBILITIES

The main responsibilities include (but not limited to):

1. Organize agricultural research plans for the purpose of achieving agricultural development.
2. Adopt the latest agricultural techniques suitable for local conditions.
3. Disseminate such technologies to farmers through extension personal.
4. Increase knowledge, improve skills of researches, and enhance abilities of extension staff through educational and training activities.
5. Conduct economic studies for the purpose of improving farmers' organization.
6. Evaluate the effect of various social and economic factors on agricultural production.
7. Coordinate and support national agricultural research and technology transfer activities for sustainable agriculture.

NCARTTs' PROGRAMS

NCARTT contains the following programs and objectives covering all water research activities:

- Irrigated Agricultural Research Program: The largest program at NCARTT, responsible for achieving the optimization of water use efficiency for vegetables and fruit trees , economic utilization of irrigated crops , introducing new crops economic use of fertilizers , improve yields and quality , minimize negative environmental impact and reduce post- harvest losses and improve marketing.
- Rainfed Agriculture Research Program: Increase yields and improve the quality of local varieties, determine the optimal timing, land preparation and seeding practices for crop production, evaluate new crops for drought tolerance and develop appropriate technology to reduce post- harvest losses.
- Low- Rainfall Agriculture Program: Develop and maximize rangeland potentials, improve management and increase productivity of rangeland, implementing soil conservation practices, restoration rangelands vegetation covers as well as using water harvesting techniques to restore vegetation.
- Water Management and Environment Research Program: Improve irrigation systems and better management and utilization of water resources, increase fertilizers' efficiency, minimize the environmental degradation, develop and transfer irrigation technologies to farmers to maintain and improve farm productivity.
- Department of Technology Transfer: Responsible for dissemination of tested technologies to farmers, extension agents, and subject matter specialists, through special education and training activities and prepare materials.

Formulation of Strategies and Prioritization of Programs

In order to ensure the most efficient use of the limited resources available for research and technology transfer activities:

- Programs will be multi-disciplinary in their approach and continue the process from the generation of technologies through on-farm demonstrations and the publication of results and recommendations.
- Include all the necessary disciplines to ensure the economic basis and social acceptance or research results and recommendations.
- Programs are to be oriented towards finding and adopting technologies, management practices and policies which address the problems and needs of the agricultural sector.

Long Term Strategy of NCARTT

NCARTT long term research strategy focuses on the following broad issues:

- Water and land use management.
- Optimizing the use of available conventional & non-conventional water resources.
- Developing and adapting different water harvesting techniques.
- Transfer research results and recommendations to the farmers.

In developing NCARTT strategy, research and technology transfer were organized into five dimensions:

Management of the Conventional Irrigation Water. This includes the following components:

- Water Requirements and irrigation scheduling.
- Management of Information Systems.
- Management of Irrigation Systems.

Efforts to encourage and enhance indigenous water research targeted at the improvement of resource management, enhancing the understanding resource economics, and adapting the research findings in other environments to local conditions, including but not limited to, crop water requirements, minimizing evaporation and controlling evapotranspiration and the like.

The main factor contributing to low irrigation management efficiencies was attributed to lack of knowledge by farmers concerning crop water requirements and scheduling of irrigation water.

Distribution uniformity of trickle system caused by emitters clogging problem as a result of unsuitable filtration system, and poor hydraulic design of the irrigation network. For the above mentioned factors, NCARTT had established Irrigation Management Information project (IMIS) to over come these problems, and improve irrigation water management for saving water and improving agriculture production and quality, and minimize environmental hazardous.

The main objective of IMIS is to implement an irrigation system program for efficient water usage in Jordan and the Middle East region. The specific objectives are:

- Establish an IMIS based on real time meteorological data, soil characteristics, water quality, crop type, and current irrigation system efficiency.
- Develop infrastructure and information management tools for rapid and accurate dissemination of irrigation scheduling information.
- Adopt state- of-the art models for predicting crop irrigation requirements.
- Establish irrigation scheduling criteria for major crops in the Jordan.
- Establish data network that can easily be used by other relevant national institutions through improved classification data entry and retrieval, and communications.

Management of the Unconventional Water and cropping system.

This includes the utilization of marginal water (treated waste water and saline) resources for irrigation. Wastewater Management Policy (Paper No. 4 “Management of Wastewater” of June 1998) focuses on the management of wastewater as a water resource and includes, amongst other, development, management, wastewater collection and treatment as well as the reuse of wastewater and sludge in the agriculture, pricing, selected priority issues, standards and regulations.

The Policy of NCARTT aims to:

- Develop a practical, environmentally safe and socially accepted method to use treated wastewater for agricultural production.
- Better utilization of available unconventional water resources by the agricultural sector to overcome water scarcity problems.
- Developing an energy–saving and resource-recycling system for improvement of treated wastewater quality.

Integrated Watershed Management in rainfed areas includes the following components:

In this regard, NCARTT policy is to demonstrate, in the pilot areas, successful and transferable technologies for combating desertification and mitigating the effects of drought through the integrated management of natural resources (land, water and vegetation) that supports the livelihoods of communities.

Improvement of the productivity of rain-fed lands could be achieved through an integrated agricultural development of watersheds. This approach provided a better integration frame for the management of available resources.

Efforts have recently started to utilize water-harvesting techniques in rain-fed farming, especially for growing fruit trees; these efforts are also aimed at protecting soil from erosion. Farmers could also plant more drought-resistant crop varieties or varieties that use water more efficiently. In addition, they could adapt better soil management and other conservation practices.

Geographic Information systems (GIS).

GIS laboratory was established in 2002.This lab aims at establishment of geographic databases, necessary for researchers as well as for decision makers for sustainable natural resources management and augmentation of water resources in order to conserve soil, land cover and to combat desertification.

In this context, the policy of NCARTT is to use the state of art tools in the implementation of many research activities such as:

- Hydrological studies using hydrological Modeling.
- Watershed management through identification of potential sites and suitable techniques for water harvesting.
- Prediction of the suitable locations for construction an earth dam, Hafaier, small dam etc.
- Derivation of mathematical modeling for rainfall prediction and surface runoff.

- Suitability of Land use.
- Cadastral map analysis.

GIS proved to be a powerful tool for water-harvesting site selection studies due to its excellent capabilities in storing, analyzing and displaying spatially distributed data. The application of GIS was effective for identifying appropriate water harvesting techniques, including micro-catchments, contour ridges, collection and storage of rainfall water in cisterns, pits and others Figure 2.:

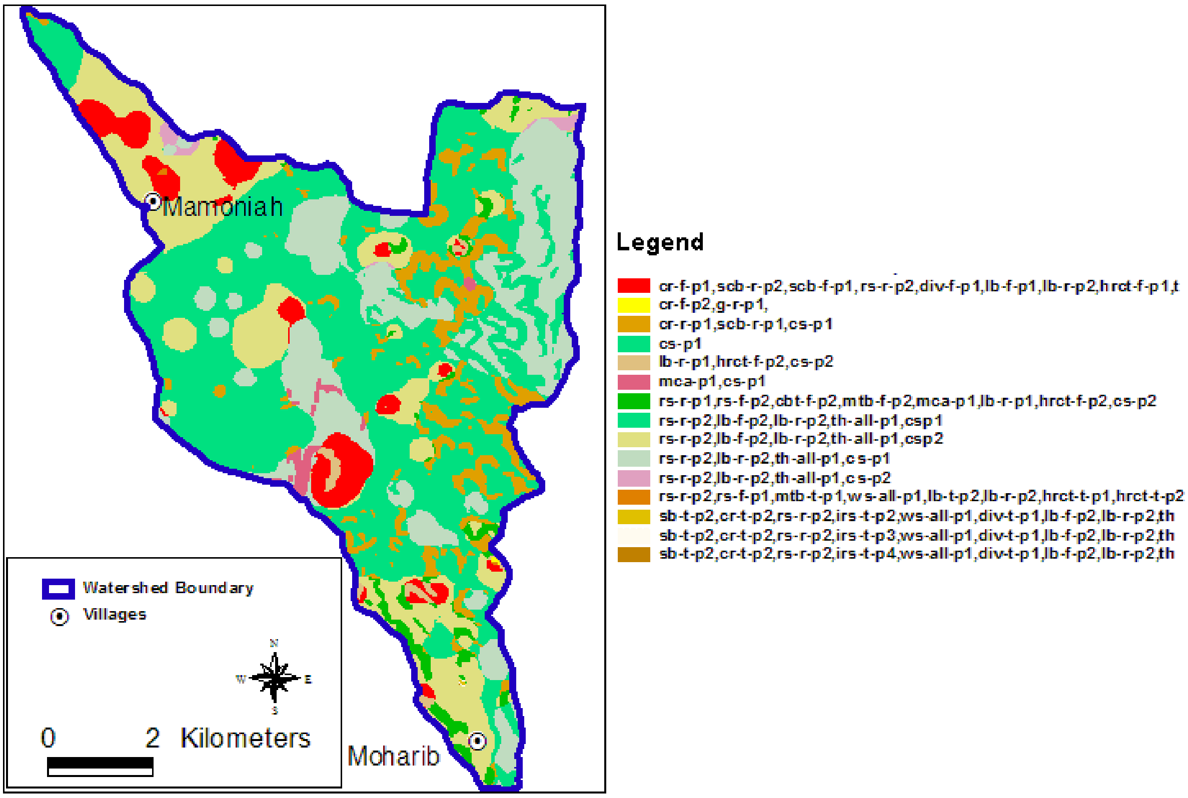

Fig. 2. Potential water harvesting option(s) suitable for each mapping unit.

Drought Prediction

Finally the long term vision for NCARTT strategy is to establish the “Drought early warning system” which aims at building the capacity of researchers for Drought Monitoring in Jordan.

The main objective is to support a Jordanian institution by building up their drought early warning and monitoring capacity. The unit has two main components:

- An applied research component designed to test and validate the utility of satellite imagery for drought early warning agricultural seasonal monitoring, production forecasts.
- An information dissemination component designed to maximize the utility of resulting project outputs, such as agricultural seasonal monitoring maps and early warning bulletins.

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HARMONIZATION AND INTEGRATION OF WATER SAVING OPTIONS IN LEBANON

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SUMMARY - In 2020, the water balance in Lebanon could be negative if concern entities in water management do not apply the water saving options. Ministry of Energy and water is the responsible of water policy and Water Authorities are the responsible for execution of his master plan. At the end users level in agriculture sector, the Ministry of Agriculture has the responsibility on farm level. The absence of Water User Associations and extension in water management, bad maintenance and water pollution are the major causes of water looses. Legislation, law enforcement, research and education center activation, tariff policy, stakeholder's capacity building are the main factors for water management enhancement. The creation of the High Council for water is a major step on coordination of decision maker's activities, sharing knowledge and exchange of experience. His role will be decisive on updating and adjustment of Water National Master Plan.

Keywords: Water Authorities, Water User Associations, High Council of Water, education and research center, Tariff policy, Legislation and Law enforcement.

INTRODUCTION

Experts warn that the impending water crisis will be the major environmental problem of the next decade. Population growth, irrigation development and urbanization are key factors underlying the enormous growth in the demand of water and increase environmental degradation.

Lebanon is the most urbanized country in the Middle East region-with more than 88% of its population in urban areas in 2005 (State of Food and Agriculture, 2005).The annual population growth rate is high (about 1.62%) (Country Report, FAO, 2005). Actual irrigated area represents only 42% of the total irrigation potential. With great efforts on technical improvement, to:

- Rehabilitate and improve efficiency of actual irrigation and domestic water network.
- Ameliorate "on farm" irrigation efficiency.
- Limit degradation and ameliorate the water quality.
- Reuse treated wastewater.
-

Water balance will be at borderline in 2020; even though total water needs will grow by 83% from the actual water needs (Litani River Authority, 2001). Of course, this figure takes in consideration the execution of new irrigation and domestic and expanding existing water projects

Actually, in Lebanon, water scarcity becomes a daily feeling for the population. Population growth, limited water management capacity, fragmented organizational structures; inadequate water planning, management, and conservation are among the contributing factors. In addition, pollution of water resources will decrease dramatically water availability.

Many efforts are previewed or ongoing to prevent possible water balance deficit before 2020. Needed actions are undertaking by many actors in water management in Lebanon. Close collaboration between these actors is needed to harmonize water saving options and to integrate them in their actions plan.

Water Management Stakeholders

Decision Makers in water sector: The law 221, dated 8th of June 2000 reformed water sector in Lebanon. Under the governance of the Ministry of Energy and Water (MEW), 22 water authorities are regrouped in four regional authorities beside the existing Litani River Authority (LRA). All water authorities along with LRA are under the patronage of MEW. The law plans the constitution by MEW and the Ministry of Finance of a committee for the evaluation of proceeding and works of water authorities. According to Law 221 duties will be describe below.

The Ministry of Energy and Water (MEW): Has the main responsibility of water policy in Lebanon (Surface and Underground); MWE is the responsible for:

- Water flow measurements on rivers and springs, quality water control, assessment on total water needs, planning, and water allocation on national level. However, due to some administrative constrains, the LRA is still achieving water flow measurements on surface water all around the country.
- All technical studies and investigations to improve actual and find new water resources
- Water master plan at national level and it is continual updating
- Underground water recharge
- Studies and execution of watercourses rehabilitation and maintenance, main hydraulic structures (Dams, ponds, reservoirs, main networks); at national level out of LRA area responsibility

Council for Development and Reconstruction (CDR) share these activities with MEW and LRA in case of foreign funds

- Water domain legislation: Preparing law drafts, law application and enforcement, and management (by mean of Water Authorities)
- Patronage of Water Management Authorities and supervision of their activities

Water Authorities: The span of responsibility is on Geo-administrative regional basis (Mount Lebanon and Greater Beirut; South Lebanon; North Lebanon and Bekaa). Regional Water Authorities (RWA) are responsible for integrated water Management: Domestic, irrigation and wastewater. RWA and LRA are responsible for direct water Management. Their responsibilities include:

- Studies, execution, operating and maintenance of water projects
- Water tariff policy
- Water quality monitoring

In matter of irrigation, repartition between LRA and RWA is summarized in the following table:

Table1 Repartition of irrigation projects by area in ha

Designation	Irrigated	Ongoing & Proposed	Total
Total Lebanon Schemes	60,900	82,000	142,900
LRA Schemes	16,530	60,330	76,860
LRA in % of Lebanon	27.14	73.75	53.79

After five years from the constitution of RWA, MEW published in 2005 organizing decrees. RWA experience in irrigation, wastewater and water quality control is still modest.

Actually, all RWA networks irrigation schemes are open channel and traditional irrigation system with a low efficiency. Great efforts must be undertaken in order to ameliorate on farm and network efficiencies.

1.1. Litani River Authority: Control domain over the Litani river basin in South Bekaa Valley, and South Lebanon regions. LRA is responsible to:

- Manage water resource on Litani River and tributaries, springs in the Litani River Basin, and underground water in south Bekaa.
- Study and construct main hydraulic structure in Litani River Basin: Dams, ponds, reservoirs, networks etc.
- Manage existing irrigation schemes in south Bekaa and south Lebanon (Action Domain of two others water authorities: Bekaa and South Lebanon Water Authority).
- Study and execute irrigation projects in south Bekaa and south Lebanon.
- Provide domestic water for a part of south Lebanon. (20 MCM per year)

All executed schemes by LRA and new projected projects are pressurized network and on farm pressurized irrigation system.

LRA has experiences since:

- 1962 in study and execution of irrigation and water structures (Dams, ponds irrigation networks) and Measurement of Water Flow (All Lebanese Rivers and main springs)
- 1968 in extension and services to farmers
- 1999, in water quality assessment
- Recently LRA (2006) create his Water Quality Department and launched in collaboration with Abdel Aal Association, water quality awareness for local communities.

2. <u>Others Concerned Institutions in water management</u>:

2.1. <u>The Ministry of Agriculture (MOA)</u>: Is concerned as water management as official responsible on agriculture policy in Lebanon. In addition, the extension service in MOA is responsible on farmers training in irrigation techniques on farm level.

Under the patronage of MOA, two autonomous institutions are acting:

- Irrigation Department in Lebanese Agriculture Research Institution: Researches on all themes related to irrigation: Crop-soil-climate interactions, fertigation, irrigation techniques etc.
- Green Plan who have responsibilities on:
  - Water harvesting by construction of mountain ponds
  - Land reclamation: The construction of terraces, which is in close correlation with irrigation technique at farm level.

The Ministry of Environment: Is responsible for all environmental policy at national level, by:

- Formulating a general strategy and long-term plans for environmental management and natural resources use
- Preparing law Drafts
- Developing detailed plans for environmental protection, including monitoring plans, and control of all sorts of pollution caused by solid waste, industrial waste, domestic wastewater, and air pollutants.

Education institutions and Research Center: Four agriculture faculties are operating in Lebanon at Lebanese, American,Saint Joseph and Holly Spirit Universities. Two research centers in water are active:

- “Centre de recherches sur l’eau”(CREEN), Saint Joseph University
- Water and Energy Research Center (WERC), Notre Dame University

Many technical schools are formatting agricultural technicians where irrigation is a part of this formation.

Farmers: Farmers as end Users are the base of water saving policy. They can be divided in two groups of users regarding their water sources:

- Individual well: For this category of users, the energy cost is an incentive to use pressurized irrigation techniques. A detailed study in South Bekaa (Litani River Authority, 1999) show, for farmers using private wells, that 77.66 % of the area is irrigated by sprinkler, 11.58% by trickle and 10.75% by traditional techniques. Irrigation modules are excessive and many problems are encountered in the farm network (IRWA, 2006). For this category, the main problem is excessive pumping from underground water. Actually, no laws restrict the water quantities withdraw from wells. Beside the extension necessity on farm, legislation on underground water is need.
- Collective Schemes: Surface source of water is shared between farmers by public networks. Total irrigated area served by 67 schemes is 59000 hectares (MEW, 2003). Only two schemes (2300 ha), executed by LRA, have pressurized network and use on farm pressurized irrigation techniques. Water saving process will have two main objectives: Shifting towards pressurized irrigation techniques and rehabilitation of the already existing networks.

Actually, water user associations in Lebanon do not exist. Some water comities, created by the MEW, have a very restricted role: Water distribution between beneficiaries and very limited intervention in channel rehabilitation.

At legislation level, existing law 320/S (dated1926) is the only text concerning “Syndical Association” in water users. This law is very old and focuses on protection from flooding. It gives the possibility to create water user associations in irrigation, but must be revised in order to be modernized and adapted to irrigation and gives more details on creation procedures.

Objectives of integrated water management in Lebanon:

Many studies, plans and actions have been undertaken without an integrated water management plan at national level. In the following a short description of this works and that to must do.
Rehabilitation of existing schemes: The number of small and medium schemes in Lebanon is 67 schemes. Equipped area is 65600 ha and potentially irrigated area is 59070 ha. The effective irrigated area is evaluated at 40000 ha. This area decrease is related to miss maintenance of these schemes. With a loan from BIRD, Lebanon achieved the rehabilitation of five medium and ten small schemes representing a total equipped area of 27200 ha. The remained areas, representing about 58% from the total area, still need rehabilitation. These schemes are the responsibilities of RWA and LRA.

The main objective of this rehabilitation is the increasing of network and water collect structure efficiencies.
Water Storage Capacity improvement: Lebanese government has approved the Ten-year action plan for the construction of dams, reservoirs and mountain ponds (MEW, 2003). The new constructions will add 743 MCM/year to the existing storage capacity. MEW and LRA (in his area of responsibility) are in charge for this plan.
Water Resources Quality Protection: Water control and monitoring are the responsibility of MEW and Water Authorities. Main problems and related actions in water quality protection are:
Wastewater Treatment: The government of Lebanon elaborates a master plan for secondary level wastewater treatment. Previewed wastewater treatment plants will serve 87.9% of the total Lebanese population and their capacities will be valuable until 2015. This plan prevents the pollution of underground and surface water. Without this plan, population still connected to sewage network or septic tanks. Raw sewerage are directly evacuated into the environment, including rivers and streams, dry riverbeds, and underground (though dry wells).The polluted water is lost for use and can affect seriously available water resources.
Agricultural pollution: Regarding the intensively agriculture exploitation, the main agriculture region concerned by this pollution is the Bekaa Valley. Excessive use of fertilizers and pesticides affect water quality. Investigations results show high levels of nitrates in groundwater and Pesticides were below the detection limits (Litani River Authority, 2005). Resolving this problem is the duty of agriculture extension services.
Solid waste: In many regions, riverbeds, streams, dry riverbeds are frequently used as landfill. This practice has two effects: Flooding by decreasing the flow in riverbeds and leach problems. However, adopted land filling processes in many municipalities may cause serious environmental impacts in liquid and gas emissions, which can pollute underground and surface water. To prevent this contamination, liquid must be collecting, controlled in quality and treated before sending to watercourses.
Sea water intrusion: Underground water use is not legislated in Lebanon. In coastal areas, the domestic water shortage, incite to an over pumping from underground water by individual entities. This cause a degradation of water quality by seawater intrusion. To remediate this problem two action are needed: Decrease well use by legislation and improve water resources for Water Authorities. Well use can be restricted to collectivities and Water Authorities. Pumped water from well must be limited and controlled by MEW.
Industrial pollution: Many factories discharge their wastewater in riverbeds or wastewater network without any treatment. To protect from this pollution, Ministry of Environment was prepared concerning laws. Law enforcement can resolve the major problems of industrial pollution.

