OPTIONS méditerranéennes

Dialogues on Mediterranean water challenges:

Rational water use, water price versus value and lessons learned from the European Water Framework Directive

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FOREWORD

Managing water resources and demand in the Mediterranean area is changing dramatically these recent years. There are many components to this change: a shift away from sole reliance on finding new sources of supply to address perceived new demand; a growing awareness on the importance of preventing and mitigating water conflicts; a growing emphasis on incorporating ecological values into water policy; a re-emphasis on meeting basic human needs for water services and associated social issues; and a conscious breaking of the ties between economic growth and water use mitigated through economic instruments and allocation of scarce water for higher value activities, usually at the expense of certain forms of agriculture. A reliance on physical solution continues to dominate traditional water planning approaches, but this approach is facing increasing opposition due to the progressive consciousness of the negative long term ecological impact of some of these solutions. At the same time, new methods are being developed to meet the demand of growing population in the Mediterranean without requiring major new construction or new large-scale water transfers. Focus is gradually shifting to explore efficiency improvements as a mean to save resources, implementing options for managing demand and reallocating water among users to reduce gaps and meet future needs. A meaningful change towards a new approach and a new way of thinking has to begin with an open discussion of the ultimate ends of water policy. It is time now to place a high value on maintaining the integrity of the ecosystem when using water resources. There are growing calls for the costs and benefits of water developments to be distributed in a more equitable manner. And more and more efforts must be made to understand and meet the diverse interests and needs of all relevant stakeholders. As an alternative to new infrastructures, efforts are now underway to rethink water planning and management, putting emphasis on the principles of integration between water policy and the three main dimension of sustainable development: environmental, cultural, social and economic. However, also the new alternative approaches fail if they are not consolidated through the exercise of participatory management, communication among interested stakeholders, water players and citizens, application of subsidiarity, building of a common knowledge, and increasing mutual awareness of interested parties.

Unfortunately, besides the impact on the ecosystem due to the natural water withdrawal, the situation shows today that water production systems (urban, agricultural, and industrial) perform poorly in the Southern and many parts of the Northern and Eastern Mediterranean. In many places, lack of policies or low awareness and inadequate management has led to dramatic misuse and misallocation of water in the different uses. There is a need to deal with the local and regional management of water resources within a comprehensive framework, in which policies can be formulated, project can be prepared and integration can be envisaged applying as much as possible the "subsidiarity principle" and its application at the river basin level and even beyond. Without sufficient water supply, any intensification of urban, agricultural and industrial inputs and outputs remains a risk to be avoided, especially by low-income water users (like for example farmers or small communities). To secure water is also a precondition for the application of modern low-water consumption technologies. Management needs to be improved, both at users and system levels. In practice, these improvements will continue to prove hard to realise, and they will require more time to debate and consensus reaching than improvements in the physical infrastructure and techniques.

However, regardless the type of water resources developments pathways, the most recent literature and field experience have revealed the need for integrated efforts in water management supported by national institutions and both regional and international organisations, focusing on the following points:

- establishment and application of water management policies coherent with the emerging need of ensuring sustainable development;
- developing coherent national-regional policies that include strategies of developing limited water resources;

- improving the efficiency of public administration at the local and central level;
- appraising water actions from the point of view of culture, economics, environment (including health);
- overseeing the promotion and enforcement of national legislation by applying, if necessary, sanctions for damages to the aquatic environment;
- setting guidelines for best practices;
- setting new and more coherent water pricing and/or operation and maintenance cost recovery depending on each country's socio-economic characteristics; and water governance;
- creating a knowledgebase to settle water competition among users and at trans-boundary scale;
- promote at all levels of the education system awareness on the water problems and its management, in order to raise the societal water culture.

Project MELIA has pursued along its development the following objectives:

- Building a knowledge base for integrated water resources management (IWRM) planning, based on integrating contributions from the wider spectra of perspectives, able to be used by the large spectrum of stakeholders and based on the general frame defined by EU Water Framework Directive.
- Develop a Mediterranean-wide awareness of the social (cultural and participatory), economic and technological issues related to water management.
- Propose participatory mechanisms and prevention tools to avoid competition in resources allocation between regions states and different waters users.
- Provide legislative and administrative bodies with criteria and arguments agreed in a consensual way by a wide representation of social, economic, scientific and political actors from different countries, to support sustainable water policies and economy.
- Provide the intellectual basis and the indicators to perform a benchmarking exercise of Integrated Water resources management in the Mediterranean area.
- General terms referred to IWRM are used with different meanings and implications. The same term is often used with different meanings or id differently interpreted by actors involved in water use and management. Therefore, beside the construction of a common frame and knowledge, also the use of common terminology and semantic will be talked in the dialogue of MELIA, in order to facilitate the development of a common language and help water negotiations.

The targeted objectives intend to cope with the fact that managing water resources and demand in the Mediterranean area is changing dramatically these recent years. There are many components to this change: a shift away from sole reliance on finding new sources of supply to address perceived new demand; a growing awareness on the importance of preventing and mitigating water conflicts; a growing emphasis on incorporating ecological values into water policy; a re-emphasis on meeting basic human needs for water services and associated social issues; and a conscious breaking of the ties between economic growth and water use mitigated through economic instruments and allocation of scarce water for higher value activities, usually at the expense of certain forms of agriculture.. At the same time, new methods are being developed to meet the demand of growing population in the Mediterranean without requiring major new construction or new large-scale water transfers. Focus is gradually shifting to explore efficiency improvements as a mean to save resources, implementing options for managing demand and reallocating water among users to reduce gaps and meet future needs.