The delay on application decrees preparation is, may be, the main cause of retard related laws applying.
Unconventional water Reuse (Karaa, 2004): Total possible collected wastewater for treatment in Lebanon was evaluated in 2015 at 213 MCM. All treatment plants are planned to work on secondary treatment. This treated water represents 10% of water needs in Lebanon. The topographical, demographic and urban conditions and economical considerations incite to a master plan where the major part of wastewater (55%) is collecting on the coastal area; 36% of treated wastewater is lost for crops irrigation in agriculture. A third treatment is necessary to recuperate this part and use it in domestic water.
Improving on farm irrigation: The main encountered problems in irrigation at farm level are:

Irrigation Equipments: In absence of water user associations, service irrigation centers and qualified extension service; the main designer for on farm network are the private market providers. Some of these providers have low qualifications in design matter. To be in the save side, they advice clients with an over sized equipments. Some farmers that do not have the possibility to equip their farm once a time, they purchase needed equipments in several times according to their needs. Consultants in this matter are the neighbor's farmers. In many regions and for annually crops, farmers are hiring the land for a seasonal time. In Bekaa region for an irrigated region of 8500 ha, only 29.37% of the area is exploited directly by owners (Karaa, 1999). Changing parcels without know how in adapting equipments can be a serious reason for using no adapted equipments. In all cases, the results will be the disparity of used equipments (Sprinklers, nozzles, etc.). Especially in farms using sprinkler equipments, very low uniformity is observed. To remediate to this bad uniformity, farmers use overdose of water. Without any predefined module of irrigation, direct visual observation by farmers is the criteria to stop irrigation; the time is defined when water is inundate the parcel surface.

Schedule and Dose of Irrigation: In general, the used irrigation technique, in traditional gravity schemes is furrow irrigation. The common characteristic for all these schemes is he excessive use of water by irrigation. When pressurized irrigation technique is used, water saving is visible. Chebli and col. found that used module is less then calculated ETC if farmers must use pumping and pressurized technique (Shebli et al., 1998)[11]. In other case the use of non-adapted equipments and bad maintenance causes losses and increase the irrigation dose. In many cases, a part of used water is drain. In all used irrigation techniques, schedules tend to use a high irrigation dose with a long interval between irrigations. This practice can be the cause of bad water productivity.

Enhance Water Economic Return: On farm level, the target is to optimize regulated deficit irrigation (RDI) practices. Some experimentations and studies are ongoing or done. Examples are:

In Lebaa center (Litani River Authority, 1998), a study conducted in collaboration between LRA and Lebanese Agricultural Research Institute (LARI), for cucumber and tomatoes in green houses. The used technique is trickle irrigation. For two years, the results shown that farmers can save up to 40% from used water.

LRA and LARI are partners in EU research and dissemination project, "Sustainable orchard irrigation for improving fruit quality and safety" begin in July 2006. The main objective is the regulated deficit irrigation for citrus in coastal area and peach in inland region.

To improve on farm irrigation practices must focalize on:

- Extension services improvement. Until now, RDI research results are not disseminating and their acceptance by farmers will be very difficult. These results must be a focal chapter in extension.
- Developing applied research on practical irrigation schedules and doses for different crops. Special attention to regulated deficit irrigation research is need.
- Water tariff policy can be use in water irrigation saving by:
  - Shifting, in traditional scheme, to on farm pressurized irrigation technique. This can be done by offering some advantages to farmers: In Qasmieh scheme, LRA establish a preferential tariff (reduction of 20% from normal tariff) for farmers using on farm pressurized technique
  - Using a binomial tariff where a fix part by hectare is related to maintenance and variable part is function of used water volume. This tariff must and can be apply in pressurized irrigation schemes.
- Complete and renew the legislation in order to encouraging the establishment of water users associations. Their role is very in application of previews actions.

CONCLUSIONS

In order to implement an effective integrated water management plan at national level where the saving water policy became reality, the following tasks must be achieved:

1. Integrated master plan by MEW with a main target of Water Equity in Allocation between regions and farmers. This plan must be review in function of needs and new resources or saved water.
2. Creation of a National High Council for Water (NHCW) as planned in 70s, who will be the coordinator between different water decision makers. Its role is different from the MEW and will be in charge for knowledge dissemination and exchange of experience between its partners.
3. Editing a law organizing the creation of water user associations and consortium between associations. Water Authorities have a principal role in encouraging farmers to be associating. WUA shall be the major partners and actors with the Decisions Makers to build a sustainable policy on Integrated Water Management.

4. Harmonization of research and education efforts: NHCW can be the focal point where exchange and harmonization of knowledge in water matter. Via this Council, different faculties and research centers can establish an annual plan for research themes, masters and PHD theses. NHCW database for water management facilitate the knowledge transfer to decision makers and extension services. NHCW will be the coordinator between research and extension.
5. Transformation of LRA to a River Basin Management Authority: An over lapping in duties remain between LRA and MEW and two RWA (South Lebanon and Bekaa). With this new status LRA can keep the management of all function related to Basin Agency as water provider:

- Control and management for all its water resources including underground water, water resources for domestic purposes water resulting from treatment plants.
- Execution of main structures and projects and transfer the management of executed and working projects to Water Authorities or Water User Associations.
- LRA keep the management of main structure (Dams, pounds, conveyers, main pumping stations, etc.) under its responsibility.

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WATER CONSERVATION POLICIES, PRACTICES AND FUTURE OPTIONS IN PALESTINE: A SPECIAL FOCUS ON AGRICULTURE

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ABSTRACT - Palestinian Authority Territories represented in the West Bank and Gaza Strip has an acute water stress since the allocated water per capita per year is 70 m^3. Agricultural sector plays a crucial role in the social well being of the Palestinian people due to the fact that it is considered for a lot of people the main source of their living, and to others, it is considered as an additional income because they can save nutritional materials. Total current water use in the West Bank and Gaza Strip (WBGS) is estimated to be about 286 million cubic meters (MCM) per year. Agriculture continues to be the largest consumer of water accounting for more than 60 percent of total use (167 MCM, about half each in the West Bank and in the Gaza Strip). Groundwater wells constitute the only source of irrigation water in the Gaza Strip. In the West Bank, wells and springs contribute almost equal amounts of irrigation water, though the vast majority of springs are concentrated in the Jordan Valley (Jericho District). This critical situation related to water resources in Palestine motivated Palestinian National Authority (PNA) in cooperation with national and international bodies to set the required policies for water conservation and design the possible future options for water use. This paper addressed in brief the following: Water resources budget, water use, agricultural water demand, and the base of water policy, main water supply policy elements, agricultural policy objective, existing water conservation practices and proposed practices.
Keywords: water stress, water use, irrigation water, water conservation practices.

Water resources budget

Water resources in the WBGS would be classified into conventional and non-conventional resources, the following table outlined the water resources budget in Million Cubic Meters (MCM):

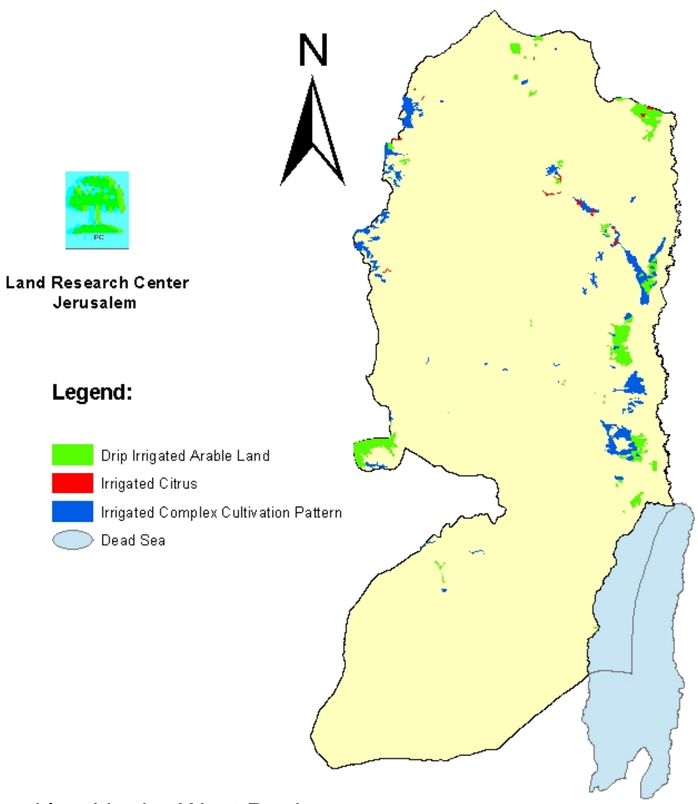
Water Resources	Quantity (MCM)
Conventional Resources	
Total Annual GW. Replenishment	679
Total Well Abstraction (Palestine + Israel)	-107.7
Max Spring Discharge	-55
Potential GW Storage	516.3
Available storage (assuming 50% of this potential Flows inter boundaries)	258.15
Surface Water (Jordan River)	200
Total Conventional Resources	458.15
Non-Conventional Resources	
Total flood water (assuming that 2/3 is captured)	30
Recycled Domestic Waste Water from urban areas	10
Brackish water available from springs	15
Total Non-Conventional Resources	55
Total available	513.15

Water Use

Palestinian total water use in the West Bank has been estimated to be 120 million m^3/year. About 86 million m^3/year of this amount (71%) is used to irrigate 90,000 dunums. The remaining 34 million m^3/year is used for domestic and industrial use (industry's share is about 3%) with more than 40% of unaccounted for water. In Gaza, Palestinians total use of water is about 125 million m^3/year. 80 Mcm is used to irrigate 120,000 dunums. The remaining 45 million m^3/year is used for domestic and industrial use (industry's share about 3%) with more than 50% unaccounted for water.

The total irrigated land which is 210,000 dunums in the West Bank and Gaza forms only 11% of the total cultivated land. In addition, there is 400,000 dunums of potential irrigable land. Agriculture uses nearly 60% of the total water allocated to Palestinians in the West Bank. It used to contribute by nearly 25% of the GDP. Currently, it only contributes by 8% now.

The following map displays the irrigated sites in the West Bank.



Map 1 Irrigated land in the West Bank.

Agricultural Water Demand

Based on the assumptions of nearly 800 m3 / dunum and 0.072 dunum / capita irrigated land, the following table displays the agricultural water demand in the WBGS:

Projection year	Population million	Irrigated lands dunum	Water demand Mcm/year
2010	4.95	356,400	285.12
2040	9.98	718,560	574.85

Estimation based on BCPS (1998) Population Figures

The Base of Water Policy

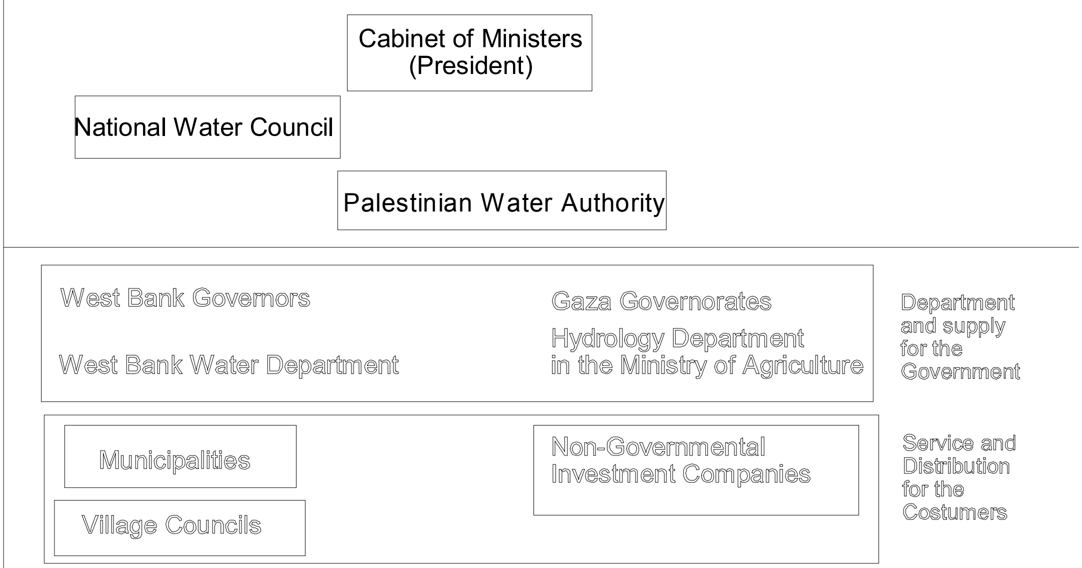
The following laws and legislation items form the basis of water policy in Palestine:
Law n. 3 (water law) has been approved by the legislative council on 18/2/02. The law has been approved by the President of Palestinian National Authority (PNA) on 17/7/02 and was then published in the official newspaper on 5/9/2002.

- Article 2 of the law states that all water resources have been declared public property.
- According to article 7, Palestinian Water Authority (PWA) has full responsibility over managing water resources and sanitation in Palestine.
- Article 8 deals with the creation of the National Water Council (NWC).
- Article 25 states that Regional Water Utilities (RWU) will be established, based on the desire of the local utilities and water user associations, to provide water and wastewater services for Palestinian communities
- Article 41 states that local village and municipal councils, government bodies and NGOs continue to provide water and wastewater services until the RWUs are established.

Water Supply Management

The following figure (Figure 2.1) displays the existing institutional framework of the water sector in Palestine:

Fig (2.I): Existing Institutional Framework of the Water Sector in Palestine



Source: PWA, Background Information

Main Water Policy Elements

The following items constitute the main water policy elements of the Palestinian National Authority:

- All sources of water should be the property of the state.
- Water has a unique value for humans' survival and health, and all citizens have the right to water of good quality for personal consumptions at cost they can afford.
- Domestic, industrial and agricultural development and investments must be compatible with the water resource quantity available.
- Water indeed is an economic commodity; therefore, the damage resulting from the destruction of its usefulness (pollution) should be paid by the party causing the damage (pollution).
- The development of the water resources of the Palestinian territory must be coordinated on the national level and carried out on the appropriate local level.
- Water supply must be based on a sustainable development for all available water resources.
- Public participation in water sector management should be ensured.

- Water management at all levels should integrate water quality and quantity.
- Water supply and wastewater management should be integrated at all administrative levels.
- Consistent water demand management must complement the optimal development of water supply.
- Protection and pollution control of water resources should be ensured.
- Conservation and optimum use of water resources should be promoted and enhanced
- The Palestinian will pursue their interests in connection with obtaining the rights of water resources shared by other countries.

MOA Agricultural Policy Objective is efficient management of irrigation water to maximize returns per cubic meter of irrigation water. This objective can be attained through the realization of the following priority actions:

- Rehabilitation of water infrastructure (wells, springs, ponds, etc.).
- Increasing the efficiently of water delivery and irrigation systems.
- Benefiting from the use of brackish and treated wastewater for irrigation.
- Enhancing water availability by encouraging water harvesting and water gathering.
- Intensifying and strengthen extension and research activities and the transfer of technology.
- Encouraging investments in water projects and preserving them.
- providing appropriate legal and institutional frameworks

Existing water conservation practices

A number of useful water conservation practices are already adapted to some degree in the West Bank and Gaza Strip, and these practices should be expanded to help conserve agricultural water use. These practices are:

- Harvesting local water runoff and floodwater to increase water supplies for dry land agriculture (construction of rainwater cisterns and ponds).
- Reducing evaporative water loss by cropping within closed environment (desert greenhouses). This method is economic with land and water use, avoids soil salinization, and produces high yields of exportable crops, such as ornamentals, fruits, vegetables, and herbs.
- Introduction of irrigation scheduling and French Project in Al-Bathan is a good example.
- Considering the use of brackish water for irrigation of salinity tolerant crops.
- Saving more freshwater by switching to irrigation with treated wastewater or with brackish water if possible.
- Shifting from high demand water crops to low demand water crops.

Conservation Program

Because of the above listed challenges, the Ministry of Agriculture and the Palestinian Water Authority should follow comprehensive water conservation and saving program. In this program, a set of the Best Management Practices (BMPs) should be presented as a guide for crop growers and practiced in Palestine where it is applicable. BMPs for agricultural water users are combinations of site-specific management, educational, and physical practices that have proven to be effective and are economical for conserving water. BMPs should focus on increasing the water use efficiency of water users such as producers of agricultural crops and of water suppliers such as irrigation districts. Best-management practices contained in the BMP Guide should be voluntary efficiency measures that save a quantifiable amount of water, either directly or indirectly, and can be implemented within a specified timeframe.

The proposed conservation practices would be outlined as follows:

- Rainwater Harvesting Reuse
- Public Awareness
- Re-Use of Treated Wastewater
- Irrigation Scheduling
- Volumetric Measurements of Irrigation Water Use
- On-Farm Irrigation Audit
- Land Levelling
- Contour Farming
- Lining of On-Farming Irrigation Ditches
- Drip/Micro-Irrigation System

- Replacement of Irrigation District Canals and Lateral Canals with Pipelines and replacement of On-Farm Irrigation Ditches With Pipelines

CONCLUSIONS

The following concluding remarks would be drawn out of all the above mentioned:

- The challenge of implementing water policy in Palestine is mainly constrained by the Israeli Occupation.
- On-farm water conservation and saving programs are still at the pilot-scale while in the off-farm considerable activities have been conducted since the establishment of the Palestinian National Authority.
- Palestinians already established their polices and strategies regarding water management and conservation while the enforcement of regulations is still very weak due to the sovereignty issue over land and water.
- Appropriate regulatory frameworks need to be developed to accommodate best management practices in water management
- Stakeholder participation and the creation of Water User Associations are needed to improve water management efficiency
- It is important to define roles and responsibilities of the various institutions dealing with water management.

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HARMONIZATION AND INTEGRATION OF WATER SAVING OPTIONS CONVENTION AND PROMOTION OF WATER SAVING POLICIES AND GUIDELINES

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WATER RESOURCES, WATER USE AND WUE IN SYRIA

Table 1. Water resources (surface and groundwater) in Syria

Water source		Hydrological basin							
		Barada & Awaj	Yarmouk	Badia	Orontes	Coastal	Tigris-Khabour	Euphrates - Aleppo	Total
Surface	m.m^3	19	168	152	1036	1453	735	7073	10635
Groundwater	m.m^3	774	249	168	1499	726	1493	346	5256
Total	m.m^3	793	417	320	2535	2179	2228	7419	15891
Regulation degree	%	90	85	60	85	65	95	98	
Available regulated WR	m.m^3	714	354	192	2155	1416	2117	7271	14218

Table 2. Available WR development and usage for different sectors

Water use		Barada & Awaj	Yarmouk	Badia	Orontes	Coastal	Tigris - Khabour	Euphrates - Aleppo	Total m.m^3
Agric. irrigation	Ground	785.8	211.8	68	1137.2	99.5	4305	1440.7	8048
	Surface	-	188.6	-	954.9	466.8	-	4314	5925.1
Domestic – drinking		269	76	44	240	81	38	322	1070
Industrial		76	38	2	229	85	45	86	561
Losses		6	31	15	148	16	132	1614	1962
Total use		1136.8	545.4	129	2709.1	748.3	5420	7777.5	17566.1

Table 3. Development of irrigated agriculture by water source

Year	Surface water-irrigated area (x 10 ^{3}) ha	Groundwater-irrigated area (x 10 ^{3}) ha	Total irrigated area (x 10 ^{3}) ha
1985	334	318	652
1990	351	342	693
1995	388	694	1082
2000	512	698	1210
2002	583	764	1347
2004	624	815	1439

GUIDELINES OF POLICIES AND MEASURES FOR ATTAINING SUSTAINABLE DEVELOPMENT OF WATER RESOURCES

Assessment of water sources

This is done to prepare new water budgets showing water movement direction and hydro-chemistry; explore deep aquifers and explain groundwater recharge and discharge.

Development of an overall water plan

This plan aims at:

- Identifying current and future uses until the year 2025.
- Collecting, treating and reusing non-conventional water (wastewater – drainage water, and others).
- Monitoring water quality and quantity.
- Developing programs for training and qualification.

Utilization and maintenance of irrigation projects

- Giving attention to exploitation and maintenance in terms of provision of necessary equipment and staff.
- Developing and rehabilitating old irrigation projects

Water use rationalization

This is done through:

- Applying scientific research results to reduce losses in on-farm water distribution systems using advanced irrigation techniques.
- Selecting good lands and applying appropriate irrigation techniques and crop rotation by soil quality and properties.
- Stopping violations and infringement on water structures.

Development of an overall research plan

This plan has been also developed to include five research programs: programs on modern irrigation methods and techniques research as compared technically and economically with traditional irrigation on all irrigated crops.

Technical results of the research plan

<u>a. Results of research centers:</u>

- Sprinkler irrigation on strategic field crops (cotton, wheat, sugar beet and maize) has led to:
  - Irrigation water saving averaged 40%.
  - Yield increase averaged 37%.
  - WUE increase from 0.38 – 2.42 kg/m^3.
- Localized irrigation on different farmings including fruit trees and excluding wheat:
  - Irrigation water saving averaged 48.5%.
  - Yield increase averaged 35.7%.
  - WUE increase from 0.86 – 3.5 kg/m^3.
- Improved surface irrigation on strategic field crops has led to:
  - Irrigation water saving averaged 29%.
  - Yield increase averaged 26%.
  - WUE increase from 0.38 – 1.89 kg/m^3.

b. Results of demonstration plots and farmers 'fields

A number of farmer fields using modern irrigation techniques were put under extensionists and irrigation specialists' supervision, control and following-up

* Sprinkler irrigation has led to:
- Irrigation water saving by 31%.
- Yield increase by 27.7%.
- WUE increase from 0.31 – 1.1 kg/m^3.

* Localized irrigation has led to:
- Irrigation water saving by 45%.
- Yield increase by 32%.
- WUE increase from 0.31 – 1.24 kg/m^3.

* Improved surface irrigation has led to:
- Irrigation water saving by 22%.
- Yield increase by 25%.
- WUE increase from 0.31 – 0.58 kg/m^3.

Modernization of water legislation and institutional system

With the aim of:
- Optimal management of WRs for several activities.
- Discussions of water use rights and water protection from pollution.
- Keeping pace with technological advance and its reflections on WRs.

New water legislation

Presidential Resolution No /31/ dated 06/11/2005 was developed and adopted by the Peoples Assembly after it had been studied for a long period by relevant technical, legal, legislative and scientific committees, in order to avoid gaps made in last legislation and setting controls for water usage and water structure protection. This resolution included /58/ articles, distributed to /12/ chapters.

General Commission for Water Resources

Responsibilities:
- Management, development and protection of WRs in the seven hydrological basins in Syria.
- Supervision on utilization and monitoring of WRs and water structures in hydrological basins all over the governorates.
- Coordination between Ministries of Irrigation and Housing for assessing drinking water sources and utilization of treated wastewater.

GOVERNMENT MEASURES FOR ON-FARM WATER MANAGEMENT IMPROVEMENT

Transfer to modern irrigation

Concerned ministries (MAAR – MoI – Industry – Economics…) were commissioned to undertake the following measures:
- Planning of irrigation areas according to the renewable water.
- Preparation of studies for the rehabilitation of old state irrigation projects, in line with the use of modern irrigation techniques.
- Determination of transfer requirements and provision of loans for funding all requirements.
- Preparation of studies necessary for establishing communal irrigation projects on wells.
- Free preparation of studies and designs of modern irrigation networks for farmers.

Directorate of the National Project of Movement to Modern Irrigation

a. Based on Minister of Agriculture's resolution No /26/ on 19/05/2005,
- Prepare and supervise studies, designs and technical books of conditions necessary for the project beneficiaries' field irrigation networks;

- Supervise the provision of loans from the special fund of beneficiaries financing;
- Coordinate with relevant institutions (MoI – Industry – GCSAR) to formulate plans necessary for project implementation; and
- Deepen the concept of water extension and participatory irrigation by adopting different training levels and conducting training course on modern irrigation for technicians, extensionists or farmers.

A fund for financing the national project of transfer to modern irrigation

Depending on the legislative decree No /91/ approved by the President on 29/09/2005, a fund was established at MAAR to finance transfer project at a capital SP 53 billion to be recovered during five years

Those who invest in agriculture whether they are owners, leaseholders, beneficiaries or farmers can benefit from this fund through free-interest ten-year loans to be recovered by equal annual payments.

Higher Committee of Transfer to Modern Irrigation

With the purpose of scientific and smooth implementation of the national programme and to iron out the difficulties encountered. He is responsible to approve the annual plan and follow-up on implementation of the national programme and the annual plan of the special fund of project financing.

Water Users Associations (WUAs)

Historic overview

- The first water users society in the modern age in Syria is dated back to the year 1928 when Al-Breika farm in Rural Damascus was established as a cooperative project for groundwater drilling.

Present situation

The government orients toward the promotion of WUAs by releasing appropriate laws and resolutions to:

- Identify water beneficiary structure;
- Identify WUAs role in water distribution; and
- Identify WUAs role in project maintenance.

A full chapter in the new water legislation was assigned to WUAs including several items addressing WUAs establishment, structure, mandate, management and their role in water and irrigation system management and participation in decision-making and implementation.

Awareness and technology transfer programmes

Awareness programmes

Ministry of Information gives great attention to development media, so that a special directorate of development media was established to follow-up on the development information plans on population and environment in coordination and collaboration with government, popular and international bodies and organizations.

Technology transfer and water awareness dissemination programme

Several activities on awareness dissemination and identification of modern irrigation advantages have been undertaken as of the second half of 2000 up to date including:

- Organizing /853/ seminars and 324 field days, attended by /54692/ extensionists and farmers from irrigated areas in Syria.

- Conducting /230/ training courses, attended by /33490/ technicians and extensionists.
- Free designing and checking irrigation systems for farmers on an area exceeding /42600/ ha.
- Providing /50/ free irrigation network for the winning cotton-growers, covering 2 ha each.
- Equipping /150/ farmer fields with modern irrigation inputs (drip – sprinkler) for farmers via collaboration with international organizations.
- Implementing laser land-leveling for more than 1500 ha of cotton and sugar beet, aiming at disseminating awareness on surface irrigation development.
- Printing /25000/ fliers on the advantages of modern irrigation and distributing them to farmer societies and centers.

Pilot projects on the participatory use of water resources in agricultural sector

On-going projects:

a. Abu Kalkal project in Aleppo:

- This project was implemented through Spanish expertise and funding with the help of national staff..

b. Orontes basin project in Hama

- Project studies and designs were prepared by the national staff and funded by FAO. Number of beneficiaries was 13 farmers

c. Participatory irrigation project in Irneh/Rural Damascus

This project depends on the participatory use of groundwater for irrigating fruit trees (apples) by localized irrigation (drip). This project was locally funded and nationally studied and designed.

Under-implementation projects:

Optimal community based-management of surface water resources for agriculture in WANA region, in collaboration with ICARDA during 2005 – 2007 project

Development of efficient irrigation techniques and agricultural extension in Syria project

Communal Management & Optimization of Vallerani System Micro-catchment Water Harvesting for Combating Desertification in the East Mediterranean Region

Rationalization of Irrigation Systems in Ras Al-Ein area - Hassakeh

- This project is executed in collaboration with the Italian side – General Directorate for Cooperation and Development. It is funded by MAIB – Bari institute at a grant € 2.3 million and development grant at € 9.3 million. MAIB – Bari institute also

CONCLUSIONS

In the light of growing pressure on water resources by all economic sectors and since agricultural sector is the largest consumer of water resources (1410 million m^3), the government options on water provision are typified by the following:

1. Establishing and supporting the scientific research centers working in the field of water management improvement.
2. Taking a range of legislative and institutional measures conducive to water saving and rational management, including the development of water legislation that fully support WUAs establishment.
3. Establishing The General Commission of Water Resources and the Directorate of National program for Movement to Modern irrigation.
4. Cooperating with international institutions and organizations to implement pilot demonstration research projects with the aim of disseminating modern irrigation techniques via water education and technology transfer programs.

WATER SAVING OPPORTUNITIES FOR SUSTAINMENT OF IRRIGATED AGRICULTURE: FIELD IRRIGATION IN TURKEY

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ABSTRACT - Water scarcity has been a major concern in Turkey since the 1960's. Agriculture is the major water consuming sector with an average of 70% of the country's total water consumption. Many studies have been conducted to ensure more efficient use of water for sustainable agricultural development through better management of the irrigation schemes by the local authorities and Water Users Organizations (WUOs).

Irrigated agriculture is the most effective means for making rapid increases in crop production. The results from all research activities on irrigation in Turkey have been collected in last 10-15 years and statistical aspects of the collected results are presented to supply information and knowledge on irrigation science and assessment of past and existing experiences and identifications of relevant gaps and problems in Turkey. Also, overviews of some scientific results are on main irrigation topics such as crop-water-atmosphere relationships, irrigation scheduling techniques, comparison of irrigation methods for some main crops, and irrigation system performances are presented.

Efforts were carried out to collect the results of all research activities on both irrigation and water saving opportunities to sustain irrigated agriculture in Turkey, however, published data and other activities on all studies could not be obtained due to the deficiencies in the archives system. Therefore, assessment of all the conducted studies is limited. Statistical aspects of the collected results for the last 10-15 years are presented to give information in experiences on irrigation science and assessment of past and existing experiences and identifications of relevant gaps and problems in Turkey.

Keywords: Water saving, Field Irrigation.

INTRODUCTION

Irrigated agriculture is the most effective means for making rapid increases in crop production. Improvements in irrigation can results in higher levels of living in low income nations because they have approximately 80% of the world's irrigated land. The introduction of irrigation is one of the turning points of the human history in that the man who learned to use the seeds and to place it into the soil had acquired the insight that greater yield would be obtained by irrigation. Water management in agriculture is the process by which water is manipulated and used in production of food and fiber.

There is no doubt that for developing countries of the Mediterranean region, with erratic rainfall pattern, efficient control and management of water use has to be an essential requirement for this continued development. Without proper water management, self efficiency in food and energy will continue to be a mirage for most of these countries. Due to increasing of population which leads to growing demand for water resources, and pollution that reduces fresh water yield, most of the Mediterranean Countries have serious water scarcity problems for agricultural production and urban/industrial consumption. Scarcity of water and reliability of its supply are major constraint for agriculture development in those countries.

In the developing countries of Mediterranean, the major challenge facing water planners and managers at the end of 20 century is that while physical availability of water is fixed, its demand will continue to increase steadily in the foreseeable future. Accordingly, the problem is how to balance demand and supply of water under those difficult conditions. In addition, the issue of potential climatic change due to global warming and what its impacts could be on natural resources including water, are basically unknown factors at present (Hamdy and Lacirignola, 1999).

Today, agriculture is the main consumer of freshwater in the Mediterranean countries and the drawn backing for agriculture is about 80% of the total freshwater sources. Even though in the world which has an urban/industrial culture today, agriculture still continues to be the biggest consumer of water. For this reason, water saving opportunities should be considered within this domain. Prospective of water saving in agriculture ranges from genetics to agronomic, engineering, and different management options, including the use of non-conventional water resources.

Irrigation has a vital role for increasing and stabilizing agricultural production in Turkey because of scarcity and unreliability of rainfall conditions prevailing during growing season in most part of the country. The 36.5% of the total land (77.95 Mha) in Turkey is suitable for agriculture (28.05 Mha). Of the total irrigable area (25.85 Mha) 16.6% is being irrigated (4.3 mha) while 65% is not. Only 16% of total water resources are used for irrigation and other purposes. Economically viable irrigation is possible for only 8.5 million hectares.

The annual potential rivers are calculated as 186 billion cubic meters and a certain level of runoff is to be allocated for water requirements of neighboring countries. The amount of flow that can be used for consumptive purposes is estimated to be around 95 billion cubic meters. Together with the 13.66 billion cubic meters of useable ground water resources total available water resource of Turkey is around 108.66 billion cubic meters. Today, Turkey can not use soil and water resources effectively, due to personnel, coordination, political and economics problems.

However, during the next 20-30 years, Turkey will want to irrigate all the irrigable lands and the population will reach 80 million by 2010 and 90 million in 2025; if 400 kg of grains for one person, the total grain demand will be around 32 million tons by 2010 and 36 million tons by 2030 (Hamdy, 1998). To meet this demand, the irrigation area should be increased. It should be up to 4.77 million ha by 2010 (a net increase of 0.47 million ha more than the current), and 5.4 million ha by 2025 (a net increase of 1.1 million ha more than the current). This will cause the agricultural water consumption to increase dramatically. Currently in Turkey, about 31 500 km^3 of water is used by agriculture, in which 70 per cent, that is, about 22 050 km^3 is for the grain production (SPO, 2001). As a result of these, sustainable quantities of freshwater supplies will be diverted from agriculture to industry and households in the country. Irrigated agriculture will face two problems of water shortage and reducing financial resources in this time. Despite these problems, irrigated agriculture has not only to supply the other sectors with their water demands, but has also to provide 70-75% of the additional food grain requirements to the increased population. This will not be possible without the implementation of demand water management in all sectors, and in particularly, the agricultural one. There is a great need to find appropriate ways to achieve greater efficiency, better saving in water losses, and an equitable distribution in irrigation sector. This will require a wider range of alternative approaches than before considered to be developed, tested and implemented with greater imagination and flexibility on the part of irrigation policy makers, managers, and planners.

In this report, water scarcity and possible water saving in Turkey are discussed and some scientific results on water saving opportunities taken some experiments carried out in the different regions and crops.

CLIMATE, SOIL AND WATER RESOURCES IN TURKEY

Climate

Turkey forms an elongated rectangle roughly 1,700 kilometers in an east-west direction and 1,000 kilometers north to south. Anatolia, except for its eastern parts, is surrounded by seas and has a total coastline of over 10,000 km, including Thrace and islands. Turkey is a bridge between Europe and Asia, with about 3 percent of its land in Europe and the rest in Asia.

Turkey is under the effect of both maritime and continental weather patterns, which cause extreme geo-climatic diversity when combined with a highly varied topography. The Mediterranean type of climate with hot, dry summers and mild winters prevails in the Southern coastal region and the Aegean region (Western Anatolia). The Black Sea region receives rain throughout the year and lives both mild summers and winters. Central Anatolia is a vast high plateau with an average altitude of 1,000 meters above sea level and a semi-arid continental climate, i.e. hot and dry summers. Southeastern Anatolia region has arid climate which is characterized by hot and dry summers and mild winters.

The average annual temperature are 18-20 ^{o}C on the south coast, 14-15^{o}C for the west coast, and finally in the interior regions, depending on the location of the place from the mean sea level, fluctuates between 4 to 19 ^{0}C. The annual average precipitation is 643 mm, but it varies from 250 mm in the central part to 3000 mm in the Eastern Black Sea region. Seventy-five percent of annual rainfall is received in the winter season. Except for the coastal areas, Thrace and Eastern Anatolia, annual rainfall is less than 500 mm; therefore irrigation is of paramount importance.

Generally, agricultural production is adversely affected by the shortage and inconsistency of the rainfall during the growing season. Solar energy makes it possible to grow arid and semi-arid crops like bananas and citrus. Moreover, it is possible to have 2-3 crops from irrigated areas by allowing

270-day crop growing seasons. However, some crops may be harvested before maturation, particularly in Eastern Anatolia with its 60-90 growing days. The southeast region records very low humidity levels. The coastal regions have quite high levels being in line with precipitation rates. Inevitably, the topographical features are main factors shaping the distribution. The highest average speed of wind is measured in the Çanakkale province, located on the northwest Aegean coast. Moreover, a speed of about 136 km per hour is detected in the provinces of Ankara, Kırşehir and İskenderun. The long-term annual evaporation rates indicate a high rate particularly in the southeast region, which receives almost no rainfall during the summer and reaches more than 2000 mm per year in Southeastern region.

Soil and Water Resources

Soil Potential: Turkey occupies a total area of about 78 million ha, of which about 1.1 million is inland lakes. The total arable lands are almost 28 million ha, and almost 26 million ha of arable lands is irrigable and 2 million ha is non-irrigable land. The irrigated area is 4.3 million ha. The area which would be economically feasible to irrigation by surface methods is estimated to be totally 8.5 million ha by DSI (State Hydraulics Works) (Table 1).

Table 1. The Distribution of Irrigable Land in Turkey (DSİ, 2001)

Land	Area Million ha	%
Irrigable Land	26.00	
Economically Irrigable Land	8.50	33
With Surface Water Resources	7.90	93
With Ground Water Resources	0.60	7
Equipped with Irrigation	4.30	51
Surface Water	3.80	90
Ground Water	0.40	10
To be Irrigated in the Next Future	4.20	49
Surface Water	4.00	96
Ground Water	0.15	4

Irrigated lands developed by DSI in the different region in Turkey are given in Table 2. Today, 17 % of total irrigable lands are developed for irrigation by different agencies including DSI being the first, KHGM (General Directorate of Village Affair), and Private Publics Organizations. Before two years ago, for the Irrigation Master Plan of Turkey, 227 projects covering a gross irrigable area of 2.94 million ha have been analyzed. 139 of these covering a gross irrigable area of 2.07 million ha, or 70 % of the total area reviewed, have an IRR of 8% or more. If that same percentage is applied to the area still to be developed, a potential additional irrigable area of 3.2 million ha will be added.

Table 2. Irrigated Lands in The Different Region In Turkey (DİE, 1995)

Regions	Irrigable Lands 1000 ha	Irrigated Lands[1] ha	Irrigated Lands %	Irrigable Lands %
Marmara	4,615	418,902	9.8	9.1
Aegean	1,797	656,390	15.4	36.5
Mediterranean	3,633	813,048	19.1	22.4
Southeastern	4,895	476,239	11.2	9.7
East Anatolia	1,073	600,404	14.1	56.0
Black Sea	1,236	390,599	9.2	31.6
Central Anatolia	8,386	905,603	21.2	10.8
Total	25,635	4,261,185		

[1] Total irrigated areas developed by DSI, KHGM, and PO. The values of 1995 year are updated for 2004.

Tables 1 and 2 show that Turkey can not use soil resources effectively due to personnel, coordination, political and economical reasons. Irrigated lands in the regions vary from a maximum value of 21.2 % for irrigated lands in Central Anatolia to a minimum of 9.2 % in Black Sea region. Mediterranean region follows Central Anatolia with 19.1 % of the irrigated lands.

The maximum irrigable lands of 8.386 million ha are placed in the Central Anatolia region, a minimum of 1.073 million ha is in East Anatolia due to their topographic properties. The ratios of irrigated lands to total irrigable areas for regions vary between 56% in the East Anatolia and falls to 9.1% in the Marmara region. Central Anatolia region, which has maximum irrigable area, however, is the one region which has small ratio. The irrigated areas in Southeastern Anatolia region is rapidly expanded at the last decade since some irrigation structures in Southeastern Anatolia Project have started to operate in some places in this region.

Water Potential: The average annual precipitation of the country is 642.6 mm, which corresponds to a water potential of 501 km^3 per year. Runoff amounts to 238 mm, an average rate of 37 %, and the remaining 63% is lost to evapotranspiration. A certain amount of the runoff is allocated to meet the water rights and requirements of the neighboring countries. The amount of surface water, which is utilized for consumptive purposes, is in the range of 95 km^3 per year. According to the studies based on groundwater resources, the total safe yield of groundwater resources is estimated to be 11.6 km^3. Thus, total potential available water resources from surface flow and groundwater would amount to 106.6 km^3 per year (Table3).

Table 3. Water Potential (DSI, 2001)

Average Annual Precipitation, mm	643
Water Potential from Precipitation, km^3	501.0
Surface Water Potential, km^3	
Annual Flow	186.05
Runoff Coefficient	0.37
Utilizable potential	95.00
Actual Annual Potential	31.49
Groundwater Reserves, km^3	
Surfaced Annual Reserve of Groundwater	12.3
Annual Water Reserved by the SHW	9.0

In order to regulate the whole surface waters in the country, the construction of 662 dams is required. Today, total dams and HEPP under operation are 504 which are suite to the rules of International Commission of Large Dams, ICOLD. Almost 100 dams and HEPP are under construction. Thus, it is obvious that the possibilities mentioned above require great amounts of investment and a long period of construction. The water supplies from these dams would be regulated to achieve the following objectives: irrigation of 6,609,382 ha; drainage of 135 801 ha, flood control of 636,794 ha; conveyance of 7,726 km^3 of water to urban areas and generation of 121,484 MKwh of electric power by the hydroelectric power plants with a total electricity capacity of 34,484 MW.

Water Scarcity in Turkey

Water consumption increased slightly during the last decade depending on the development of soil and water resources, expanding of urban population and development of industrial sector. Total water consumption rose to 42.0 km^3 by the end of 2000 as a result of numerous projects developed by various agencies, including the DSI who is, in charge of developing water resources. Breakdown of the total figure is as follows: Irrigation (31.5 km^3, 75%); drinking water (6.4 km^3, 15%); and for industrial purposes; 4.1 km^3, 10% (Table 4). Sectarian breakdown of utilized surface water resources is as follows: Irrigation (82 %), drinking-use (10 %) and industrial purposes (8 %). Corresponding percentages for the utilization of groundwater are 39, 37 and 24, respectively.

Table 4. Actual Water Consumption in the last decade of 1990-2000 (SPO, 2001)

Year	Total water consumption km^3	Potential use (%)	Water Consumption by Sectors, km^3					
			Irrigation		Drinking-Use		Industrial	
			Volume	%	Volume	%	Volume	%
1990	30.6	28	22,016	72	5,141	17	3,443	11
1992	31.6	29	22,939	73	5,195	16	3,466	11
1998	38.9	35	29,200	75	5,700	15	4,000	10
2000	42.0	38	31,500	75	6,400	15	4,100	10

Water amount utilized for irrigation is calculated and given in Table 5. Industrial and urban consumptions are not considered in the calculation. Average steady flow for whole Turkey is estimated as 1.1 L s^{-1} ha^{-1} using steady flow values from irrigation systems placed at the different regions. All plants grown in the different regions are assumed to be irrigated 120 days per year.