A meaningful change towards a new approach and a new way of thinking has to begin with an open discussion of the ultimate ends of water policy and water economy. It is time now to place a high value on maintaining the integrity of the ecosystem when using water resources. There are growing calls for the costs and benefits of water developments to be distributed in a more equitable manner. And more and more efforts must be made to understand and meet the diverse interests and needs of all relevant stakeholders, starting from the citizens rights. Many of the Mediterranean developing countries suffer from the lack of funds necessary to establish water development projects and plans, which if not seriously considered would lead to aggravation of the economic problems. Upgrading the efficiency of existing municipal and irrigation water supply systems requires new investments that are not easily available. Financing of the systems and tariff collecting for system maintenance is an important constrain to the water management. The formulation of a common conceptual frame must give emphasis to developing new sources of funds to supplement the traditional dependence on national budgetary allocations. As an alternative to new infrastructures, efforts are now underway to rethink water planning and management, putting emphasis on the principles of integration between water policy and the three main dimension of sustainable development: environmental, cultural, social and economic There is today an increasing awareness of the need of benchmarking in the water sector of different countries. Benchmarking exercise is encouraged in the new EC Framework Program R&D to assess sector policies effectiveness and impact, physical and non physical state, to enhance spatial replication of good sector policy practices to pursue regionalization, standardization and integration, the same approach could be used in the Mediterranean Countries. But the new alternative approaches will fail if they are not consolidated through the exercise of participatory management, communication among interested stakeholders, water players and citizens, application of subsidiarity, building of a common knowledge, and increasing mutual awareness of interested parties.

The literature is plenty of models for the implementation and application of adequate water pricing and tariff schemes-strategies. These models have been formulated and re-formulated in many years for their application in developed and developing countries. In spite of that, many problems still exist particularly in many developing countries of the Southern Mediterranean and many southern-most parts of the Northern Mediterranean. Chief among these approaches are measures that seek to mobilize local funds, in particular under the “user pays” and “polluter pays” principle. However, the absence in most countries of modern utilities that meter and charges for their services, coupled with the ineffectiveness of most regulatory controls, limit the source of income and the possibility to fully implement tariff scheme. Needless to mention the strong social and cultural perception in some countries of water as a gift from god or nature. Consensus on shared frame must address the re-assessment and appraisal of economic, cultural and environmental values of water. The introduction of irrigation charges is very important for good. Misuse of water in agriculture is widespread in current irrigation management practices. This is due mainly to the failure in the past to recognize water’s economic value and the real cost of water. It is therefore important to formulate a new-common conceptual frame and strategy based on the fact that managing water as an economic good is an important tool to achieving efficient and equitable water use by all demanding stakeholder: agriculture, industry, tourism and urban development as well as encouraging the conservation and protection of scarce water resources.

Some solutions lie outside the conventional “hydrology” concepts. Trade and negotiated change in practices enabled by multi-stakeholder dialogue is the way forward, thus further increasing the importance of political processes, the definition of water value and the knowledge and enabling conditions for such definition.

Prof. Rafael Rodríguez-Clemente | **Dr Cosimo Lacirignola**

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The growing population of the world together with the impact of climate change will make water policy the big issue of this century. Water issues are long term problems that need long term solutions. These solutions are partly technical, but in many cases they depend on policy decisions or the behaviour of water users.

Water scarcity is the issue (nearly) all papers are dealing with. Generally the papers agree on the fact that water demand management is required, both in drinking water, but definitely also in irrigated agriculture. One of the ways to achieve this would be by making people more aware of the value of water, as a source of life and health, a part of culture, a requirement to grow food but also a sustainer of nature and the environment.

Water issues need to be viewed in their entirety: not just water demand, but also water availability; not just irrigation water, but also drinking water; not just water quantity but also water quality. This notion has lead to the development of the concept of Integrated Water Resource Management. Due to the complexity of integrated water resources management, a need has arisen to develop adequate indicators to assess the extent of the problem and explore policy alternatives. The concept of Rational Use of Water, as discussed by Kolberg and Berbel and Mandi and Moujabber, and the review of indicator sets by Lutter are the focal point of the first part of this volume. The following two papers give examples of rational water use: Omrani and Ouessar for the oasis in Tunisia, and Elkassar and El-Fotouh for Egypt. Groundwater pollution as a threat to RUW, by Ghreib *et al.,* and water use in ancient times by Buxó complete this part.

The second part deals specifically with the issue of the value of water and the price that is asked to users of this water. Water pricing is a disputed issue. Some believe that water cannot be priced by all, but perhaps the service of providing water can be priced. Shatanawi and Naber demonstrate that water value is different from the water costs. Demir *et al.,* provide a method that indicates what costs can be recovered from users, based on an index of the living standard of the users. Polycarpou describes a mathematical approach to establish a water price taking into account the social and economical situation of users as well as the availability of water. Finally Giannoccaro *et al.,* report their findings on optimization methods to compare the efficiency of various price policy options.

The third and final part concerns the Water Framework Directive. This directive is a vital piece of law for member countries of the European Union, but its concepts are a source of inspiration for many other countries, close to Europe but also far away in China and the USA. The implementation of the WFD in Italy is the subject of the paper by Rana *et al.*, Abdin compares the requirements of WFD with Egyptian water policy as does Choukr-Allah with the Moroccan.

First part

Rational use of water
and development of indicators

Defining rational use of water in Mediterranean irrigation

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Abstract. Rational use of water (RUW) is a catch-all term that takes in a wide variety of water use dimensions and is a frequently referred to in water planning, science and the public debate. In spite of this general adoption, the term lacks a unitary conceptual foundation. The aim of the paper is to provide a conceptual starting point for developing a practical working definition of RUW in the context of irrigation in the Mediterranean in order to facilitate dialogue and water negotiations. The paper shows that the concept of RUW is relevant to irrigation as water scarcity and pressures on water are increasing. At a micro-level (household, farm and community level), the definition includes maximising profit, water use efficiency and productivity; at a meso-level (institutions, river basin, infrastructure) to achieve an equitable and economic efficient allocation that does not increase the conflict level between competing uses; while at a macro-level (legal, national and international policy) sustainability and food security appear to be core aspects of RUW. Although multi-dimensional indicator have advantages, they are also rather complex. The paper therefore presents a number of single dimensional indicators that can potentially be used to measure RUW.

Keywords. Irrigation – Efficiency – Productivity – Indicators

Définition d'une utilisation rationnelle de l'eau pour l'irrigation en Méditerranée

Résumé. *L'utilisation rationnelle de l'eau (UReau) est un terme générique recouvrant une large variété de dimensions de l'utilisation de l'eau. La gestion de l'eau, les sciences de l'eau et le débat public font référence à ce terme. Bien que largement usité, il ne désigne pas une notion conceptuelle unitaire. Le but de ce document de réflexion est de fournir un point de départ conceptuel au développement d'une définition de travail pratique de l'UReau dans le contexte de l'irrigation en Méditerranée afin de faciliter le dialogue et les négociations sur l'eau. Ce document de réflexion montre que le concept d'UReau revêt une grande importance pour l'irrigation en raison de la raréfaction des ressources en eau et des pressions croissantes sur ces ressources. Au niveau local (ménages, fermes, populations locales), la définition inclut la maximisation de la rentabilité, de l'efficacité de l'utilisation de l'eau et de la productivité. Au niveau intermédiaire (collectivités, bassins fluviaux, infrastructure), l'objectif est de réaliser une distribution équitable et économiquement efficace qui n'augmente pas le niveau de conflit entre les utilisations concurrentes. Au niveau global (politiques légales, nationales et internationales), la durabilité et la sécurité alimentaire sont des aspects clés de l'UReau. Bien que des indicateurs multidimensionnels offrent des avantages, ils sont également complexes. Ce document de réflexion présente par conséquent un certain nombre d'indicateurs unidimensionnels susceptibles d'être utilisés pour mesurer l'UReau.*

Mots clés. *Irrigation – Efficience – Productivité – Indicateurs*

I – Background

'Water is abundant globally but scarce locally.'
Rosegrant (1995)

1. Water scarcity in the Mediterranean region

The Mediterranean region comprises the countries surrounding the Mediterranean Sea (plus Portugal)[1]. The Mediterranean Sea literally means the 'sea between lands'. It is the largest of the semi-enclosed European seas and it is surrounded by 22 riparian countries and territories having shores on three continents (Europe, Africa and Asia). In 2008 these countries and territories accounted for 5.7% of the world's land mass and 7% of the world's population with 460 million people out of which two thirds are urban; 60% of the population of the world's 'water-poor' countries; 12% of world GDP[2]; 30% of international tourism with 275 million visitors; and 8% of global CO_2 emissions. Moreover, the Mediterranean water demand has doubled since 1950 to reach 280 km^3 per year in 2007 (UNEP/MAP-Plan Bleu, 2009). Within this region, the Middle East and North Africa are the most water-scarce regions of the World. The aquifers are over-exploited; water quality is worsening and water supply is often restricted affecting human health, agricultural productivity and the environment. Water scarcity leads to tensions within communities and migration in search of better opportunities. As the population grows in this region, per capita water availability is expected to decrease by 50% by 2050 and climate change is predicted to result in more frequent and severe droughts and floods (The World Bank, 2007). In recent years, there has been a growing concern throughout the Mediterranean region regarding drought events leading to water scarcity problems. Here, the semi-arid/arid climate enhances water scarcity and rainfall is the main source of recharge. The competition between various uses, especially agriculture and tourism, is high in this area that relies on both for its GDP. Hence, conflicts over water are increasing and they are complex, involving competition among alternative uses, among geographical regions with disparate water endowments, and between water resource development and other natural resources lost due to that development. The challenge of water use and allocation is already a major political concern and will most likely amplify in the coming years. 'Integrated water resource management' is high on the policy agenda and affects people in their daily life. As the water resource is becoming scarce and/or is deteriorating, it becomes clear that plentiful water of good quality can no longer be free to all who desire to use it and a more in-depth understanding of water resource use and its consequences is needed.