Turkey has approximately 26 Mha irrigable lands in spite of the water resources to be allocated for irrigation are not seem to be enough to irrigation of all the lands. It is estimated that in Table 5, only 8.5 Mha areas can be irrigated with present water resources. It is clear that water resources in Turkey are considerably limited. When all irrigable lands are opened to irrigation, roughly 200 km^3 water deficits can be expected. Water is a constraint to agricultural productivity in comparison with the extent of existing irrigable land resources, especially for Mediterranean, Central and Southeast Anatolia regions, which are arid and semi-arid regions.

Table 5. Net Water Requirements of the Average Crops Pattern Grown on the Irrigated and to be Irrigated Areas

Lands, ha	Average Steady Flow L s^{-1} ha^{-1}	Average Irrigation Season, day	Net Water Requirement, km^3 $year^{-1}$
4,261,185 (being irrigated)	1.1	120	49.0
8,500,000 (to be irrigated)	1.1	120	96.0
25,635,000 (to be irrigated in future)	1.1	120	296.5

In Turkey, as in several Mediterranean countries, the dominant fact which will be strongly evident over the next few decades is the structural imbalance between constantly increasing demand for water to meet the needs and the natural available water resources. This imbalance will appear around the year 2000 and beyond. In foreseen future, in Turkey, excessive reduction in water withdrawals per capita will create notable competition and conflicts among users in the various sectors, in the irrigation and domestic sectors in particularly. Priorities will be given to satisfy the drinking water demands to the expenses of the available water allocated for the irrigation sector with the consequence of less irrigated surface and more land degradation.

POSSIBLE WATER SAVING IN TURKEY

There is a high opportunity for saving significant volumes of water losses through a better use of technical and economical tools, as well as, the institutional and human resources capacities Turkey already has. It is possible to reduce losses and leaks in drinking water in industry; through recycling it is visible to reduce the water consumption. However, in spite of the water saving could be achieved in both drinking and industrial sectors, yet, the most beneficial saving in terms of volume would be in irrigation sector.

In Turkey, where more than 72% of its water resources are allocated to agriculture, major efforts should be directed to increase the efficiency in the field, as the opportunity of water saving is notable higher compared to other water use sectors. For instance, in the irrigation sector, the reduction of conveyance losses and the improvement of irrigation efficiency can provide too much water saving.

In this section, some summarized results, which showed the water saving approaches and total saved water amount are given. The results are taken from experiments carried out in the different regions and different topics. These are the new mechanisms which are to protect the resource and allocating diminishing water supplies to increasing and competing uses.

Deficit Irrigation

Generally, irrigation and irrigation water requirement of crops were determined without any consideration of likely water limitation of available water supplies. In arid and semi-arid regions, because of increasing allocations of water for municipal and industrial use, major changes came about in water use under irrigated agriculture. New innovations had to be tested and adapted to increase effective use of decreasing water allocations for agricultural use (Hanks, 1983).

Research effort has focused on developing new techniques to receive high returns from restricted supply of water. Among the techniques of increasing effective use of water, deficit evapotranspiration should also be used. Deficit irrigation can be used either through agronomic practices or through changing management schemes to decrease crop evapotranspiration (Kanber et al., 1993). The end result is so called ‘‘deficit irrigation’’ (Vaux and Pruitt, 1983). To save irrigation water, crops are exposed to water stress either throughout the whole growth season or at certain growth stages. With this application, water sawing is obtained without significant yield decrease and also irrigated area can be increased without additional water supply available (Merriam, 1965). Deficit irrigation is promoted widely and used for some crops in Turkey. Experiments on the deficit irrigation of crops are being considered with different ways: 1) To spread of water deficiencies equally through the growing season. For this reason, different approaches are being consedered such as to use different soil depth for wetting, to decrease irrigation water as control treatment, to use different plant-pan coefficients, to use different irrigation intervals, to use different furrow spacing in surface, lateral and trickle spacings in drip irrigation systems, and to use line source sprinkler irrigation technique. In some deficit irrigation experiments crops are exposed to water stress at the different growth stages. This technique is named as omitted irrigation. In the all deficit irrigation experiments, yield response factors (Ky) given by Stewars Equation are worked to be calculated. Yield response factors for some maih crops are given in the Table 6.

Table 6. The Empirical Yield Response Factors for Some Main Crops

Crops	Ky Values, Growth stage / Irrigation Method	Region	Sources
Cotton	0.76 (flowering-yield formation) 0.99 (seasonal, Furrow) 0.93 (seasonal, furrow) 0.86 (seasonal, drip) 0.72 (sprinkler, sprinkler) 1.22 (sprinkler, Seasonal)	Çukurova Çukurova Harran	Baştuğ, 1987 Yavuz, 1993 Kanber et al., 1991
Pistachio	0.62 (Seasonal, Ponded) 0.77 (seasonal, drip)	Şanlıurfa Gaziantep	Kanber et al.,1993 Aydın, 2004
Maize	0.98 (Seasonal, Furrow) 0.85 (seasonal, sprinkler) 0.69 (Vegetative) 1.03 Tasseing) 1.00 (Milk stage) 0.66 (Ripening) 1.14 (Seasonal, surface)	Tarsus Tarsus Tharece	Kanber et al., 1990 Köksal, 1995 Çakır, 1999
Wheat	0.87 (Seasonal, surface) 1.14 (seasonal, sprinkler) 0.76 (Seasonal, surface) 0.32 (seasonal, surface)	Southeast Southeast Centre Anatolia East Anatolia	Karaata, 1987 Sezen, 2000 Madanoğlu, 1977 Sevim, 1988
Sunflower	0.62 (Seasonal, surface)	Tharece	Karaata, 1991
Bean	1.3 (Seasonal, Sprinkler)	Centre Anatolia	Bahçeci, 1995
Soybean	1.1 (seasonal, sprinkler)	Souteast	Kara, 1995

Water saving with deficit irrigation approach is used in the different ways in the some experiments. For instance, in some studies, different irrigation season lengths are use while in others evapotranspiration losses are prevented by chemical applications.

Different irrigation season lengths were used for cotton under Seyhan Plain conditions (Kanber et al., 1994). In this study, different irrigation interval, first and last irrigation times are considered. According to results, different yield reductions and irrigation water savings were obtained depended on irrigation season lengths. When the last irrigation was applied at the ball diameter was 1-2 cm, the maximum water saving was measured 46-62 percent.

In some places where the evaporation losses are very high, chemicals were applied to reduce evapotranspiration of cotton. In this study, the effects of irrigation intervals and antitranspirant doses on evapotranspiration, yield, and water use efficiency of cotton were investigated on the field plots in Harran Plain for 4 years (Kanber et al., 1992). Different irrigation intervals (I_1: 7, I_2: 14, and I_3: 21 days) and four antitranspirant doses (D_0: 0; D_1: 40 g/ha; D_2: 80 g/ha; and D_3: 160 g/ha) were tested. The antitranspirant that contains N, N, N-tributtill-3- (trifluoromethyl) benzene methananium chloride as the effective substance was used in sub-plots of the experiment. The antitranspirant application was done in the two times in which the reddish color on the main stem of cotton 5-7 cm reach to the top bud (as the first application) and at the 5-7th days of ball formation (as the second application) during the growing season. The irrigation programs were begun after the first application of antitranspirant and 90 cm soil depth was wetted in irrigation events.

Results show that the frequent irrigation increased evapotranspiration (ET) and net irrigation water requirement (IR). The maximum ET and IR values were found to be 1670 and 1555 mm, respectively in treatment I_1 (Table 7). The highest WUE values, although not statistically significant, were obtained from I_2 as 2.41 and 2.69; and from D_1 as 2.34 and 2.60.

Table 7. Results from experiment of antitranspirant doses and irrigation program

Treat	No of Irr.	IR mm	ET mm	IWUE	TWUE	Yield* kg/da	Average Values No of irr.	IR	ET	IWUE	TWUE
I_1D_0	13	1555	1670	2.45	2.28	384a	8 (D_0)	1201(D_0)	1322(D_0)	2.51(D_0)	2.26(D_0)
I_1D_1	13	1555	1670	2.55	2.36	394a	8 (D_1)	1182(D_1)	1310(D_1)	2.60(D_1)	2.34(D_1)
I_1D_2	13	1555	1670	2.39	2.23	361a	8 (D_2)	1172(D_2)	1290(D_2)	2.54(D_2)	2.29(D_2)
I_1D_3	13	1555	1670	2.35	2.18	376a	8 (D_3)	1196(D_3)	1312(D_3)	2.49(D_3)	2.25(D_3)
I_2D_0	7	1113	1234	2.62	2.34	295b					
I_2D_1	7	1113	1234	2.76	2.48	302b					
I_2D_2	7	1113	1234	2.65	2.36	298b				2.44(I_1)	2.26(I_1)
I_2D_3	7	1113	1234	2.74	2.46	304b				2.69(I_2)	2.41(I_2)
										2.47(I_3)	2.18(I_3)
I_3D_0	5	894	1019	2.45	2.15	223c					
I_3D_1	5	894	1019	2.48	2.18	224c					
I_3D_2	5	894	1019	2.57	2.27	227c					
I_3D_3	5	894	1019	2.38	2.11	209c					

*20.94 and 9.77; the yield groups were statically obtained by the orthogonal comparison methods

The application of various antitranspirant doses had no significant effect both on seasonal ET and WUE values. The irrigation intervals have significant effect on the yield and quality of cotton. The maximum cotton yield was obtained from frequent irrigations. Frequent irrigation applications increased lint length, whereas, infrequent irrigations and antitranspirant doses resulted in shorter and thicker lint.

Use of Unconventional Water

Applying deficit irrigation programs including supplemental irrigation and to manage the irrigation systems according to deficit irrigation approach can be considered as best solution. However, this solution is very expensive and requires new approaches. On the other hand, to find new water resources for different purposes including irrigation is another possibility to solve the problems related with insufficient water resources. To use unconventional water such as brackish water (treated waste water, drainage water, ground water table), shallow ground water and saline water supplied from different resources is considered to be one of the best solutions. Table 8 shows the waste water amount in Turkey from urban and industrial consumption in 2001.

Table 8. Waste water amount from urban and industrial consumption in 2001 (DIE, 1995)[1]

Resources	Amount, km^3
Urban waste water	3.700
Industrial waste water	3.000

[1]The values of 1995 year are updated for 2004.

The use of drainage and saline water for irrigation seems to be an attractive alternative for solving water scarcity problem. Saline water is a potential source for irrigation. The use of saline water for irrigation increases the quantity of water available for agricultural production if the sustainable management strategies for their utilization are evolved. Such water occur extensively in the arid and semi arid parts of the Mediterranean, Central and Southeast Anatolia regions and are being used for irrigating some summer crops which are tolerant to salinity. Some times saline water is blended with fresh water with different quantity and used to irrigate the salt sensitivity crops. There are enough evidences taken from several studies carried out either in Turkey or in the other countries to show the potentiality of using water with saline up to 6 dS/m for major cereal crops (Hamdy, 2002). Unconventional water use for irrigation gradually increases in a lot of countries where irrigation is evitable but water resources are scarce.

Use waste water

Inspite of standards which are detaily prepared in Turkey, waste water is not widely used in irrigation except in a pilot project in the GAP areas and few small industries. Enough water is being supplied for irrigated areas therefore total irrigated areas did not reach to the marginal limit value for the water resources. Frankly, farmers still can find enough water for irrigation. The experiments on use of waste water for irrigation purpose are persisted (Sarikaya, 1994). A study using urban waste water treated by Çiğli purification plant for irrigating Menemen plain (Eagen Region) is been carried out for a long period. On the other side, in the GAP areas two experiments on use of waste water and drainage water for irrigation were carried out (Altınbilek and Akçakoca, 1997).

Bilgin et al. (1997) have carried out studied to determine the effects of Ankara stream-water which is polluted by wastes from urban and industrial consumptions on soil, plants (lettuce and broccoli) and environment. Moreover, they have examined that the chemical composition of stream water for such as heavy metals, microbiological pollution, etc, at time and places, where the samples were taken, dimensions. Experiment was conducted in the open areas and greenhouse conditions. According to results heavy metal concentrations of Ankara stream were found to be not hazardous level to plants and soils. However, microbiological pollution of the water was obtained to be too high. Irrigations caused to the yield decreases due to detergent content of the stream flow.

Use of drainage water

Yarpuzlu (1999) has studied in order to evaluate the response of cotton and wheat grown on a clay soil in a sequence to drainage water applications with different leaching fractions (5 treatments in 1991-1995; In 1996-1997, three different irrigation water sources (drainage canal water, collector water and Seyhan canal water with different leaching fractions were utilized) as well as salinity build-up in the soil profile was evaluated during each growing season in Tarsus plain. The results of the study showed that the effect of irrigation with different leaching fractions statistically were not important on the yield of wheat crop, and it is determined that the effect of different leaching fractions on cotton yield was statistically significant at the 99 signification level. Drainage water applications in the wheat sowing periods did not cause salt accumulations in the soil however, in the cotton sowing periods it did cause salt accumulations. In addition, after long years of winter rainfalls, these precipitations were effective for leaching the salt accumulations in the soil.

Bahçeci (1991) has examined to determine the effect of groundwater used in irrigation, the accumulation of salts, sodium and boron in the Konya-Yarma district soils for wheat and sugar beet crops. The trial was designed in randomized block with three replications. According to the results, the salt accumulation wasn't significant but both the boron amount in the soil has increased and the increasing amount of exchangeable sodium statistically was significant. The exchangeable sodium accumulation was taken into consideration as a trend function and $YB= 0.193+0.309X$ relationships obtained. This relationship showed that only 20 years later the amount of ESP with a 90 percent probability would be reached to 23 - 47 percents limits.

Bahçeci (1993) studied in order to explore the quality and the suitability of main drainage channel waters for irrigation of Konya. In the research, the drainage water of Alakova and Arapçayiri branches of the main drainage channel were tested. The results showed that drainage waters may cause salt and boron accumulations in the soil. Besides the study also determined that Keçeli branch of the main drainage channel in the region was polluted from urban areas and reuse of this drainage water may cause serious environmental problems.

Use of saline water

There are various studies regarding the use of saline water for irrigation purpose. In these studies, surface and pressurized irrigation methods are used with saline water which is diluted at different levels. Diluted-saline water is used with various irrigation systems such as drip, sprinkler and surface methods. In surface irrigation methods, different amount of irrigation water with different saline levels are directly applied to plots whereas in pressurized systems, different salinity levels of irrigation water were used with line source sprinkler and drip which had different line and trickle head spacing (Sönmez and Yurtseven, 1995). Line source sprinkler system and drip system which has different trickle intervals can be shown as examples (Kanber and Bahçeci, 1995; Ödemiş, 2001). The results on saline irrigation of some crops in Turkey are given in the Table 9 (Yurtseven et al., 1999a and b; Şener, 1993; Yurtseven et al., 1996; Yurtseven and Bozkurt, 1997; Çizikçi, 1998; Yurtseven and Baran, 2000; Yurtseven et al., 2001a and b; Yurtseven and Öztürk, 2001; Yurtseven et al., 2002). This table contains both threshold and zero yield values of crops.

Table 9. The Rersults of Saline Irrigation for Various Crops

Crops	Threshold Value, dS/m	Zero Yield Value, dS/m
Maize	0.81	4.0
Tomato	2.7	11.0
Pepper	1.8	7.0
Lettuce	1.5	7.0
Broccoli	3.5	9.0
Radish	1.5	7.0
Rape	2.3	9.0
Spanish	3.5	
Cotton	5.7	

The values in the Table 9 are close to values given in some literatures; however, some little differences may be reasoned by irrigation programs, soil properties and other factors.

Irrigation system performances

Several irrigation systems in different regions were evaluated to obtain their system performance (Benli et. al., 1987; Yavuz, 1993; Uçar, 1994; Kanber et al., 2001). Open channel systems, and pressurized systems (sprinkler and drip), were examined in these studies. Moreover, the irrigation systems, which convey irrigation water from earth dams constructed in the high plateaus, were worked for their performance. Results from different regions and systems are summarized in Tab. 10.

Table 10. Irrigation Efficiencies (Ea), Conveyance Efficiencies (Ec) and Distribution Efficiencies (CU) for Different Regions and Irrigation Systems

Regions	Trickle Irrigation			Sprinkler Irrigation			Surface Irrigation		
	Ea	Ec	CU	Ea	Ec	CU	Ea	Ec	CU
Mediterranean	95	-	97	75	-	85	55	65	40
Southeast	80		-	61		85	38-85	55	85
Central Anatolia	89			34		58-82	23-77	85	-
Black Sea	-			-			35-55		

According to the results referring to all relevant scientific studies, performance of irrigation schemes located in different regions of Turkey, overall, is not at acceptable levels. This inadequacy can be highly related to the infrastructure, management (agency, joint, and farmer), allocation and distribution procedures (demand vs supply), and the climate and socio-economic setting. In almost all systems, the whole area can not be irrigated for various reasons; such as, water scarcity, fallow land, socioeconomic reasons, and lack of infrastructure. On the other hand, there are considerable changes in the size of irrigated area and cropping pattern from year to year in all irrigation schemes, referring to all relevant studies. It can also be stated that efficient irrigation scheduling has still not achieved properly and this causes too low water application efficiencies with high water conveyance losses.

CONCLUSIONS

As the demand for the limited water resources continues to rise, the irrigation comes to be caught in the middle: on one side, with the development of the industry and agriculture and acceleration of the urbanization process, agriculture will have to give way for the industry and urban living; on the other side, in order to feed the increasing population, the new irrigation area must be expanded while the current irrigation area and guarantee rate are maintained, and more water will be needed. This determines that for a sustained development, Turkey's agriculture must stick to economy and efficiency.

As the irrigation water-using efficiency in Turkey is much lower than that in western countries, if the water-saving irrigation techniques are practiced generally, the potential to save water will be very prospective. To adopt canal lining or water pipes will increase the water delivery efficiency in a canal system; furrow and border irrigation for dry farmlands will improve the usage of field water; the sprinkling irrigation and micro irrigation will improve the usage of water at its delivery section and in the field, and improve the evapotranspiration environment and reduce evapotranspiration.

As a technical measure, the water-saving irrigation method is employed to make full use of irrigation water resources, improve water usage efficiency, and achieve high yield and efficiency in grain production. It is an integrated technical system, combining water-saving techniques concerning water resources, engineering, agriculture, management and other links. With it, the overall using rate of irrigation water resources will be improved, the grain production at unit area or total area will be heightened, and the sustained development of agriculture can be guaranteed.

Agriculture is the basis for the national economy, providing necessary agricultural products and industrial raw materials for the living of 72 million people. Because of the special topographic characteristics and climate of Turkey, its agriculture production mostly depends on irrigation, and appropriate irrigation measures will result in a stable and high yield. Due to the serious lack of water resources, the traditional irrigation methods cannot catch up. Hence, to practice water saving is a prerequisite for the sustained development of the national agriculture and national economy.

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ASSESSING THE IMPACT OF DIFFERENT WATER POLICY OPTIONS ON AGRICULTURE

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INTRODUCTION

A 'Review of Water Resources' for the Maltese Islands was carried out by the Malta Resources Authority (MRA) with the collaboration of the Food and Agriculture Organization of the United Nations (FAO) during 2002/03. This study, amongst others, included a holistic assessment of the sectorial water demand in the islands which, in contrast to previous demand estimates, took into consideration both public and private water production sources. The results obtained showed that the arable agricultural sector, annually consumed an estimated 32% (app. 18 million m^3) of the total water produced (collected, abstracted and/or treated) in the Maltese islands. These results thus placed arable agriculture, together with the domestic sector (at 33%) as the two highest water consumers in Malta.

Agricultural water use for irrigation was also identified as the sector with the largest share of groundwater utilisation. In fact, use of groundwater accounted for around 81% of the sector's total water demand. The estimated utilisation of other water resources such as harvested rainwater and treated sewage effluent for irrigation was rather limited.

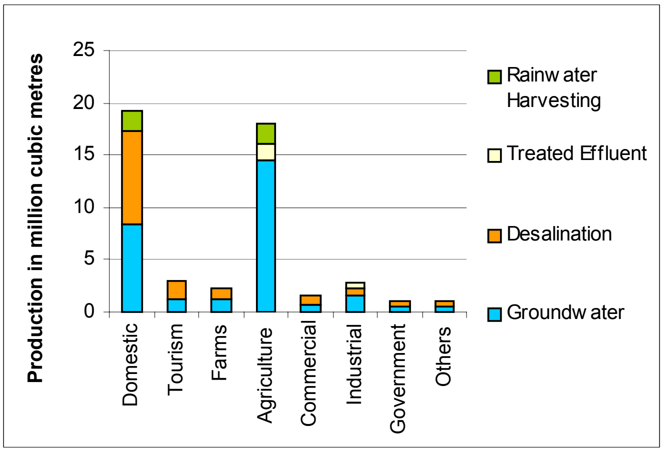

Fig. 1 Water consumption by sector (2003)

These water demand estimates were based on deficit irrigation requirements; that is the water required by the crops in excess to that supplied by the average annual rainfall. Should, however one consider the utilization of direct rain-water by agriculture, then, the sector would by far have the largest water demand in the islands; estimated in excess of 45 million m^3 annually; and thus solely almost accounting for Malta's estimated total current water demand.