2. Irrigation trends

At a global level, agriculture is by far the largest user of water diverted by man. In the Mediterranean region agriculture accounts for 64% of total water demand, followed by industry (including the energy sector) at 22% and the domestic sector with 14%. Crop production is essentially rain-fed. Irrigation water demand varies from 5,000 m^3 ha^{-1} per year in the north to almost twice that much (9,600 m^3 ha^{-1} per year) in the south and east (UNEP/MAP-Plan Bleu, 2009), depending on irrigation techniques, water use efficiency and climate conditions. Irrigation water accounts for over 50% of water use in all countries in the region apart from those in the eastern Adriatic and France, reaching almost 90% in Syria and Morocco (see Annex 2). The countries or territories in the region share many common features including: arid and semi-arid climate with hot summers, mild winters, and wet falls and springs; limited water resources, agricultural development limited by water availability and high socio-economic value of water. Crop production is in particular vulnerable to climate change due to predicted deficits in available water resources and threats of farm land degradation. In April 2009 the European Commission published the White Paper: 'Adapting to climate change: Towards a European framework for action'. This policy paper presents the framework for adaptation measures and policies to reduce the European Union's vulnerability to the impacts of climate change, including specific strategies aimed at agriculture. Most of these adaption measures are aimed at national, regional or local level to address the regional variability and severity of climate change impact. Several studies show that the efficiency of water use in agriculture is low[3], though some locations and crops have high efficiency and productivity (Berbel *et al.,* 2011a). Still, to improve water use is crucial for the Mediterranean irrigation. Although 'rational use of water' (RUW) is a term that is frequently referred to in water planning, science and the public debate when water grows scarce, it continues to be an ill-defined catch-all term that takes in a wide variety of water use dimensions as it lacks a unitary conceptual foundation. The aim of the paper is to provide a conceptual starting point for developing a practical working definition on RUW in the context of irrigation in the Mediterranean region to facilitate dialogue and water negotiations[4].

The paper is divided into four parts. First, a background on Mediterranean water resources and irrigation is given. Second, we continue with a review of the historical-philosophical background of the concept of rationality, followed by an analysis of the dimensions of ´rational use of water´ on, respectively, a micro-, meso- and macro-level. Third, we describe selected indictors that could be used to define the rational use of irrigation water in terms of efficiency and productivity. Fourth, and last, we present some concluding remarks.

II – Rationality

'The irrationality of a thing is no argument against its existence, rather a condition of it.'
Friedrich Nietzsche (1844 - 1900)

1. What is understood by rationality?

Rationality normally refers to human or institutional behaviour or situations where decisions are involved. If a chosen action or means is favourable to accomplish a purpose or goal, they are regarded rational; otherwise, they are regarded irrational. Behaviour which is arbitrary or random is normally judged as irrational. Nevertheless, purposes and goals can themselves be judged rational or irrational, with reference to other relevant means-ends relationships. In economics, sociology and political science, a decision or situation is often considered rational if it is considered optimal, and individuals or institutions are often called rational if they tend to act somehow optimally in achieving their goals. Regarding rationality in this manner, the individual's goals or motives are taken for granted and not made subject to criticism, ethics, fairness and so on. Hence rationality simply refers to the success of goal realization, whatever that goal consists of. Sometimes, rationality is equated with behaviour that is self-interested to the point of being selfish. It can be claimed that because the goals are not important in definition of rationality, it really only demands logical consistency in choice making.

2. Economic Rationality

In neo-classical economy individuals' preferences are revealed by the choices they make and efficiency and consistency of choice reflect rational behaviour. The criteria of social interest is usually expressed in terms of the pareto criterion where a pareto optimum situation is one where it is impossible to make any individual better off (´more preferred´) without making someone else worse off (´less preferred´). Critics to neo-classical theory of self-interested rationality argue that individuals are capable of altruistic acts and that an extended notion of rationality is necessary (Pearce and Turner 1990). Extended rationality could be understood in terms of multiple preferences rankings within a single individual – one self-interested and the other altruistic (group interested). As a result, moral considerations will then determine a ´meta-ranking´ of alternative motivation where the individuals possess a sense of community which is reflected in a willingness to view assets and resources as common pool. This extended rationality also generates a strong commitment to abide by particular laws which are seen by the individual as endorsing an individual's meta-preferences, despite a potential conflict between the law and the narrow-self interest (Ibid.). Thus, a choice is rational if it is consistent with the objectives and preferences of those making the decision, given the available information. An allocation choice is economically rational if it is seen as yielding a benefit that exceeds the opportunity cost. In other words: when a choice is made from among competing options that is anticipated to yield net benefits that exceed the opportunity cost. When a scarce resource, good, or service is allocated to one use, the opportunity cost of that allocation represents the value of the best alternative that was foregone.

From the perspective of economics, individuals are sometimes considered to have perfect or at least bounded rationality: that is, they always act in a rational way, and are capable of arbitrarily complex deductions towards that end. That is to say, they will always be capable of thinking through all possible outcomes and choosing the best possible thing to do (full information). Economic rationality is closely related to economic efficiency which is a general term to capture the amount of waste or other undesirable features. Herbert Simon introduced the term bounded rationality in the 1950s to designate rational choice that takes into account the cognitive limitations of both knowledge and cognitive capacity (See e.g. Simon, 1982). Hence, theories of bounded rationality relax one or more assumptions of classical utility theory. Bounded rationality is an important theme in behavioural economics and it is related to how the actual decision-making process influences decisions. Kahneman and Tversky (1979) developed the prospect theory that can be seen as an alternative to expected utility theory and aims at modelling real-life choices, rather than optimal decisions. In summary this theory claims that people's attitudes toward risks concerning gains may be quite different from their attitudes toward risks concerning losses. Though this is not necessarily irrational, it is important for analysts to acknowledge the asymmetry of human choices.

3. Rational Use of Water

'All science depends on its concepts. These are ideas which receive names.
They determine the questions one asks,
and the answers one gets. They are more fundamental than the theories which are stated in terms of them.'
Sir G. Thompson (1892 – 1975).

Water demand management under scarcity is challenging. Improved performance in water use and water saving is key to meet the general objectives of economic efficiency, environmental conservation and community/consumer satisfaction. Socially, efficiency looks after the interests of future generations; environmentally, sustainable use of water ensures good ecological status and minimum flows; and economically, water efficiency reduces business costs and defers costly investment in water supply development and sewage treatment capacity expansions. Water policy should be designed in a way that reduces the conflict level between competing uses and ensures environmental sustainability. As stated before, RUW is commonly referred to, but is not a very well defined general concept. What RUW is depends upon the academic field we refer to, stakeholder groups, what level we operate and the interdependence between these levels.

For defining RUW for the irrigation sector we suggest three different levels of analysis:

a. Micro-level (household, farm and community);

b. Meso-level (infrastructure, institutions, river basin); and

c. Macro-level (legal, national and international policy).

On a micro-level, household, farm and community level, the main objective is water productivity and efficient use of water; on a meso-level (infrastructure, institutions, river basin) the main goal is to achieve a territorial and social efficient and equitable allocation of water and to reduce conflict level between competing uses, while on a macro-level (legal, national and international policy) sustainability and food security are core objectives. Table 1 attempts to give an overview on rationality at different levels for the sector of irrigated agriculture.

Table 1: Micro-, meso- and macro-levels of RUW in irrigated agriculture.

Level	Type	Field of Research	Rationality	Research objective
MICRO	Crop	Physiology, agronomy	Optimal use of water	Water efficiency and productivity, drought tolerance
	Plot or Field	Agronomy, hydrology	Maximize resources productivity	Efficiency of irrigation systems and crop management, i.e. minimising losses, maximize technical productivity
	Farm and household	Agronomy, crop level economy, social science	Optimal crop management plan, individual households preferences and capabilities in allocation of productive assets	Livelihood strategies, especially profit maximization and risk minimization.
MESO	Irrigation scheme	Agriculture Engineering	Technical and economical	Irrigation efficiency and cost minimization
	Basin	Socio-economic and environmental science	Economical, social, environmental, territorial, cultural (water rights) and regional.	Efficient and equitable water allocation, hydrological models (basins and aquifers), conflicting environmental and socio-economic objectives
	Institutions	Social science	Social efficiency[a]	Maximize present value of stakeholders benefits, public choice models, conflict resolution
MACRO	Country	Socio-economic policy	Economic and social allocation	Transfer conflicts, food security and maximize economic and social welfare
	International	International policy	Political consensus	Fairness, ethics
	Planet	Sustainability, climate change	Ethics and comparative advantages	Global sustainability

[a] *Many vital socio-cultural and environmental benefits cannot be monetized, and these would have to be taken into account in order to judge what Barbier (1990) calls the "social efficiency" of the system.*

A. Micro level

At field and community level, water is by many considered a main production factor and RUW is often closely linked to efficiency and productivity of water. Efficiency generally refers to the condition of minimal waste (Hackett, 1998) and productivity, normally, is a ratio referring to the unit of output per unit of input (Kijne *et al.,* 2002). The term water efficiency was probably first introduced by Viets (1966). In economic terms what we are looking at is a ratio between a desired output (yield, economic returns) and a parameter estimating input use. However, because of the different connotation attached to the term 'efficiency', some authors claim that it has outlived its usefulness (see e.g. Seckler *et al.,* 2003). Economists refer to total factor productivity as the value of output divided by the value of all inputs. However, the concept of partial productivity is widely used by economists and non-economists alike. Water productivity can be expressed in general physical or economic terms as follows (Seckler *et al.,* 1998):

- Pure physical productivity: quantity of the product divided by the amount of water depleted or diverted.
- Combined physical and economic productivity: either the gross or net present value of the crop divided by the amount of water diverted or depleted.
- Economic productivity: gross or net present value of the product divided by the value of the water diverted or depleted, which can be defined in terms of its value or opportunity cost in the highest alternative use.

Zoebl (2006) argues that the term water productivity is not always meaningful or appropriate to use and should be reserved for genuine production factors such as labour, land and capital. Furthermore, in contrast to fertilizers, pesticides and animal feeds, irrigation water is generally not a purchased input provided by individuals or corporations (Zoebl, 2002). He claims that irrigation efficiency and water use efficiency are still useful and meaningful terms given that they are well defined and used at the level of individual farmers (Zoebl 2006). Alternative concepts have been introduced in recent years, e.g. consumed fraction (Willardson *et al.,* 1994); beneficial and non-beneficial depleted or consumed fractions (Perry 1996; Clemmens and Burt 1997; and Molden 1997). These new terminologies are used in the context of water accounting relating to the engineers view of 'efficiency', though the definition and interpretation of these new terminologies still remain to be widely understood.