A secure supply of good quality water for agriculture is therefore recognized as an essential area for this sector's development. This implies that agriculture must continue to use available water to best effect and aim to cost-effectively develop other non-conventional sources of water in order to diversify from its existing dependence on groundwater.

Malta's Article 5 Report, prepared as part of the implementation process of the EU Water Framework Directive (WFD), identified a number of major groundwater bodies as being under threat of failing to achieve the Environmental Objectives of the Directive. One of the major reasons for this classification is the over-abstraction of groundwater. Notably, all the major groundwater bodies on the islands are at risk of not attaining good 'groundwater quantitative status'[11], since currently estimated abstraction from these groundwater bodies closely approaches or exceeds their mean an nual recharge. These are the same roundwater bodies which by far, till today, have sustained Malta's agriculture.

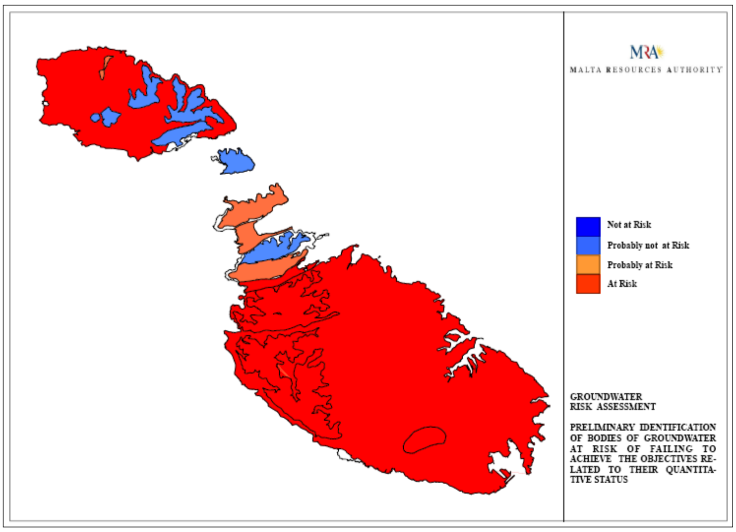

Fig. 2. Preliminary identification of groundwater bodies at risk of failing to achieve 'good groundwater quantitative status'.

The current groundwater demand situation is therefore not sustainable in the long-term and thus policies to address this issue and restore groundwater status are warranted. Being a major user of the water resource, any proposed policy and subsequent implementation measures will inevitably have an impact on the agricultural sector. It is clear that the sector should thus aim for increased productivity and efficiency through the utilisation of smart cropping and irrigation techniques in order to enhance its sustainability. In simple terms, agricultural research should aim to "*obtain more from less water*".

Long term policies also need to consider and address the expected effects of climate change; where in the Mediterranean region annual rainfall is anticipated to fall by 10 to 40% by 2100 and changes in the rainfall pattern are predicted to lead to a shorter rainy season with shorter but higher intensity storms. The expected consequences of these changes will be a greater generation of runoff in lieu of groundwater recharge. These changes will be expected to have a profound impact on the agricultural sector which is particularly heavily dependent on direct rainwater irrigation during the wet season.

WATER USE FOR IRRIGATION

The major constraints facing agricultural activity in Malta are the opportunity costs of land, the scarcity of water resources and the high labour costs. Official Statistics, however, have shown a constant increasing trend in agricultural productivity over the last years, which has also been reflected in an increase in irrigated land. In fact official figures from the Agricultural Census of 2001, show that declared irrigated land[12] has increased from 816ha in 1955 to 1508ha in 2000. The major driver behind this increase in irrigated land area was revenue increase backed by increased water

[11] Good 'Groundwater Quantitative Status' is introduced in Article 4.1(b)(ii) of the WFD which states that "*Member States shall protect, enhance and restore all bodies of groundwater, ensure a balance between abstraction and recharge of groundwater, with the aim of achieving good groundwater status at the latest 15 years after the date of entry into force of this Directive*….."

[12] Irrigated Land is defined by the National Statistics Office as "*land which has a continuous supply of water all year round irrespective of whether it has a natural spring, is served by second class water or water supplied by other sources*".

availability through declining costs of borehole construction and improvements in irrigation technology.

Further impacts on agricultural land use were expected, and in fact in part happened, as a result of land-based subsidies on agricultural investment from the EU, which subsidies became available in 2003. The outcome of the negotiations preceding Malta's accession to the EU can be considered as a viable starting point for projecting these possible changes in the agricultural sector. The main points of interest from these negotiations are:

i. the base area applicable to Malta for arable crops was set at 4565ha;

ii. Malta was granted new planting rights for the production of quality wine up to a total planted area of 1000ha;

iii. the national guaranteed quantity of olive oil for Malta was set provisionally at 150 tonnes which requires between 50 and 75ha of olive plantations; and

iv. an area of 1800ha was indicated for the cultivation of potatoes.

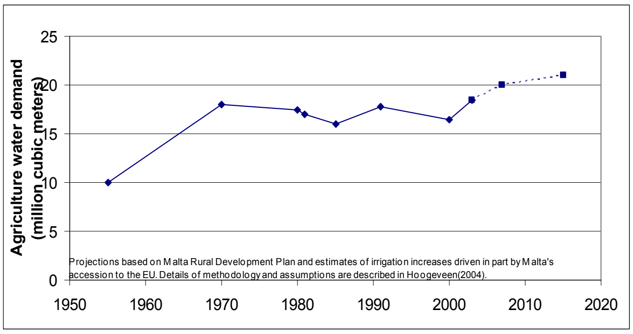

Fig. 3: Projections on Agricultural water demand.

Assuming that the utilized agricultural land area remains constant, attaining these thresholds would result in the net irrigated land increasing to about 2,250ha. Consequently, an increase in the demand for irrigated water in response to these changes in land utilisation and cropping patterns is expected. These indicators clearly show that currently the sector is going through what can be called a 'boom' period.

The major concern for the sector is that if the water supply scenarios remain the same, the projected increases in agricultural water demand will not be achievable without further deterioration in groundwater status.

It is therefore clear that the demand of the sector cannot be met by groundwater alone. Other sources must be brought into play – treated sewage effluent and rainwater harvesting in particular. More efficient methods of groundwater management such as supply augmentation measures involving aquifer recharge with excess treated effluent and rainwater runoff should also be considered.

Therefore immediate improvements in water resource planning in the agricultural sector are needed to avert an ensuing 'bust' period; which albeit has happened in many parts of the world whenever irrigated expansion was solely based on unsustainable groundwater abstraction.

Maintaining the sector's achievements will depend on various factors such as:

i. the extent to which unconventional water sources can substitute for the demand of groundwater;

ii. whether or not the cost of unconventional water sources will enable irrigated agriculture to remain profitable; and

iii. the extent to which improved water resource planning can impact very rapidly on water use of the sector.

In the long-term, unless the demand generated by the agricultural sector is met through the involvement of unconventional sources, the current levels of agricultural activity cannot be maintained.

GENERAL POLICY PRINCIPLES

This situation clearly calls for a review of existing policies. Such an initiative should embrace a holistic and integrated view with respect to the management of water resources, and therefore consider both demand management and supply augmentation aspects in an equitable and just framework. Only by taking such a holistic view can the crucial changes in attitude and behavior required, be acceptable to all stakeholders.

Implementation measures based on ‘Demand Management’ principles will require the formulation of regulatory instruments in order to adjust, limit or stop water uses or users who are utilising the resource inefficiently and thus contributing to the degradation of the natural resource base. The underlying aim should be to give priority to the environment and to water uses that have the highest social and economic value.

On the other hand ‘Supply Augmentation’ policies will require the development of a programme of measures which should, wherever possible aim to encourage incentives for the augmentation of the existing and the identification of new water resources both at a local and a regional level.

Many different options exist for augmenting supply and managing demand. A problem-focused approach is therefore needed to ensure that the options selected are the most suitable in the local context.

DEMAND MANAGEMENT

Measures implementing demand management policies (water savings) are generally associated with municipal water use; such as encouraging domestic users to practice water conservation and utilities to reduce leakages in their supply systems.

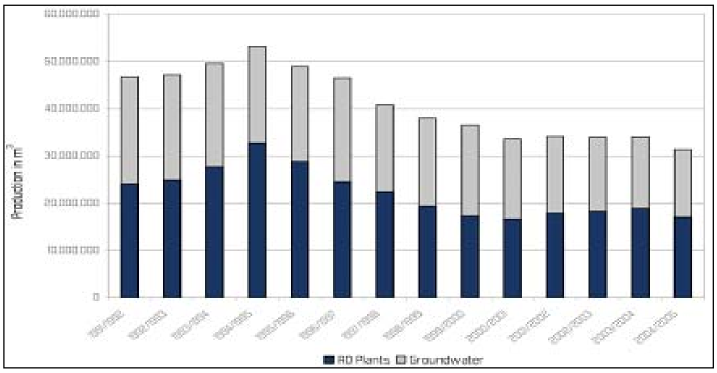

Fig. 4. Reduction in municipal water production (Source: WSC Annual Report 2005)

In fact, municipal water production in Malta has decreased significantly since 1994/95, largely as a result of demand management actions adopted by the Water Services Corporation (WSC). These actions included intensive leakage control, improved management practices and water conservation programmes.

The real question is: Can similar demand management actions be applied with the same success to the agricultural sector?

Clearly, initially, existing water losses and system inefficiencies must be identified and appropriate management actions need to be formulated in order to address these issues. In the agricultural sector, these include:

Fig. 5. Typical uncovered reservoir in the Maltese countryside

i. open reservoirs and distribution channels which are vulnerable to water losses due to evaporation;

ii. the use of inefficient irrigation techniques such as furrow irrigation whenever other forms of hi-tech and more efficient irrigation methods can be used;

iii. improperly managed and un-maintained irrigation systems which result in excessive leakages or in the spilling of water in non-cultivated areas such as roads; and

iv. the cultivation of water inefficient crops and crop varieties which leads to decreased productivity for the water used.

POLICY OPTIONS

A national policy statement reflecting the water demand objectives described above would read: *"Water demand management objectives in water planning processes will be supported and promoted as an alternative to supply augmentation; and to ensure that demand requirements are attained."*

For the agricultural sector this policy statement implies that synergies will need to be developed between Malta's water and agricultural policies. In this scenario, water utilisation by the agricultural sector will be assessed and its efficient use promoted.

Initial measures have already been taken by the Ministry of Rural Affairs and the Environment (MRAE) through a number of 'Voluntary Codes' in Malta's Code of Good Agricultural Practice. Further measures however are needed in the short term to provide incentives for the application of the measures outlined in these codes. Economic instruments would also gradually have to be introduced, in the long term, in order to disincentivise wasteful practices.

The Code of Good Agricultural Practice addresses several important aspects and provides guidelines to farmers to help them make good decisions aimed at amongst others, to protecting the status of the water resource-base. These guidelines address issues such as efficient irrigation techniques, the correct timing of irrigation in order to reduce evaporative losses and the scheduling of irrigation in order to ensure the application of the right amount of water at the right time, thus ensuring that the water is available when the crop needs it.

The most important codes in the field of irrigation are presented below:

Code 55*: The quantity of irrigation water applied to the field should be based on the requirements of the crop and the amount of available water in the root zone.*

Code 56*: Water losses by evaporation can be reduced by good cultivation practices.*

Code 57*: Irrigation should be scheduled by use of actual agro meteorological data and the soil water content.*

Code 58*: The irrigation system with the highest water use efficiency should be used.*

Code 60*: The irrigation system should be maintained regularly to ensure even distribution of water.*

Synergies will need also to be created with rural development policies in order to address infrastructural issues such as those relating to uncovered reservoirs. In a typical Mediterranean climate with a long, hot and dry summer season, these structures are effectively prone to major water losses from evaporation. Development policies should guide farmers towards the construction of covered reservoirs. Furthermore, wholly underground reservoirs should be encouraged since these, apart from being significantly lagged and thus less prone to losses, do not encroach on the arable land footprint.

The maximisation of crop-yield efficiency through the use of hi-tech irrigation systems should also be promoted. The possibilities of introducing fiscal incentives within existing Rural Development Programmes for the installation of such irrigation systems should also be considered.

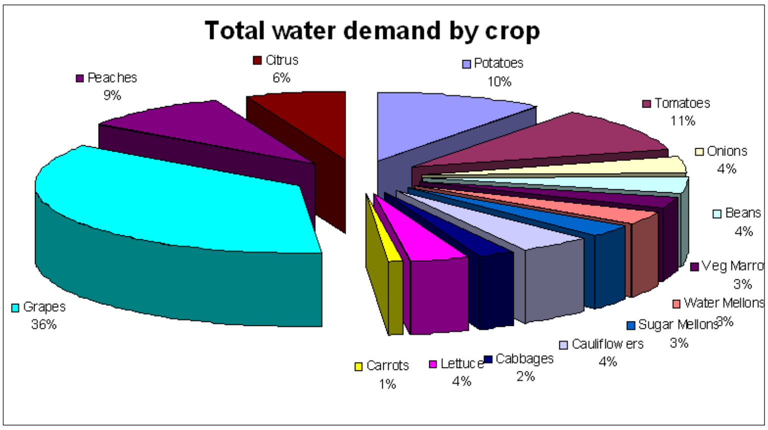

Fig. 6. Total percentage water demand per crop.

Studies on 'alternative cropping' to determine the viability of current agricultural practices and their impact on water resources management should be initiated. These studies should take full account of aspects concerning productivity, water demand and economic benefits in order to identify the most suitable crops in the local situation.

SUPPLY AUGMENTATION

Current estimates place the arable agricultural sector as the major user of groundwater in the islands. In fact, around 81% of the sector's supply is derived from groundwater. In a scenario, where the major groundwater bodies in the islands have been identified as being under threat due to over-exploitation, changes to this situation are warranted.

Policies aimed at the augmentation of water supplies need therefore to be developed. These polices have to address two major issues:

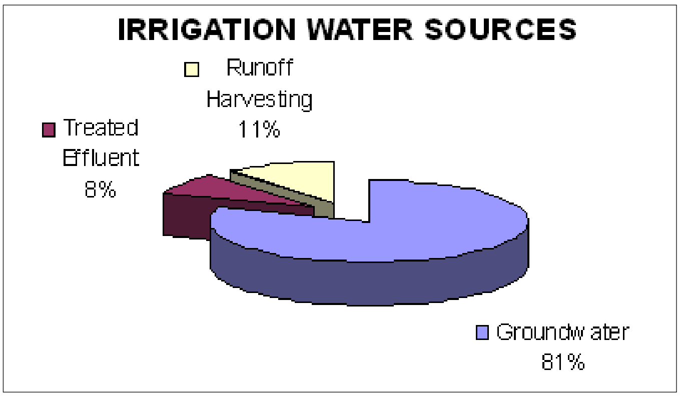

Fig. 7. Sources of irrigation water for the agricultural sector.

(i) Increasing the availability of groundwater through strategies aimed at artificially increasing its recharge;

(ii) Increasing the availability and utilisation of other water sources such as through increased harvesting of rainwater-runoff and increased production and utilisation of treated sewage effluent.

It should be noted that although the contribution from both fields can result, through a targeted development programme, in significant increases to the current water supply scenario; the success of such programmes will eventually depend on their cost-effectiveness for the end-user.

The development of a water supply plan aimed at maximising the use of all water resources available should however take into consideration a number of constraints. Issues relating to:

Water availability - since groundwater and treated effluent are the only water sources available all year round in significant quantities;

Water quality – since groundwater from certain regions of the mean sea level aquifer is saline; and treated sewage effluent, unless further treated over the secondary stage, is saline and could contain pollutants (mainly of industrial/pharmaceutical origin) which cannot be removed by conventional treatment;

Need for investments – sufficient storage space is needed to store rainwater and unutilised TSE from the rainy to the dry season, both on a local and national scale; whilst since a highly centralised approach has been adopted in waste water treatment new infrastructures are required to store and distribute this water; and

Health issues - potential threats to human health, such as viruses and bio-accumulating pollutants, arising from the utilisation of treated sewage effluent;

will all need to be considered in formulating management actions for the implementation of supply augmentation policies.

GROUNDWATER

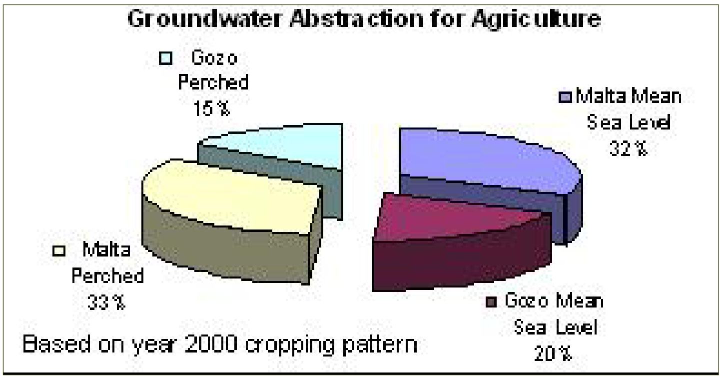

Fig. 8. Breakdown of groundwater abstraction from different aquifer systems.

Groundwater is abstracted for irrigation through a number of private boreholes conveniently located at the point of use. These sources are currently estimated as serving around 81% of the sector's demand.

Most of the irrigated lands are located in the north-western areas of Malta and the northern areas of Gozo, primarily overlying or in the vicinity of the perched aquifers, where historically groundwater was more available. During the early 1980's the commissioning of the Sant'Antnin Sewage Treatment Plant saw the establishment of a number of irrigated areas in the south-eastern region of the island of Malta. However, during the late 1990's the advent of more advanced drilling technology and the subsequent lowering of drilling costs, resulted in the gradual spreading of groundwater-irrigation sources all over the islands.

Mal-practice in abstraction and abstraction source construction is however substantially damaging the resource and consequently the ability of the resource to sustain the agricultural and other sectors. In fact, such mal-abstraction practice has led to the abandonment of wells in several areas due to salinization – this has been the case in the island of Gozo in particular; where the sea-level groundwater body due to its smaller size is more responsive to changes.

Restoration of the resource does not depend exclusively on cut-backs in abstraction but should also consider ways and means of increasing the potential groundwater yield through increasing the annual aquifer recharge, even where feasible by artificial methods.

The main policy objective for ensuring sustainable groundwater use in the islands could plausibly state that: "*Malta should seek the long-term sustainable management and exploitation of groundwater resources, meeting the needs of existing users and without compromising the ability of future generations to meet their own needs*."

Basically, for the agricultural sector such a policy statement will require the adoption and enforcement of a code of 'good abstraction practice'. This code will regulate according to scientific best-practice, functions such as well-location, well-depth, construction of the well-head and pumping-rates, to ensure that both the quality of the groundwater resource and that of the abstracted groundwater is ensured and sustained.

The use of other sources in lieu of groundwater will have to be promoted – so as to reduce the pressure on the resource and aim at the full utilisation of all available resources. Incentives related to the harvesting of rainwater and the use of treated effluent are considered in the subsequent sections.

Incentives will have to be devised for users who use available resources efficiently and development programmes initiated for other users to upgrade their irrigation systems. It is of paramount importance that the necessary technical information and expertise is made available to all involved stakeholders. In the long term wasteful practices will have to be disincentivised even through fiscal measures, if necessary. Such fiscal measures may include the setting up of a graded abstraction licensing regime and targeting of the major water users through rising-block abstraction charges.

RAINWATER HARVESTING

The climate of the Maltese islands is typically semi-arid Mediterranean, characterised by hot, dry summers and mild, wet winters. The mean annual rainfall[13] is around 550mm but with high seasonal and interannual variability, with some years being excessively wet and other being extremely dry. The highest precipitation rates generally occur between October and February. Rainfall is characterised by storms of high intensity but of relatively short duration.

Figure 9 presents the deviation from the mean annual rainfall for the Luqa meteorological station for the period 1974-2004. The average rainfall at this site for this period was 569mm. The figure shows that annual rainfall of 300mm more or 250mm less than the average is common. Although there is no indication of systematic variability, consecutive years of above- or below-average annual rainfall are common.

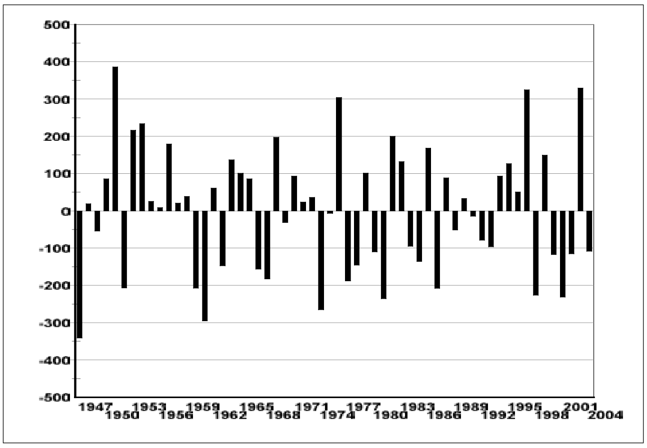

Fig. 9. Deviation form the mean annual rainfall for Luqa meteorological station, 1947-2004.

Rainwater for agricultural use is generally stored in open reservoirs, whence runoff is channelled from adjoining streets or upstream catchment areas. The average reservoir size is generally small and reservoirs more often than not are utilised to store abstracted groundwater instead of rain-water. This situation leads to a limited rain-water storage capacity compared to its potential availability.