Rain-fed agriculture predominates in the Mediterranean region; however, it is on irrigated land that the highest productivity gains have been obtained. Accordingly, although the areas of arable land and permanent crops tended overall to stabilise if not decline from 1961-2005, the annual average growth rate for irrigated land remained unchanged and the total irrigated area in the Mediterranean countries has thus doubled in 40 years to exceed 26 million hectares in 2005, i.e. over 20% of all land under cultivation. Albeit that total agricultural production in the Southern and Eastern Mediterranean countries (SEMCs) has made a huge progress over the past 40 years through improved forms of production; yet, these countries are more and more dependent on secure food supplies (UNEP/MAP-Plan Bleu, 2009).

According to the neoclassical definition of externalities, most water problems in irrigation sector stem from situations where clear misalignments exist between farmers' private objectives and more general social objectives. The presence of divergences between private and social objectives is manifested by various trends. One is the widening of the divergence between farmers' low water marginal productivity in irrigated commodity production and the sum of the costs incurred by society for making the resources available to them (except for the case of high-value crops). Another is the confirmation that the water costs of competing users may be rising as a result of farmers' water use or polluting practices.

The manifestation of adverse incentives is perceived through time and not with snapshots. This implies that policy judgments should preferably be based on whether observed trends show improvements or are worsening, however, consistent time-series data are often difficult to obtain.

B. Meso- level

At meso- or intermediate-level we consider structures, institutions and river basin. Irrigation systems in many countries will more and more need to find ways to improve performance as the pressure on available water resources is increasing. The need to improve irrigation and drainage sector is driven by several factors (Malano 2004):

- Population growth leading to a need for greater agricultural production
- Increasing water scarcity within river basins leading to a need for irrigated agriculture to produce ‘more crop per drop’
- Higher expectations from farmers and their families to their livelihoods
- Higher expectations by farmers of the level of service provided by the irrigation and drainage agency
- Changing perceptions, attitudes and practices within government on provision of public services.

People engage in irrigation to secure their basic needs and to earn income; however their activities depend greatly on their access to land, labour, water, markets, knowledge and capital, which are the main resources in irrigated agriculture. Within any given culture, access to resources varies according to gender, age, wealth, caste and ethnicity, and therefore, so does livelihood. When water is locked into uses that are no longer high-valued inefficiency abounds, or when the distribution of resource use cannot adapt to changing economic conditions conflicts increases. In most places in the world, water has up till now been treated as a free resource to the effect that no charge is imposed for withdrawing water from a surface or groundwater source. The users have only paid for the transport of water from its source to its place of use, and sometimes for treatment of the water and disposal of the return flows. Traditionally, restrictions in many areas have limited or banned the possibilities of water users to trade or sell their water rights. Water rights systems in many places have allocated water rights based on historical claims. Traditional water right systems often gave many water users a low incentive to increase their water use efficiency, particular for those with historical rights. The introduction of water markets could allow water users to sell the unused share of their water rights to another user, providing an incentive to improve the efficiency of their water use (Schoengold and Zilberman, 2004).

C. Macro level

At the macro level, international and national policies determine resource availability and distribution, such as water resource policies; international funding and loan agreements; legal arrangements, etc. A policy can be Pareto-efficient compared to the status quo when it makes some people better off and nobody worse off. In contrast, a proposed policy is potentially Pareto efficient compared to the status quo when it generates net social benefits that could potentially be used to compensate those made worse off.

In year 2000, the European Union[5] adopted the Water Framework Directive (WFD) as a response to the numerous, and increasing, pressures on the European water resources. The Directive (2000/60/EC) is probably the most ambitious effort for a common integrated management of natural resources in the union (Berbel and Gutiérrez, 2004) and sets the clear objective that ‘good status’ must be achieved for all European waters by 2015. The Water Framework Directive proposes regulating the use of water and of associated areas on the basis of their capacity to withstand different kinds of pressures and impacts. It thus intends to promote and guarantee a responsible, rational and sustainable exploitation and use of the environment:

> ‘*As set out in Article 174 of the Treaty, the Community policy on the environment is to contribute to the pursuit of the objectives of preserving, protecting and improving the quality of the environment, in prudent and rational utilisation of natural resources, and to be based on the precautionary principle and on the principles that preventive action should be taken, environmental damage should, as a priority, be rectified at source and that the polluter should pay*. ’
>
> (European Commission, 2000, L327/2)

Other international agreements include: the Millennium Development Goals (safe and sufficient water) and Agenda 21:

"…to plan for the sustainable and rational utilization, protection, conservation and management of water resources based on community needs and priorities within the framework of national economic development policy"

In most international agreements, rationality is strongly linked to sustainability. A community's control and prudent use of natural, human, human-made, social, and cultural capital to foster economic security and vitality, social and political democracy, and ecological integrity for present and future generations. Ecological sustainability more narrowly focuses on maintaining and enhancing ecological integrity and biodiversity, and generally on protecting the life-support and waste-sink functions of the earth. The most often quoted definition of Integrated Water Resource Management (IWRM) has been developed by the Global Water Partnership (GWP);

'…a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.'

(GWP-TAC, 2000)

This definition has been criticised to be very limited for practical guidance to present and future water management practices, though all encompassing and impressive (Biswas, 2004).

We see from this chapter that planners must be aware of resources and constraints at all three levels (macro, intermediate and micro) in order to determine which changes are needed at each level. Rationality depends upon the level of pressure, stakeholders, science, the quality of water, property rights, norms and moral (fairness) and ecological minimum standards. Stakeholders need to get involved to comply with human rights considerations. To improve the theoretical framework for policy considerations and methodology on water use, analytical frameworks such as the logical framework analysis and sustainable livelihoods analysis could potentially be used. The logical framework approach is a management tool mainly used in the design, monitoring and evaluation of international development projects while the livelihoods analysis provides a framework for research and policy that takes into account the complex and multidimensional relationships between the social and physical environments.

III – Efficiency and productivity indicators

'Efficiency is intelligent laziness.'

David Dunham

1. Methods

The key issue in defining efficiency and productivity indicators is related to answering the following questions, which are closely related to the level of analysis (micro, meso or macro-level):

- Who is the decision maker (farmer, administration, etc.) and what are the decision making objectives (profit, employment, risk reduction, etc.)?
- What are the limiting resources (land, labour, capital, water, etc.)?
- How is the decision making model (data quality and availability, time-span, etc.)?

Then, generally, water efficiency and productivity is defined in the literature in relation to micro- and meso-level. Also, the definitions are single dimensional, i.e. the authors give a list of output ratios (economic, physical, etc.) versus inputs (water, fertilizer, etc.). This paper uses these definitions as they are the most general used in literature regarding irrigation efficiency, nevertheless there are more complex definitions that take into account more than one objective (multi-criteria analysis or MCA) and ; data envelop analysis (DEA) where analysis is done based upon combination of various inputs to give one or more outputs. For a complete review of MCA in irrigation economics, see Gomez-Limon *et al.* (2007), regarding DEA, see e.g. Malano *et al.* (2004) and the paper in this volume by Giannoccaro *et al.,* Other attributes to the problem such as irreversibility, equity, minimising uncertainty, etc. may also be introduced in the analysis. Cost-effectiveness analysis (CEA) and cost benefit analysis (CBA) could also be considered. The cost-effectiveness approach is in WFD considered a management and planning instrument when formulating the program of measures to be implemented in the European river basins (Berbel *et al.,* 2011b) and could be relevant to all scales (national, river basin, local).

All the above mentioned methods (MCA, DEA, CEA, CBA) imply a further complexity to the analysis of efficiency. For these methods we may set as a common ground the concept of bounded rationality (Simon, 1982), so that instead of an 'optimum' solution, the aim is to find a 'satisfactory' solution between different and conflicting objectives. A farmer, when deciding on water allocation to crops, may be interested in maximizing profits and minimizing risk, or minimizing cost of labour. A solution to this multi-criteria problem needs to be analysed under multi-attribute utility. The result may be that the revealed solution may look non-optimal (non-rational) from the single profit maximizing hypothesis. This makes the practical definition of rational choices more complex, but nevertheless we should go beyond this problem in order to find practical definitions of RUW. These methods are outside the scope of this paper, consequently, this document is focused on the simplest approach which is single dimensional ratios.

2. Irrigation and hydrological cycle

'Irrigation' can be defined as the artificial supply of water to supplement or substitute natural precipitation for agricultural production (Bazza, 2006). 'Precipitation' can be defined as all deposits on the earth of hail, mist, rain, sleet, snow, dew, fog, frost, and dust[6]. Generally the rainy season over the Mediterranean Sea extends from October to March, with maximum rainfall taking place during November to December. The average rain rate is ~1–2 mm day−1, but during the rainy season there is 20% larger rainfall over the western than that over the eastern Mediterranean Sea (Mehta and Yang, 2008). Precipitation is also a critical variable to evaluate regional and global water supplies and time variability. It characterizes the input of water into the entire hydrological system that is important for a variety of models including climate, weather, ecosystem, hydrological and biogeochemical models.

Currently, the number of 'water-poor' Mediterranean people (less than 1,000 m^3 per capita per year of renewable water resources) amounts to 180 million (Morocco, Egypt, Cyprus and Syria). Those faced with 'water shortage' (less than 500 m^3 per capita per year) amount to 60 million (Malta, Libya, Palestinian Territories, Israel, Algeria and Tunisia). These countries to the south and east have run up a 160% renewable water resources deficit to meet the 1,700 m^3 per capita per year, deemed to be the minimum threshold of water required to fully meet the peoples' needs (UNEP/MAP-Plan Bleu, 2009). The 'renewable water resources' can be estimated on the basis of the water cycle, e.g. they represent the long-term average annual flow of rivers (surface water) and groundwater, while non-renewable water resources are e.g. groundwater bodies or deep aquifers that have a negligible rate of recharge on the human time-scale and thus can be regard as non-renewable (FAO, 2003). 'Surface water' can be defined as all waters on the surface of the Earth found in streams, rivers, ponds, lakes, marshes or wetlands, and as ice and snow[7]. 'Groundwater' can be defined as all water below the surface of the ground in the saturated zone, commonly referred to as an aquifer, and in direct contact with the ground or subsoil[8]. This zone consist of a subsurface layer, or layers, of rock or other geological strata of sufficient porosity and permeability to allow a significant flow of groundwater or the abstraction of significant quantities of groundwater.