It should also be noted that the last survey on the agricultural sector carried out by the National Statistics Office (NSO) during 2000 registered a reduction in investments in reservoir construction for the post 1996/7 period compared to the previous 20 year period. This, whilst the expansion in irrigated land was under-way. This data possibly indicates that users consider investments in the development of groundwater abstraction sources (boreholes) as offering more security in terms of a

[13] Mean for the years 1900 to 2000.

more reliable and constant water supply; compared to rainwater harvesting which apart from being highly dependent on a nature's variability is solely available during the winter months.

Fig. 10. Uncollected rainwater runoff on a field surface after a storm.

A policy statement addressing the main issues in the field of rainwater harvesting might read: *"Exploitation of opportunities for the capturing and utilisation of rainwater as a means of increasing the use of renewable water resources whilst reducing the reliance on groundwater should be encouraged."*

Possible measures implementing such a policy statement will include actions both on a national and local scale, such as:

i. the formulation of appropriate incentives for the construction of reservoirs of sufficient capacity for the irrigation of a whole cropping cycle;

ii. the alignment of national development policies to permit reservoir construction solely when it can be demonstrated that the reservoir will be effectively utilized for the harvesting of rainwater runoff;

iii. the rehabilitation of dams in the major valley lines (and construction of new ones) in order to enhance groundwater storage and recharge; and

iv. the creation of runoff storage facilities (such as major roadside reservoirs) within new flood management or infrastructural projects which can be utilised by the agricultural sector.

TREATED SEWAGE EFFLUENT

Fig. 11. Sant'Antnin Wastewater Treatment Plant

Currently, in Malta there is only one Waste Water Treatment Plant which produces around 2 million m^3 of treated effluent annually. Approximately 75% of this volume is provided to the agricultural sector and utilised for the irrigation of land in the Zabbar area.

The relatively high Electrical Conductivity of the raw wastewater (influent) creates a number of operational problems and also deteriorates the quality of the resulting effluent. These high conductivity values arise due to a number of factors such as infiltration of sea-water in certain segments of the sewerage network, dumping of RO-reject from upstream private installations and the utilisation of sea-water for flushing purposes in a number of hotels.

Apart from salinity, there are other considerations which limit the utilisability of treated sewage effluent (TSE). In principle, any type of application involving the infiltration of TSE in the ground, as in the case of irrigation, is constrained by hydrogeological conditions, the quality of the effluent and the cost of the treatment. The degradation and/or elimination of microbiological pollutants from surface recharge is directly related to travel time in the unsaturated zone besides retention in the aquifer before abstraction. The Maltese aquifers are geologically composed of fractured and weathered limestones having a high permeability and thus prone to rapid infiltrations from the surface.

Viruses and the presence of emerging industrially derived bio-accumulating pollutants which cannot be removed with traditional treatments are the main points of concern in relation to public health issues. In view of these considerations, and with the available knowledge to date, it is desirable to utilize, for the time being, TSE (bacteriologically purified) exclusively in those areas, where flow gradients in the aquifers are directed towards the shoreline and away from public abstraction points, and/or where groundwater is known to be poor in quality and not exploited for potable purposes.

A highly centralised wastewater management plan has been adopted for the country, wherein three main new waste-water treatment plants have been planned which when commissioned are expected to produce an annual volume of treated effluent in the region of 14 million m^3. Two of these plants are located at Cumnija and Wied Ghammieq, respectively in the northern and south-eastern regions of the island of Malta, whilst the other treatment plant is located at Ras il-Hobz in the island of Gozo. The Wied Ghammieq plant is by far the largest of the three and will treat an estimated 85% of the total sewage generated.

The application of TSE is thus further constrained by the location of the plants and the varying seasonal demand.[14] Production is expected to be fairly constant throughout the year, peaking slightly during the summer months due to the increased water consumption registered by the tourism sector.

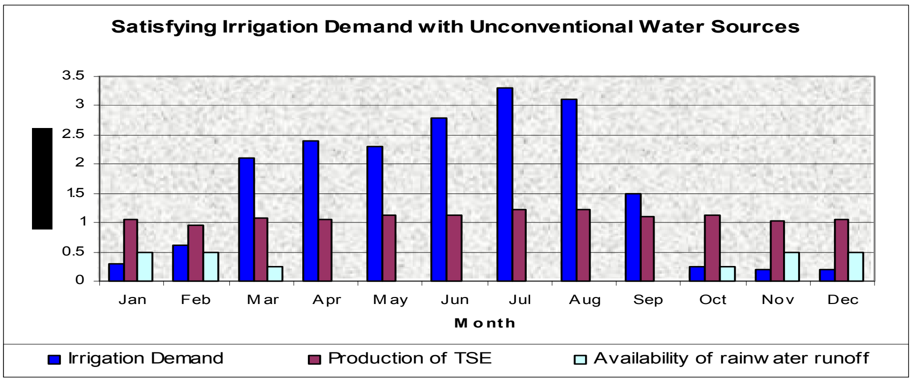

Fig. 12. Satisfying irrigation demand with unconventional water sources. TSE production is modelled on monthly water consumption for the years 2001-03.

TSE production is thus expected to outstrip the national irrigation demand during the rainy seasons (when better quality harvested rainwater runoff is available). During these months the demand for TSE is therefore expected to be minimal. The demand for TSE is expected to materialize mainly in the period from March till September, which basically means that around half of the total production will not be utilized. The effluent produced in this period is estimated to be far below the irrigation demand. This is shown in figure 12, where the irrigation demand for the period October to January can be satisfied by the existing rainwater runoff collecting facilities; whilst during the remaining part of the year, there is a good potential for TSE utilization since the irrigation demand exceeds the volume of TSE produced.

The location of the plants poses further problems. It is expected that the TSE produced in the Malta-north and Gozo plants can be fully utilised within the agricultural regions neighbouring the plants and thus requiring only localized distribution networks. However, the production from the Malta-south plant is expected to exceed the demand in the southern region. A correlation of TSE production

[14] This correlation assumes that TSE will be utilised exclusively by the agricultural sector and does not take into consideration other potential users such as the industrial sector and landscaping consortia.

in the latter plant with the irrigation demand in the neighbouring agricultural regions (Zabbar, M'Scala, Zejtun, Xghajra and Kalkara local council areas) is presented in figure 13. The plot shows that supply is expected to exceed demand throughout the whole year. This scenario risks the global non-usage of around 6.4 million m^3 of treated effluent produced in the Malta-south plant annually, unless efficient distribution methods can be found. Of these, 2.7million m^3 will be produced during the summer period.

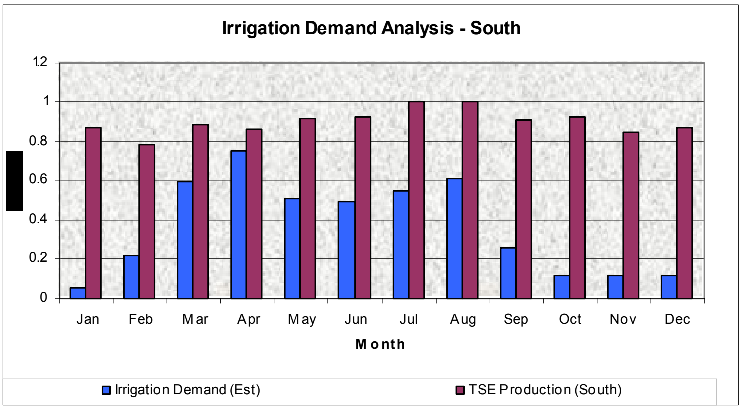

Fig. 13. Irrigation demand analysis in the southern region of Malta.

A policy statement aimed at encouraging the utilisation of unconventional water resources would read: *"Malta should seek to promote the cost effective utilisation of non-conventional water resources, particularly treated sewage effluent for secondary uses including agriculture."*

The eventual use of TSE in the agricultural sector has to be effectively regulated with due account of health considerations and protection of groundwater resources being taken. This needs the identification of areas where treated sewage effluent can be safely and effectively utilised by the agriculture sector or for groundwater recharge purposes.

The principal problems to address involve the eventual distribution of the treated effluent produced and its cost. Obviously the cost will depend on the amount of further treatment above statutory requirements[15] which will be needed to make the effluent usable and as such can be significantly reduced through regulatory measures (mainly discharge control and sewer maintenance). For TSE to be utilised as an alternative to existing sources, the final cost of the effluent should be such that agriculture would still remain profitable.

Distribution on the other hand will most likely require the development of a separate second class water distribution network. The management of such a system should also be considered, since it will have a direct bearing on the cost of the effluent to the end-user. Existing infrastructure such as unutilised sections of the municipal distribution system and reservoirs should were possible be employed. Various management scenarios ranging from placing the onus of distribution on the producer (WSC) to setting up separate distribution co-operatives should be considered.

Facilities for diverting un-utilised treated effluent for artificial recharge purposes should also be considered, subject to the provisions of existing national and European legislation; particularly in the light of the fact that a considerable volume of treated effluent is not expected to be utilised during the winter months. Such actions should form part of the river basin management plan currently being developed by the MRA under the Water Framework Directive.

ROLE OF POLICY, INSTITUTIONS AND INCENTIVES

An effective implementation of the water policy objectives stated above will require alignment of other policies that have the potential to impact on water supply and demand. The implementation of

[15] Malta in line with the requirements of the Urban Waste Water Treatment Directive is required to process all wastewaters up to secondary treatment prior to discharge into the marine environment. In this paper it is therefore being assumed that the costs for treating wastewaters up to these statutory requirements will be borne by the polluter and not any eventual user of the treated effluent.

such a holistic water policy will almost certainly lead to changes in patterns of water availability and use that may result in distinct winners and losers and reduced equity. If there is a risk of this happening, conflicts should be managed by ensuring that losers are compensated.

This, since in order to be effective, proposed policies must have an impact on the water demand of the water-using sectors. While there is scope for many users to make more efficient and productive use of water, and thereby to reduce their overall demand, there is a risk that there will be negative impacts on some commercial operations and the livelihoods of some users. In such cases, policy measures should be accompanied by the necessary safeguards in order to ensure minimal impacts on poorer social groups.

Finally, even a perfectly spelled out water policy is doomed to fail if the measures proposed are not effectively implemented and enforced. Therefore any proposed policy options in the agricultural sector (and not only) must be backed up with sufficient resources aimed initially at introducing and incentivising; and progressively at enforcing the proposed measures.

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INTEGRATION AND HARMONIZATION OF WATER POLICIES IN MALTA WITH SPECIAL REFERENCE TO IRRIGATION

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PRESENT SITUATION IN MALTA

Scarcity of water is a fact of life in Malta: as far as historical records go back, it has always been so and there seems to be no realistic likelihood that it will be any different in the foreseeable future. Modern society also makes ever-increasing demands on the limited supply as both the population (local and tourist) and the standard of living go up. Given this background, one would expect that there should be coordination between the various sections of society to make sure that water is used in the best possible manner. However, experience shows that this is rarely the case and rather than cooperation there is usually fierce competition between the potential users.

Among the sectors putting pressure on the water supply is, undoubtedly agricultutre. Yhis is an essential sector of Maltese society and one that merits protection and assistance. However, as always happens, even in other countries, the amount of water used by agriculture bears no connection to the actual production value. In Malta, agriculture uses 40% of the groundwater while producing only about 2% of the GDP.

OBJECTIVES FOR THE FUTURE

At the present time, the water sector in Malta is facing the following major challenges and development objectives (EMWIS):

1. Meeting water demand by different sectors.
2. Achieving EU quality standards for drinking water supply.
3. Governing water resources and allocating water to all users in a fair manner.
4. Managing all water resources in an integrated manner,
5. Recognising the diverse requirements of different sectors of the economy.
6. Maximising efficiency and cost effectiveness in the use of water resources.
7. Applying “user pays” and “cost-recovery” principles effectively.
8. Restoring the aquifers and protecting the aquatic ecosystems.
9. Raising public awareness on water conservation.

OVER-EXTRACTION

This is a serious concern, principally because some farmers extract water illegally and, obviously, have no intention of cooperating with the authorities to curb the abuse. It is one important instance where lack of coordination is glaringly apparent.

The practice has an adverse effect on the water quality and the farmers themselves are usually aware of it. They still prefer to use such methods because they want to hide from the Inland revenue Department the fact that they are irrigating their land and therefore earning higher incomes that those declared officially.

As often happens in such cases, those who break the law in this way are also putting their more law-abiding colleagues at a disadvantage.

COOPERATION IN ENFORCEMENT

One should perhaps consider whether the Ministry for Rural Affairs and Environment (MRAE) should cooperate with the Water Services Corporation (WSC) in enforcing the law in this regard, through inspections, reports and, above all, through an information and education campaign to render the farming community conscious of the harm that such illegal practices are doing.

Another initiative to be taken is the setting up of a distribution network for recycled water – the planning stage should involve not only the WSC, MRAE and farmers' organisations but also the Malta Environment and Planning Authority (MEPA) as one can imagine the amount of bureaucracy that would be involved in laying down such an extensive system.

NEW SOURCE OF WATER FOR IRRIGATION

In the (relatively) near future Malta will have a new source of irrigation water that could represent a small revolution in agriculture. As signatory of the 'The Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean', Malta is in the process of treating all sewage effluent and this will have a side-effect of producing about 12 million m^3 of so-called 'second class' water which is suitable for industrial and agricultural use.

Although the country as a whole will still suffer from scarcity of water, in this particular sector of economic activity, water resources will no longer be the limiting factor they are at present.

Re-use of treated waste water will become increasingly important in Malta's overall strategy. Although the reclaimed water will not necessarily be of very good quality because of its high salinity, it will be a reliable resource, even during the dry season, and can thus substitute potable water for secondary uses. Agriculture and Industry are two potential sectors where treated sewage can be safely employed after suitable treatment. If it becomes economically feasible, this water can undergo further processing to lower its salinity and thus improve its agronomic qualities. Decentralised treatment of sewage close or, at the point of use, needs to be also examined further as it will allow multiple usage of the effluent while doing away with expensive distribution networks.

Ironically, Maltese agriculture does not, at present, have the capacity to make full use of this soon-to-be-available resource and this is again, another instance where more integration between the WSC and the MRAE is called for. The agricultural system is adapted for a situation where water is very scarce and one of the constraints limiting production. This means that crops are grown which need as little water as possible. Application efficiency is the only practical consideration for irrigation.

The Ministry needs to bring together the farmers' organisations and start thinking how best to utilise this water by modifying the traditional agricultural practices; such a consultation process is already long overdue.

There are two main changes that will probably need to be made to exploit the abundant reclaimed water: the types of crops which are cultivated and the irrigation systems to be employed. Most farmers are at present cultivating relatively salt-tolerant crops but in some areas, more sensitive crops are grown. Areas where irrigation water has low salinity should not be supplied with recycled water (unless this can be further treated) as it would lower the quality of the available resources.

Ideally, the WSC and the MRAE would discuss the matter and draw up a general plan for the islands identifying and distinguishing between the different areas and how they are to be supplied. This would be especially important if the WSC can feasibly provide different grades of water.

IRRIGATION SYSTEM

At present the most popular and widespread system is drip irrigation. In general this has had a beneficial effect – the amount of irrigated land has passed from 5% in 1993 to 10% in 2005. However, drip irrigation has advantages and disadvantages from an agro-environmental aspect. It does avoid water loss and makes the most of scarce resources and the same amount of water can be used to irrigate a wider area. At the same time it can give rise to localised problems with concentration of salinity near the roots, especially when the water has a high salt content. This means that the reclaimed water, with its high salinity will exacerbate the problem.

At present, because of the scarcity of irrigation water, the advantage has outweighed the disadvantage, however this may change in future. As irrigation water becomes less scarce, the advantage will decrease. At the same time, the probably higher salinity of the recycled water will emphasis the disadvantage of the drip system.

DRIP IRRIGATION SALINITY PROBLEMS

This has been the experience in other countries:

"*The re-use of drainage water for the irrigation of salt tolerant plants is one of several methods being developed to address salinity and drainage problems on the Westside San Joaquin Valley.*

However, there have been serious failures of drip systems due to salt accumulation around drip emitters – indicating serious potential problems in arid areas (such as the San Joaquin Valley) with the sustainability of some types of drip irrigation." **California State University**

NEED FOR INFORMATION

At the moment, this is of course, all based on theory. Studies have to be carried out to see what will be the real risk of salinity if drip irrigation continues to be used. Alternative systems will eventually have to be developed – perhaps re-introduced and modernised – in view of the new agronomic circumstances.

Another variable that will need to be considered is soil fertilisation. Up to a few months ago, the vast majority of farmers used artificial fertilizers especially nitrates and ammonium sulphate. Their use is now severely curtailed because of health considerations as expressed by EU 'Nitrates Directive'. Gradually manures and composts will have to be utilised more widely in place of the mineral ones. This will hopefully augment the organic content of the soils and have a beneficial effect by lowering salinity both through physical and chemical means.

ECONOMIC ASPECTS

Economic considerations also have to be kept in mind: how much will it cost to make use of this water and what will be its effect in terms of added value to agricultural production. When looking into this aspect, we must not look only at the market value of the produce but also at the environmental costs of over-exploitation of groundwater. A major benefit of making recycled water widely available could be this: it would no longer be economically feasible for farmers to extract groundwater illegally.

RECOMMENDATIONS

More cooperation is needed between public and private stakeholders such as the Ministry for Rural Affairs and Environment, the Water Services Corporation and farmers' coops and producer organizations. This cooperation is essential to implement the present regulations regarding water-use and extraction.

Moreover, there should be a joint committee between Malta Resource Authority, the WSC, MRAE and the Malta Union of Farmers to establish a general policy for the use of recycled second class water. Studies will also have to be carried out by the MRAE (with the help of the farmers' organizations) regarding the most appropriate irrigation system to adopt in order to make the best use of the available water. Both public and private enterprise should create – possibly together - specific projects to restructure agriculture so that the available water may be used in the most rational manner.

The recycled water will have to be distributed to farmers throughout the country and, for this purpose, a distribution network should be established. This would involve not only the WSC, MRAE and farmers but also the Malta Environment and Planning Authority.

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OTHER CONTRIBUTIONS

LAND USE CHANGES AND CROP PRODUCTIVITY IN EARLY AGRICULTURE: COMPARISON WITH CURRENT CONDITIONS IN THE MID-EUPHRATES VALLEY

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INTRODUCTION

Water management in either irrigated or rain-fed crops has been practised for thousands of years in the Mediterranean. Whereas history tell us that most irrigation-based societies of the region failed (Postel 1999)

, many traditional activities that have survived until present times are admirably adapted to particularly arid environments (Mortimore 1989). In general, the sustainability (and cost value) of traditional agricultural systems is substantially higher than that of today's systems, and therefore much can be learnt from the past. Several studies have addressed the benefits from combining indigenous with modern knowledge and have explored the potential of several techniques for water harvesting and their adaptation to local conditions (see references in Araus 2004). However, much less emphasis has been placed to valorise traditional agronomic practices, which may be of value and especially in rain-fed conditions. Thus traditional agronomic practices (related with water harvesting, sowing and soil conditions, fertilizing, fallow, etc) may provide by far more water and nutrients to rainfed crops and in a more sustainable manner than conventional (present-time) systems (Capillon and Séguy 2002; Prew *et al.* 1995; Raupp and König 1996). Moreover, most of these agronomic techniques were likely developed at the beginnings of agriculture and, probably, conformed the basis of the origin and spread of agriculture in the Region. In fact cultivation in (naturally) wet soils (Araus *et al.* 1999) and their positive consequences in terms of productivity (Araus *et al.* 2001; Araus *et al.* 2003) has been evidenced in Neolithic sites (*ca.* 10th millennium BP) of the Middle East.

Improving our knowledge about the way early farmers reacted to environmental constraints might help to unveil alternative methods to face current water issues. Up to now, the most evident way to get insight into ancient water management methods has been the study of archaeological structures related to water uptake or distribution. However, this approach is limited to relatively advanced societies, and does not give any information about the actual results of this management on crop performance or the characteristics of ancient crops. Agronomic and ecophysiological characteristics of plants at the time of emergence of agriculture as well as further changes occurring through time, may add additional clues on the interaction between agriculture, man and environment. Indeed, the study of archaeological plant remains have provided direct evidences about the evolution of land use (e.g. deforestation processes; see Willcox 2002), changes in the preferred crops (McCorriston and Weisberg 2002), crop management (Bogaard *et al.* 1999; Jones *et al.* 2000), and the origin and spread of relevant agronomic traits, such as greater grain size (Ferrio *et al.* 2004a; Willcox 2004) or non-shattering raquis (Harlan *et al.* 1976; Zohary and Hopf 1988).

In this work we compared crop distribution, cereal crop yields and population data for Tell Halula, a 10th millennium BP site on the Euphrates, with contemporary data from the surrounding region on population, crop management and productivity. Comparing contemporary changes in land use and management during the last 50 years with those recorded in archaeological contexts, we can get a better understanding of the long-term effect of the interaction between man and environment in the area.

MATERIALS AND METHODS

Area of study

We focused our research on the area around the archaeological site of Tell Halula (36º25'N, 38º10'E, 337 m.a.s.l.), placed in the Mid-Euphrates region (Governorate of Rakka, Syria) about 105 km east of Aleppo and 25 km northwest of Membij (see Fig. 1). Tell Halula is a representative site for the beginnings of agriculture, and comprises (to date) three main excavated periods: Middle and Late Pre-Pottery Neolithic B (M-PPNB, 9750 years Before Present -BP- and L-PPNB, 9300 years BP, respectively), and Pottery Neolithic (PN, 8750 BP). The archaeological site was occupied in an uninterrupted way during *ca.* 2000 years, and since then till the second half of the 19^{th} century, the region remained unsettled, being used only by the Bedouins for grazing. It was not until the 20^{th} century when some of the tribes started a transformation from herders into farmers and founded current communities. The area is characterised by an steppe climate, with an average annual rainfall ranging from 255 to 265 mm, mean temperatures from 17.8ºC to 17.9ºC, and an annual ratio between precipitation and evaporative demand varying between 0.15 and 0.17.

Data compilation

Archaeological data was compiled from the literature to provide information about the structure and socio-economics of ancient farming communities, including the estimation of past yields of the main crops cultivated (Araus *et al.* 1999; Araus *et al.* 2001; Araus *et al.* 2003; Araus *et al*., submitted). Ancient population at the archaeological site was inferred by applying ethnoarchaeological criteria (population density in present villages from the Near East, following Aurenche (1981) and from built surface, taking an average of 21 m^2 $person^{-1}$, as established by Holladay (1992).

Contemporary data was derived from data published by the Syrian Ministry of Agriculture and Agrarian Reform (The Annual Agricultural Statistical Abstract, 1996), data provided by the Membij Farmers Union and Department of Agriculture, and from a field survey performed in twelve communities in the surroundings of the archaeological site (see Fig. 1b).

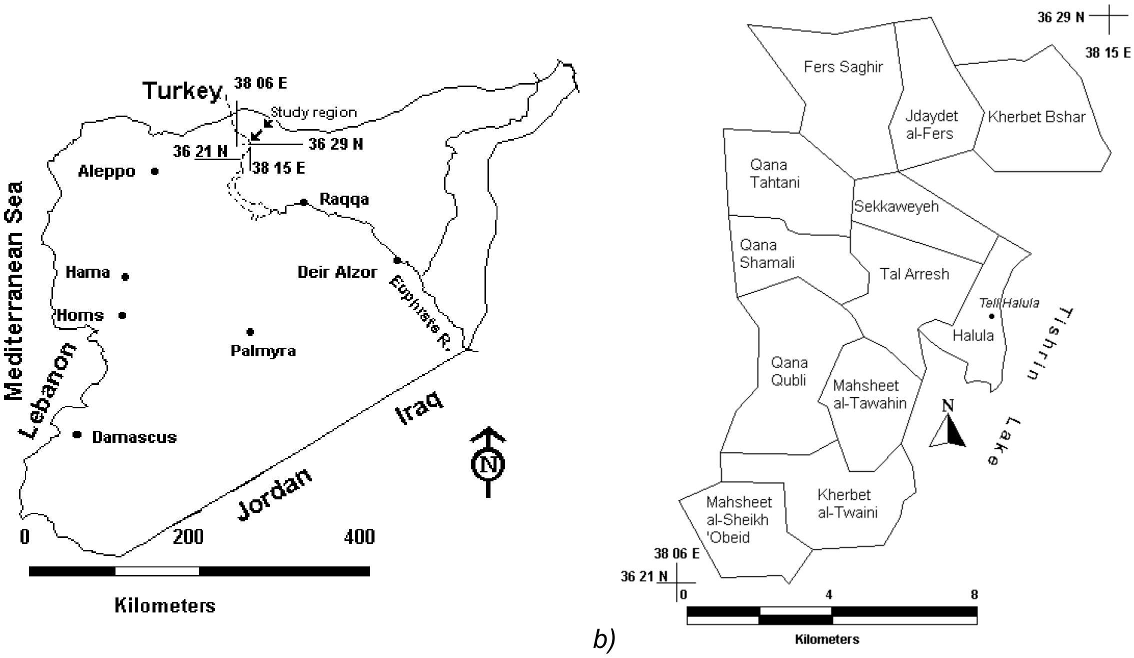

Fig. 1. a) Geographical location of the area of study and b) detail of the communities included in the field survey, indicating the location of the archaeological site, Tell Halula.

RESULTS AND DISCUSSION

Crop distribution and management in present times

Currently, the area of study is strongly limited in terms of land resources, considering that almost all arable land is cultivated. Of a total area of 9318 ha, 8019 ha are cultivated. Barley is the dominant rainfed crop in the area (66.1%), followed by wheat (28.2%), and the extension of fallow is very low (3.6%) (Table 1). Even considering also irrigated land, which covers 10.6% of the total cultivated area, cereals are by far the most abundant crop, representing the 91.2% of the total arable land. On the contrary, legume crops are restricted only to small irrigated plots, covering less than 1% of the total area. Thus, the situation is close to a monoculture, probably forced by the increasing population pressure, which is the main cause of the current limitation in land resources. On the other hand, the lack of fallow and rotation practices in the crop cycle has lead to a progressive soil degradation, further enhancing the expansion of barley, as it grows relatively well in the poorest soils. Indeed, during the field survey, 92% of the farmers mentioned that their soils have degraded in terms of productivity, despite the increased use of fertilisers and improved varieties. When asked about the reasons that caused the degradation, 75% of them attributed this degradation to the exclusion of fallow from the crop rotation. Moreover, 67.5% of the soils in the region were classified in the survey as of category 1 (depth between 0-0.5 m, stony and with low fertility), whereas only 8% of the soils were classified as of category 5 (depth =5.1-25 m, without stones and with high fertility). On the other hand, and except for the communities just beside the new “Tishrin” dam on the Euphrates (e.g. Halula), the water table has decreased considerably in the last 50 years, from 29 m on average in the 1950s to 57 m depth twenty years ago, and 60 m depth at present, mostly due to an overexploitation of water reservoirs used for irrigation.

Table 1. Percentage of the different rainfed and irrigated crops sown in the season 2003-2004 in the area of study. Source: Membij Farmers Union and Department of Agriculture.

Rainfed crops (ha)	Barley (%)	Wheat (%)	Fallow (%)	Olive (%)	Pistachio (%)	Grape (%)	Almond (%)
7165	66.1	28.2	3.6	1.7	0.3	0.1	0.04
Irrigated crops (ha)	**Cotton (%)**	**Wheat (%)**	**Broad beans (%)**	**Sesame (%)**	**Maize (%)**	**Vegetables (%)**	**Olive (%)**
854	22.2	65.3	5.7	3.4	2.5	0.8	0.2

Crop distribution and management during the Neolithic

Up to now, 1662 seeds have been recovered and identified from the archaeological site of Tell Halula, 1154 from the PPNB layers (M-PPNB and L-PPNB samples were combined for quantitative analysis) and 508 from the PN period. Overall, naked wheat (*Triticum aestivum/durum*), emmer (*Triticum dicoccum*) and barley (*Hordeum vulgare*) were the main cultivated crops, together with two pulses: lentil (*Lens culinaris*) and pea (*Pisum sativum*) and a single oil-and-fibre crop, flax (*Linum usitatissimum)*. Of minor importance were einkorn (*Triticum monococcum*) and wild cereals (wild barley, *Hordeum spontaneum* and wild rye, *Secale* sp.), as well as some fruit-trees, probably harvested from natural vegetation, such as *Amygdalus* sp., *Capparis* sp., *Ficus* sp. and *Pistacia* sp. Nevertheless, cereals were by far the most abundant crops (66.9% of the total findings), followed by legumes (18.9%). We found significant differences between the two periods studied, with a strong depletion in legume cultivation (from 26.7% to 1.2%), when compared with the cereals (Figure 2a). Similarly, the third major crop (flax) also showed a significant reduction from the PPNB to the PN (from 13.1% to 2.7%). Indeed, the situation during the PN was more similar to that found in present times, showing nearly a monoculture of cereals (92.1% of the seeds).

Looking at the distribution among different cereal crops (Fig. 2b), we found that their relative importance varied substantially between the two periods studied. Thus, for the PPNB layers, naked wheat was the most abundant cereal (42.5%), followed by emmer (28.8%) and 2-row barley (14.6%), while 6-row barley and einkorn were relatively rare. During this period, significant amounts of wild cereals were still gathered, in particular *Hordeum spontaneum*. In contrast, during the PN phase, naked wheat lost its relevance (15.4%) and emmer became the dominant cereal, together with 2-row barley (43.6% and 37.6%, respectively). Whereas einkorn showed a slight expansion during this period, 6-row barley disappeared and wild cereals became very rare. Again, this situation resembles present conditions, in which the area dedicated to barley is almost two-fold greater than the area under wheat (4734 ha and 2578 ha, respectively) (see Fig. 2b).

Overall, we found a wider variety of crops during the earlier phases of the settlement, which afterwards moved into a cereal monoculture. During this transition, harvesting of wild material (fruits, nuts and wild cereals) almost disappeared. This probably reflect a significant expansion of the area dedicated to agriculture, which should be necessarily restricted to extensive crops requiring relatively low labour efforts, such as cereals. Indeed, it has been reported in traditional farming communities that intensive crops tend to be located near the settlement, while more extensive ones can spread over wider territories, and this was probably also a common practice among Early Neolithic farmer communities (Hillman 1973; Wilkinson 1994). On the other hand, the expansion of cultivated land would imply the cultivation in poorer soils, with lower water table and/or poorer in nutrients, as land resources began to be limited. This would explain the relative reduction in wheat cultivation, in favour of emmer and 2-row barley, as the latter tend to perform better under harsher conditions than wheat (López-Castañeda and Richards 1994; Stallknecht *et al.* 1996). Moreover, as we will discuss later, estimated crop yields showed a declining trend during this period, further confirming this explanation.

The significant reduction in legume cultivation might have also implied the lost of crop rotation, as happenned during the last decades in the area (due to the scarcity of land resources), further enhancing soil degradation and nutrient losses. Nevertheless, previous studies have shown that the legumes and flax were generally grown under more humid conditions than the cereals, suggesting the potential use of irrigation in small plots, rather than an extensive cultivation, in alternation with cereals (Araus *et al.* 1999; Ferrio *et al.* 2004b; Ferrio *et al.* 2005). Indeed, the site of Tell Halula provided one of the oldest evidences of waterworks in the Near East (dated about 8000 years BP), an irrigation/drainage ditch located just outside the walls of the village (Molist 1996). On the other hand, among the cereals, naked wheat showed generally better water availability than barley (Ferrio *et al.* 2004b; Ferrio *et al.* 2005), suggesting that it was planted either in naturally wet soils or under supplementary irrigation. Nowadays, it is a common traditional practice to reserve the best soils for wheat and legumes, given their added value and their higher requirements, when compared with barley. Effectively, in our area of study, crop legumes (broad beans) and wheat are currently among the preferred species for irrigation, although they are combined with more recently introduced crops, such as cotton, sesame and maize (see Table 1).

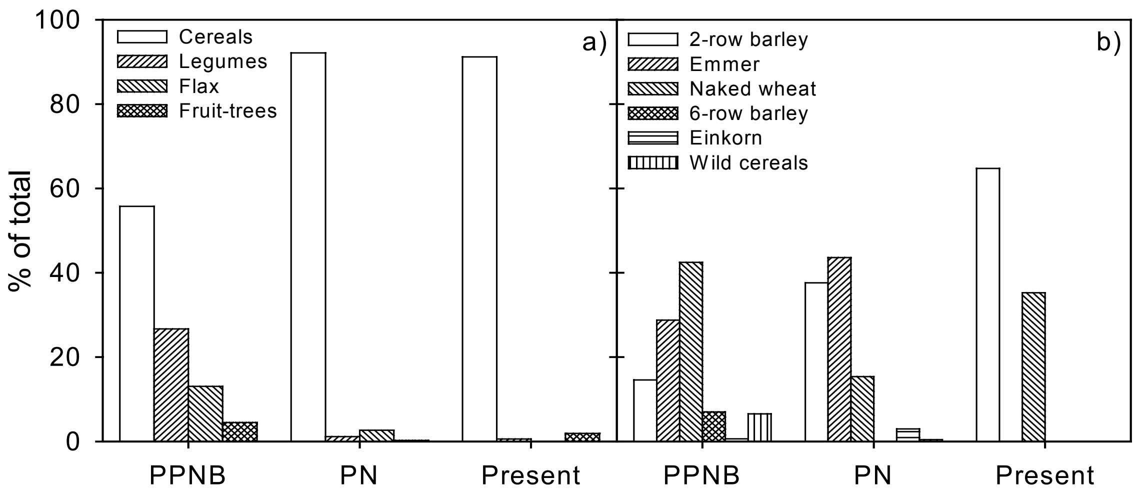

Fig. 2. Comparison between the percentage of seeds from each kind of crop that were recovered in the archaeological site of Tell Halula (a surrogate for crop distribution in the past) and the percentage of land currently dedicated to each crop, as derived from Table 1. PPNB, Pre-pottery Neolithic B; PN, Pottery Neolithic.

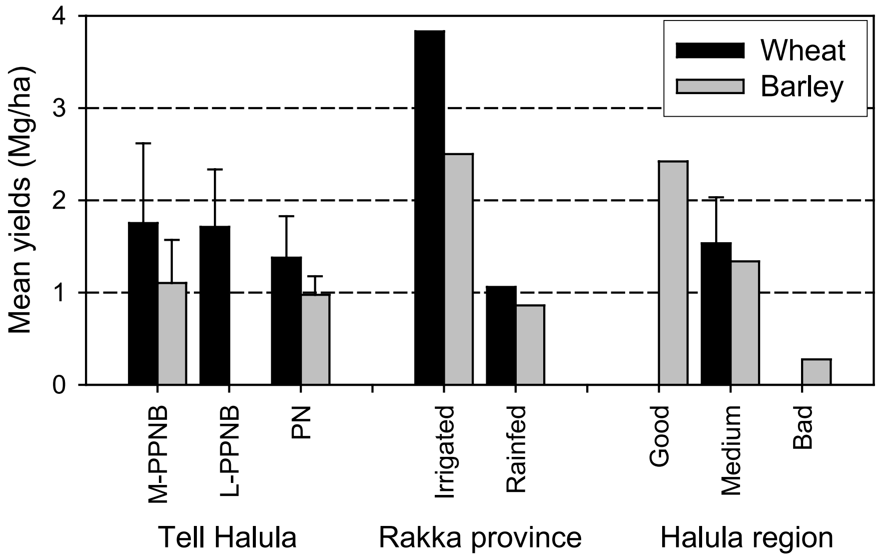

Fig. 3. Comparison between estimated yields for the archaeological site of Tell Halula (derived from carbon isotope discrimination of cereal grains, as described in Araus *et al.* (1999); Araus *et al.* (2001); Araus *et al.* (2003), current yields in the Rakka province (1987-1996) for irrigated and rainfed crops, and average yields in "good", "medium" and "bad" years for rainfed barley in Halula region (1994-2004), according to the Membij Farmers Union and Department of Agriculture and the data from the field survey (for wheat only the average value across communities for 2004 is given). M-PPNB, L-PPNB, Middle and Late Pre-pottery Neolithic B; PN, Pottery Neolithic.

Cereal yields in the past and in present times: evidences of land degradation

During the last years, our group developed a method to estimate ancient cereal yields from the analysis of carbon isotope discrimination in archaeological grains Araus *et al.* (1999). The method is based on the strong relationship observed between carbon isotope discrimination and grain yield, across a wide range of environmental conditions, but taking into account the effect of recent changes in harvest index and atmospheric CO_2 (see details in Araus *et al.* (2003). Using this methodology, we obtained estimations of grain yield for the archaeological site of Tell Halula, which could be directly compared with those currently found in the area (Fig. 3). Our estimates are similar or even higher than present yields under rainfed conditions. Thus, despite the recent agronomic and genetic advances, the better growing conditions prevailing during the Neolithic allowed ancient farmers to obtain relatively high yields. On the other hand, considering the high yields attained in the past, and the fact that wild species were still rather common in the archaeological context (at least during the PPNB), it is likely that the pressure of agriculture over the soils were smaller in the Neolithic than in present. Nevertheless, a declining trend in grain yield was found for both wheat and barley, suggesting an effect of land degradation. This coincides with a significant reduction in the size of the site in terms of occupied area and, presumably, of population, along with an overall degradation in the quality of built structures (e.g. the substitution of "cimento"-coated soils by bare soils; Molist 1996). As shown in Fig. 2, the change from a mixed culture of cereals, legumes and flax (probably including some crop rotation or, at least, fallow) to a nearly monoculture regime of cereals might be the cause behind the lost in crop yields, thus resembling the present situation.

Table 2. Estimated population, barley yields, minimum required land area per person (based on nutritional needs), and total cultivated area per person and settlement (assuming that 50% of land is under fallow) for the PPNB layers of Tell Halula. For comparison, present average values for the same variables across the twelve communities of the area of study are also included.

Period	Population	Average yield (kg ha^{-1})	Required area (ha $person^{-1}$)	Cultivated area (ha $person^{-1}$)	Total cultivated area (ha $site^{-1}$)
PPNB	625 ± 100 [a]	1104 ± 467 [b]	0.29 ± 0.11 [b]	0.29 ± 0.11 [b]	180 ± 70 [b]
1994	655 ± 249 [c]	1140 ± 844 [d]	0.57 ± 0.45 [d]		
2004	921 ± 350 [c]	1140 ± 844 [d]	0.57 ± 0.45 [d]	0.66 ± 0.20 [c]	611 ± 421 [c]

[a] Average ± range of estimated values
[b] Average ± standard deviation across archaeological samples
[c] Average ± standard deviation across communities (results from the field survey)
[d] Average ± standard deviation across years for the whole study area (period 1994-2004)

Changes in demography and land resources

The inferred population in Tell Halula during the PPNB, based on ethnoarchaeological criteria (Aurenche 1981) was of 525.4 inhabitants, whereas using the estimations from built surface (Holladay 1992) the estimation was of 711.6 inhabitants (M. Molist, pers. comm.). Thus, we adopted as the most probable population the range between 525 and 625 inhabitants (Table 2). This population is almost identical to the average population across the twelve communities studied in 1994. Nevertheless, the average size of the communities has grown notably in the last ten years (40.6% of increase), and thus present population per settlement is significantly higher.

In order to assess the potential effect of demographic pressure on land resources in prehistoric settlements, one approach is to estimate land requirements based on the nutritional demand to be satisfied. Considering an average nutritional requirement of 2600 kcal day^{-1} $person^{-1}$, and the known energetic values of cereal grains (*ca.* 3.5 kcal g^{-1}), we can determine how much cereal is required to meet an individual's minimum annual nutritional demand (Araus *et al.* 2003). Thus for a cereal monoculture settlement, the result is *ca.* 300 kg yr^{-1} $person^{-1}$, assuming that 10% of production is reserved for sowing, as previously reported (Wilkinson 1994). Following these assumptions, and taking into account population and yield estimates, we can finally obtain an estimation of the required cultivated area per person, as well as for the whole settlement, as displayed in Table 2. For simplicity, we took the average yield estimated for barley, although the approach could be refined by considering the relative frequencies of each crop (see Fig. 2). When compared with the current situation, we found that estimated land requirements were significantly lower during the PPNB, despite having similar average yields. In this case, the main difference is the lower variability observed in ancient yields when compared with present data, which may indicate more stable climatic conditions. Indeed, according to the field survey, during the period 1994-2004 the mean number of "good", "medium" and "bad" years across communities were 2.3, 3.5 and 4.2 respectively, which means that every ten years, four are giving very low yields (275 kg ha^{-1} on average, see Fig. 2). Thus, yield stability, as much as yield itself, strongly determines the extension of land required by the settlement. On the other hand, comparing actual cultivated area in present times with the estimations from nutritional requirements, we found that current productivity is so low that only exceeds slightly these minimum needs, leaving few margin for commercial purposes. Moreover, during "bad" years, cultivated area per person is well below the nutritional needs of the population under such conditions (1.09 ha $person^{-1}$).

CONCLUSIONS

Despite the constraints of comparing past and present conditions, when the source data available for each period is not directly comparable, we have shown that it is possible to make reliable estimations of population, past yields and land use from the study of archaeobotanical remains, together with other archaeological data. Such estimations can be related to the current conditions in farmer communities from the area, in order to understand the long-term consequences of agronomic practices. We found that ancient crop yields in the area were similar to those found in present times, despite recent agronomic and genetic advances, and that land requirements per person appeared to be lower in the past due to more stable climatic conditions. On the other hand, we found evidences of progressive soil degradation in the area not only during the last decades, but also in the Early Neolithic settlement. In both cases, such degradation appears to be associated with the lost in crop diversity and a trend towards a cereal monoculture.

ACKNOWLEDGEMENTS

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OPTIMUM CROP DESIGN UNDER LIMITED AND ADEQUATE IRRIGATION POSSIBILITIES IN SMALL SCALE FARMING ENTERPRISES OF GAP-TAHILALAN IRRIGATION UNION

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ABSTRACT - The GAP region enjoys a rather high agricultural potential in terms of its climatic and soil characteristics. Approximately 1.8 million hectares of land will be brought under irrigation in this region. In order to utilise the existing water and land resources of the region in most efficient way, studies on post-irrigation crop patterns and their respective shares are critical in the process of transition from rainfed to irrigated farming. The objective of the present study is to determine the crop design that will ensure maximum returns in a small-scale farm (30 decares) in the Tahılalan Irrigation Union in the Harran Plain under adequate and deficit irrigation conditions. In this context the study determines plant water needs for crops cultivable under given conditions, irrigation plans under adequate and deficit irrigation conditions, necessary inputs and costs gross profit margins. On the basis of this information, the optimum crop design is obtained by linear programming.
Key words: irrigation, land resources, crop pattern, deficit irrigation

INTRODUCTION

In the GAP region we observe irrigation water as the scarcest resource among all necessary inputs for agricultural production. Consequently, the optimum utilisation of this scarce resource is taken as the basis of selecting the most appropriate approach to farming. At present, irrigation unions in the region make their plans for the most economic use of available water resources.

In cases where there is plenty of irrigable land whereas irrigation water capacity is limited and irrigation water is costly, preference can be made for more up-to –date irrigation technologies and restricted irrigation practices. In the latter, instead of seeking maximum yield, some fall in yield is tolerated by restricting the volume of water used for irrigation. Nevertheless, it is still possible, in these cases, to irrigate larger tracts of land with a given water availability and to get higher returns per unit of water used. (1,2). Researchers in this field assert that considerable saving can be made in energy, water and capital and returns to the enterprise can be increased in case the irrigation system is planned with respect to limited water availability (3). It is further stated that farming enterprises working with limited water supply enjoy higher returns per unit of water used despite a fall in returns per unit of land compared to cases where sufficient water is used (4,5).

The irrigation programming envisages determining the number of irrigation, timing and volume of water to be used in each irrigation under given soil, crop and climate conditions. These programmes are important in that they can help use resources optimally and enhance production under both adequate and deficit irrigation conditions (6, 7).

In an enterprise where deficit irrigation is applied, such questions as which crops can tolerate deficit irrigation, which others require full irrigation, possible profit margins, water and labour needs etc. can be answered through the linear programming method in order to achieve the highest possible return on limited water supply (8).

The objective of this study is to determine that particular crop design, which would ensure the maximum return under both adequate and deficit irrigation conditions in a small-scale farming enterprise in Tahılalan Irrigation Union selected as the field of study.

MATERIAL AND METHOD

Material

The survey covers agricultural enterprises comprising the Tahılalan Irrigation Union located in the 1st part of Şanlıurfa-Harran Plains where irrigation was introduced in 1995. There are 12 villages in the union and total irrigated area is 6,538 hectares (Figure 1). Climatic data as measured by Akçakale meteorology station were used in the study. According to these data the average annual temperature in the area is 17.9 ºC and total annual precipitation is 214.8 mm.

Although the Harran Plain is conducive to policulture, low precipitation and its seasonal distribution which does not coincide with the growth period of many crops as well as low relative humidity restricts the culture of some crops. In those parts of the plain where dry farming is practiced, common crops include wheat in the first place followed by lentil, barley and sesame as well as some pistachio orchards and vineyards. In the irrigated parts of the plain the leading crop is cotton followed by vegetables (eggplant, pepper and tomato) and fruits (apricot, prune and pomegranate) (9).

Method

After examining the size of agricultural enterprises in the area, it was decided to work on small farms up to 50 decares (average size is 30 decares) (9).

Considering the climatic features and marketing outlets of the area 20 crops were selected including those grown under both rainfed and irrigated conditions as well as secondary crops.

A single type of soil is assumed since the dominant pattern is clayish soil in the area. The usable water holding capacity of soil is assumed as 150 mm/m, and infiltration rate as 13 mm/h (10).

Calculation of Reference Water Consumption (ETo) Values

The reference water consumption values for Akçakale were calculated through the Penman method (as modified by the FAO) ad the computer software IRSIS was used for this purpose (11).

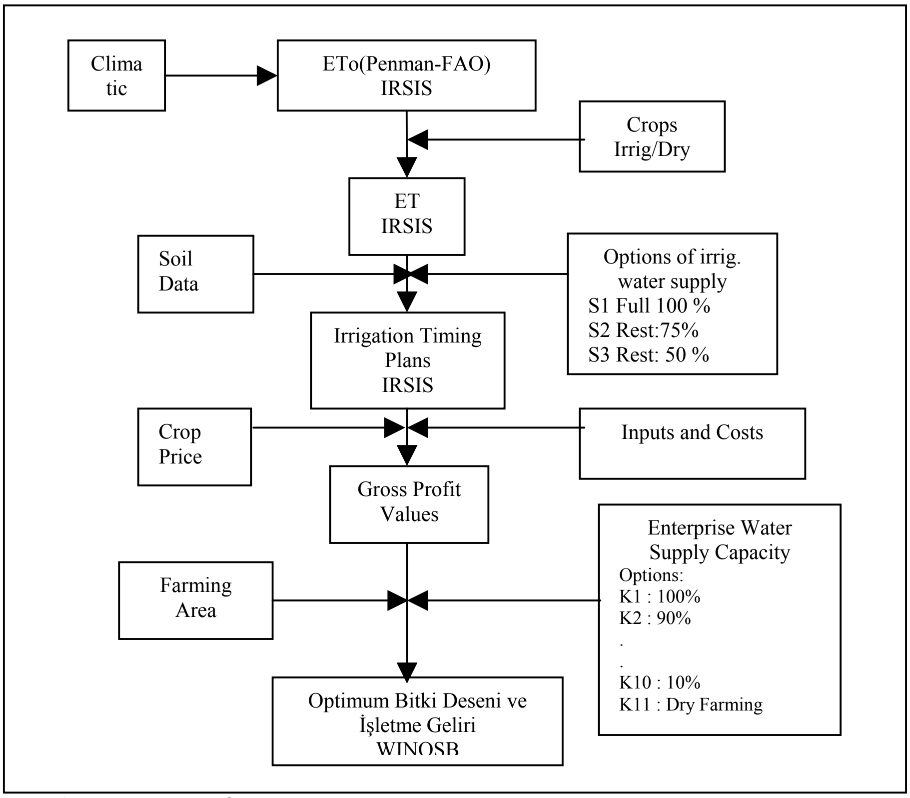

Fig. 1: Work Flow Chart

Developing Crop Water Consumption and Irrigation Programmes under Adequate and Deficit Irrigation

The study sought to obtain plant water consumption and irrigation programmes under deficit irrigation in addition to cases where plant water need is fully met. With respect to the level of satisfying given water needs the following three options were developed as shown in table below.

Table 1. Options Relating to the Volume of Irrigation Water Used in the Model

Symbol	Rate	Comment
S1	100%	The case where full water need of the plant is met
S2	75%	The case where 75 % of water need of the plant is met
S3	50%	The case where 50 % of water need of the plant is met

By using the IRSIS computer software in relation to water supply options given in Table 1, estimates of plant water consumption and irrigation programmes were developed. Firstly, the full satisfaction of plant water need is calculated (100 %) and values related to deficit irrigation are then calculated by taking 75 5 and 50 % of the earlier figure.

Plant file information including kc plant coefficients, ky yield factors, plant root depth and soil moisture level was prepared by referring to the FAO 24, FAO 33 and FAO 56. Seasonal water restriction is applied in the study (12, 13, 14).

Calculation of Gross Profit for the enterprise under Adequate and Deficit Irrigation

Gross profit from individual crops are calculated by subtracting specific variable costs incurred during the production of the crop concerned from gross value of output relating to that crop (9).

Gross profit for crops was calculated on the assumption that family labour would be sufficient and thus no labour cost was considered. However, considering that hiring labour might be necessary in cases where family labour fell short of need, additional labour cost variables were also added to the model (15).

Optimum Crop Design for the enterprise under Adequate and Deficit Irrigation

Linear programming technique was used to reach the optimum crop design in both adequate and deficit water supply conditions (16, 17, 18, 19, 20, 21, 22). The WINQSB computer software was used in the finalisation of linear programming models developed.

Table 2 below gives the 11 options emerging with respect to the irrigation water capacity of the enterprise. As can be seen in this table, K1 stands for the enterprise which is endowed with water capacity needed by the optimum crop design yielding the maximum return. Symbols from K2 to K10 stand for those enterprises where existing water capacity is variably below what is needed. Finally, K11 denotes the enterprise engaged in dry farming. Outcomes were obtained by developing linear programming models for each water capacity level. (15).

Table 2. Water Source Capacity Options Used in the Study

Symbol	Rate	Comment	Symbol	Rate	Comment
K1	100%	Enterprise with required cap.	K7	40%	40% Capacity
K2	90%	90% Capacity	K8	30%	30% Capacity
K3	80%	80% Capacity	K9	20%	20% Capacity
K4	70%	70% Capacity	K10	10%	10% Capacity
K5	60%	60% Capacity	K11	Rainfed	Rainfed farming
K6	50%	50% Capacity			

FINDINGS AND DISCUSSION

Irrigation Programmes Developed under Adequate and Deficit Irrigation

Table 3 gives as an example one of the irrigation programmes for cotton under adequate and deficit irrigation conditions. In adequate irrigation conditions the total volume of water applied is 872 mm and the proportion of actual water use to maximum use is 1.00. Hence, the actual yield (Ya) is equal to maximum yield (Ym). While working on S2, the volume of irrigation water is made equal or close to 872.0 * 0.75 = 654.0 mm. The irrigation programme developed denotes the use of 650.6 mm of irrigation water. Since the crop is confronted with water stress, Eta/Etm = 0.77 and Ya/Ym = 81.4%.

Table 4 summarizes the results of irrigation programmes. The table gives actual yield (Ya) values basing on the volume of seasonal irrigation water (I), number of irrigations (N) and Ya/Ym values. Examining these values we find that as lesser and lesser water is given to the crop, there are parallel decreases in the number of irrigations and yield.

Table 3. Irrigation Programmes Developed for Cotton Farming Under Adequate and Restricted Irrigation Possibilities

Irrigation Conditions	Irrigation	Irrigation Date	Water Used (mm)	Irrigation Interval (day)	Yield (%)
	1	22.05	66.5	-	
	2	05.06	60.7	14	100
	3	15.06	61.3	10	
	4	23.06	59.6	8	
S1	5	30.06	58.3	7	
(100%)	6	07.07	63.7	7	
	7	14.07	64.9	7	
	8	21.07	64.5	7	
	9	29.07	73.1	8	
	10	07.08	78.1	9	
	11	17.08	80.6	10	
	12	28.08	80.5	11	
	13	14.09	60.1	17	
	1	25.05	31.9	-	
	2	04.06	35.7	10	81.4
	3	13.06	39.5	9	
	4	21.06	42.8	8	
S2	5	29.06	47.6	8	
75 (%)	6	06.07	49.0	7	
	7	14.07	54.7	8	
	8	23.07	61.1	9	
	9	01.08	64.3	9	
	10	12.08	72.7	11	
	11	24.08	74.1	12	
	12	08.09	77.3	15	
	1	30.05	26.5	-	
	2	10.06	32.2	11	62.0
	3	21.06	39.1	11	
	4	02.07	46.3	11	
	5	13.07	52.8	11	
S3	6	26.07	62.3	13	
50 (%)	7	10.08	60.4	15	
	8	25.08	57.5	15	
	9	11.09	58.5	17	

Gross Profit of the Enterprise under Adequate and Deficit Irrigation

Gross profit values corresponding to adequate and deficit irrigation conditions were calculated by considering costs varying or not varying with respect to yield (9,15). Production costs independent of yield were calculated under adequate water supply conditions and then applied to other conditions. On the other hand, production costs variable with yield were calculated with respect to the case S1 where actual yield overlapped with maximum yield. Then, for deficit irrigation conditions (S2, S3), this value and ratio (Ya/Ym) were used to obtain production costs variable with real yield.

Table 4 gives gross profit values calculated for all crops and irrigation conditions covered in the study. When these values are examined by taking adequate irrigation as given, it is observed that in

2000 prices eggplant stands as the most profitable crop, followed by green pepper, tomato and water melon.

Table 4: Results of Irrigation Programmes for All Crops Covered in the Study and Corresponding Gross Profit

	Crop and Water	I (mm)	N (no)	Ya (kg/da)	Gross Profit 10^6Tl/da		Crop and Water	I (mm)	N (no)	Ya (kg/da)	Gross Profit 10^6Tl/da
X1	Barley Opt.	131	2	500	35.1	x28	Eggplant Opt.	939	21	5000	366.2
X2	75%	100	1	473	32.8	x29	75%	702	14	3805	274.7
X3	50%	65	1	426	28.9	x30	50%	474	8	2530	175.8
X4	Wheat Opt.	131	2	600	49.6	x31	Onion Opt.	278	6	2500	157.3
X5	75%	97	1	563	46.1	x32	75%	205	3	2300	143.9
X6	50%	65	1	510	41.1	x33	50%	135	2	1995	123.3
X7	Pepper Opt.	883	21	2400	330.8	x34	Clover Opt.	1012	10	10000	116.4
X8	75%	661	10	1858	251.4	x35	75%	761	8	7470	69.1
X9	50%	439	6	1200	154.3	x36	50%	508	8	5390	30.1
X10	Tomato Opt.	1007	24	4500	278.2	x37	Soya II Opt.	543	5	250	41.8
X11	75%	753	14	3344	201.1	x38	75%	406	3	204	28.2
X12	50%	503	9	2174	121.9	x39	50%	270	2	147	10.7
X13	Spinach Opt.	84	4	2500	185.8	x40	S.flower II Opt	568	8	244	29.4
X14	75%	64	2	2173	158.2	x41	75%	437	7	193	19.3
X15	50%	31	1	1548	103.8	x42	50%	284	6	128	6.2
X16	Cabbage Opt.	527	10	1150	131.1	x43	Corn II Opt.	573	8	1000	50.2
X17	75%	395	5	957	103.4	x44	75%	422	6	692	23.9
X18	50%	263	5	719	69.0	x46	Sesame II Opt.	514	4	70	16.7
X19	Water m. Opt.	711	15	4500	264.7	x47	75%	386	3	57	10.2
X20	75%	528	8	3276	176.7	x48	50%	276	3	42	2.7
X21	50%	352	5	2268	104.3	x49	Barley Dry	-	-	250	14.8
X22	Lentil Opt.	138	2	250	45.1	x50	S.flower Dry	-	-	113	5.0
X23	75%	102	1	240	42.6	x51	Wheat Dry	-	-	200	11.6
X24	50%	69	1	224	38.5	x52	Sesame Dry	-	-	30	0.7
X25	Cotton Opt.	872	13	350	100.8						
X26	75%	651	12	285	77.0						
X27	50%	436	9	217	52.1						

Examining gross profit values with respect to irrigation water used, it is observed that gross profit values tend to fall as the volume of irrigation water applied falls. Since negative gross profit emerges in corn (second crop) under S3 mode of deficit irrigation, this was excluded from the model.

Optimum Crop Designs for the Enterprise under Adequate and Deficit Irrigation

The linear programming model for an enterprise with adequate irrigation water capacity (K1) is given in Table 5.

Values relating to maximum cultivation possible for crops under dry and irrigated farming conditions were derived from values given by Dernek and Erdem (1993) (23) as well as information provided by the Urfa Directorate of Rural Services and faculty staff from the Department of Agricultural Economics, Faculty of Agriculture, Ankara University. The model was further refined in terms of given capacity by considering second crops and rotation.

As far as restrictions relating to labour force capacity, relevant variable coefficients were the labour force need of each crop and the sum of family labour force capacity and the variable relating to the availability of temporary labour in the period concerned. Variable coefficients relating to irrigation water restrictions in 10-day periods were irrigation water need of each crop corresponding to each period and, in terms of capacity, a value greater than what is needed for adequate water supply. Following the solution of the model and obtainment of optimum crop design, the volume of irrigation water needed for this optimum design under adequate water supply conditions (K1) was calculated in terms of values corresponding to enhanced capacity in peak periods.

Table 5: Linear Programming Model for Adequate Water Capacity

Function

$35.1*10^6 X1 + 32.8*10^6 X2 + \ldots + 0.7*10^6 X52 - (0.5*10^6 X53 + \ldots + 0.5*10^6 X61)$

II. **Restrictions**

A. Restrictions relating to cultivation area (da)

1. I. Cultivation area

X1..X6 + X22..X24 + X49 + X51 <= 0.50*30

2. II. Cultivation area

–(X1..X6) – (X22..X24) – X49 – X51 + (X37..X48) <=0

3. Rotational restriction

X7..X21 + X25..X36 + X50 + X52 <= 0.50 * 30

4. Restriction on clover culture area

X34 + X35 + X36 <= 0.10 * 30

5. Restriction on vegetable culture area

X7..X18 + X28..X33 <= 15

6. Restriction on dry farming land

X49 + X51 <= 0.50 * 30

X52 + X50 <= 0.50 * 30

B. Labour restrictions (sa)

1. March. 2.95 X1 + 2.95 X2+....+ 11.08 X33 + 0.05 X49 + 0.06 X51 <= 559
2. April. 8.1 X7 + 8.1 X8+.....+ 2.05 X32 + 5.42X34 +..+ 5.42X36 <= 559

..

11. November. 80.62 X13 +....+44.63 X15 + 0.19X31+....+0.50 X36 +...+ 0.86 X52<=674

C. Irrigation water restrictions (m^3)

1. April1. 61.3 X31 <= 5000
2. April2. 67.9 X1 + 67.9 X4 +......+ 55.0 X36 <= 5000

.....

.22. November1. 5.6 X13 <= 5000

In cases where there is shortage in irrigation water capacity (K2, K3, K4, K5, K6, K7, K8, K9, K10 and K11), values obtained by multiplying the K1 value by ratios given in Table 2 stand for irrigation water capacity values in the model. Table 6 gives optimum crop designs and enterprise revenues under adequate and deficit irrigation conditions as obtained from the solution of linear programming models constructed through similar methods.

The optimum crop design in K1 (100% water capacity) gives wheat culture on 15 decares of land and eggplant on another 15 decares of land. Both of these crops make up the crop design possible under the culture area restriction adopted in the model. Corn culture on 15 decares of land finds its place in the design as the second crop. This optimum crop design under adequate water supply is based on S1 where all water need of the crop concerned is satisfied. In K3 where the irrigation water capacity of the enterprise falls to 80 %, the crop design envisages both adequate and deficit irrigation conditions. In K10 where irrigation water capacity is as low as 10 %, dry farming finds its place in the design and furthermore, uprooting and cleaning spinach in November make it necessary to find additional labour force in this month when labour supply capacity is actually low. Finally, in K11 where dry farming is practiced, the crop design allowed by given restrictions includes barley and sunflower, each grown on 15 decares of land.

Table 6: Optimum Crop Designs under Adequate and Deficit Irrigation

Variable No	Crop Type and Water	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11
x4	Wheat Opt.	15.0	15.0	15.0	15.0	15.0	15.0	11,14	8,35	5,57		
x5	Wheat 75%							3,86	6,65	6,3	3,15	
x6	Wheat 50%										2,69	
x7	Pepper Opt.						0,7	3,13	2,34	1,56	0,78	
x13	Spinach Opt.							1,03	4,52	8,01	11,51	
x23	Lentil 75%									0,54		
x24	Lentil 50%									2,59	4,43	
x28	Eggplant Opt.	15	15	15	15	15	14,3	10,85	8,13	5,42	2,71	
x37	Soya II Opt.		2,52	3,4	2,13	0,86						
x39	Soya II 50%					1,85	1,7	2,37	1,78	1,19	0,59	
x43	Corn II Opt.	15	12,48	9,86	6,92	3,97	1,11					
x44	Corn II 75%			0,13	0,86	1,59	1,62					
x46	Sesame II Opt.			1,12	2,34	1,48	0,76					
x49	Barley Dry										4,73	15
x50	S.flower Dry											15
x61	Labour, Nov.										253,7	
Total area under the culture of the first crop (da)		15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Total area under the culture of the second crop (da)		15.0	15.0	14.51	12.25	9.76	5.17	2.37	1.78	1.19	0.59	-
Enterprise Revenue (10^9 TL)		6.99	6.97	6.90	6.77	6.56	6.34	5.95	5.33	4.69	3.77	0.30
Water Source Capacity (m^3/10 day)		3058	2754	2448	2142	1836	1530	1224	918	612	306	-
Total Irrigation Water Used (m^3)		26475	26090	25394	23669	21369	18463	15498	12278	9038	5150	-

Examining Table 6 in terms of enterprise revenues, we observe that as a response to falling irrigation capacity enterprise revenues first fall very slowly and then rather rapidly. It is interesting to note that returns to an enterprise working with 10 % irrigation capacity are equivalent to 50 % of the revenue of an enterprise working with 100 % irrigation water capacity while the former enjoys 12 times as much return as a dry farming enterprise can obtain. It should still be noted that it is essential, to attain these results, to apply limited irrigation water at times and volumes specified in the irrigation timing plan. There may be significant falls in both yield and returns if an enterprise with limited irrigation water supply opts for a crop design other than what is found optimum and makes mistakes in the timing of irrigation and volume of water applied.

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Specific objectives of the Project are:

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