The transpiration ratio is applicable to crop production and was introduced by Van Helmont (1600-1700). The transpiration ratio represents the amount of water used by a crop to reach a certain weight and is the term that later led to the concept of water productivity or the 'crop per drop' slogan (Zoebl, 2002). The potential transpiration, introduced by Penman in 1948 (Ibid.), is the water loss from an extended surface of a short green crop, actively growing, completely shading the soil and never short of water. This is applicable to crop and field level. Evaporation is the transition from a liquid to a vapour state. The actual and potential evapotranspiration is the net water loss (in vapour form) per unit area of land, both directly from the land surface, and indirectly through transpiring leaves[9]. Evapotranspiration is applicable to crop and field level and is the sum of evaporation and plant transpiration. The term was introduced by Thornthwaite in 1944 in response to irrigation engineers who did not distinguish between actual and the so-called potential evapotranspiration. However, this difference became less important from the 1960s onwards, after Penman's formula became the established way to calculate crop water needs by irrigation engineers globally (Zoebl, 2002).

In order to develop standards, it is important to take into consideration: (i) examination of long time series of past-to-present hydrological data (including palaeodata and proxy data, especially for droughts and floods); (ii) do projections into the future (running hydrological models fed by scenarios resulting from climate modelling, and in particular regional climate models, via downscaling); and (iii) monitor extreme hydrological events such as floods and droughts.

In view of population growth and of the immediate impacts of changes in the water cycle, it is estimated that, by 2050, about 290 million people in the SEMC could end up in a situation of water scarcity (Plan Bleu, 2008). When considering uncertainty, we will need to identify critical gaps in knowledge related to climate change and water, as well as interlinked issues of the global environment change. According to Kundzewicz and Mata (n.y.) the existing gaps include, among others:

- scarcity of geophysical data, with sufficient accuracy and spatial and temporal coverage
- scarcity of socio-economic information
- validation and integrated interpretation of proxy data
- credibility and accuracy of hydrologically-relevant outputs from climate models
- credibility and accuracy of downscaling schemes
- development of climate models for hydrological forecasting
- uncertainty in results related to extremes - floods and droughts (frequency, intensity, persistence, spatial extent).

3. Related indicators

'*Let not even a small quantity of water that comes from the rain go to the sea without being made useful to man.*'
King Parakramabahu of Sri Lanka (AD 1153-1186)

Most governmental agencies, international bodies (e.g. FAO) and research institutions set as target for irrigation to manage water efficiently in the agricultural sector, measured as 'more crop and value per drop' and recently 'more jobs per drop'. This target is based upon measuring water use efficiency as a ratio of desired output (physical, economic or social) compared to consumed input. Nevertheless, the application of this intuitive concept should be done with precaution.

The terms 'water use efficiency' (WUE) and 'water productivity' (WP) has been loosely used to describe a number of water use indicators, and irrigation efficiency ratios. Irrigation is frequently said to have a high potential to achieve efficiency gains in the Mediterranean region, due to low efficiency and a general high value of water that allows for investment in water saving technologies. However, improving efficiency in irrigation to alleviate meso- and macro- level water scarcity may not be as significant as one might have thought. The explanation is that many of the frequently used concepts of water use efficiency systematically underestimate the true efficiency (Seckler *et al.,* 2003). For example not all water purportedly 'lost' from a farm or irrigation district in fact represent a loss to the hydrological system, as the water returns to the hydrological system (either surface or groundwater). Losses to the system are strictly losses to the sea, losses through evaporation from e.g. canals, transfers or water being severely polluted. Therefore how we define water and at what scale we refer to is critical to management and decision making.

In general terms, irrigation efficiency is defined as the ratio of water consumed to water supplied and water productivity is the ratio of crop output to water either diverted or consumed, the ratio being expressed in either physical or monetary terms or some combination of the two. Seckler *et al.* (2003) distinguish between 'classical' and 'neoclassical' concepts of irrigation efficiency. Classical irrigation efficiency can be defined as the crop water requirement (actual evotranspiration minus effective precipitation) divided by the water withdrawn or diverted from a specific surface water or groundwater source. The classical concepts of irrigation efficiency ignore the reuse and recycling of water and thus tend to underestimated real basin efficiency while the newer neoclassical concepts such as e.g. net efficiency, effective efficiency and fractions (see e.g. Seckler *et al.,* 2003) aim to take into account real water losses. The level at which efficiency is measured is quite a relevant decision. Table 2 shows definitions of water productivity by crop, farm and basin level.

Table 2: Crop, farm and basin level water productivity.

Water productivity	Definitions
Crop water productivity	Crop water productivity or 'crops per drops' can be defined for different crops by comparing output per unit of water input[b]. 'Output' may either be in physical (usually measured in kg) or monetary terms. The amount of water depleted is usually limited to crop evapotranspiration (measured in m^3). Two examples: (i) Smith (2000): Yield (tc) / Transpiration (mm); (ii) Kassam and Smith (2001): Crop yield/water consumptively used in evapotranspiration. Here crop water productivity may be quantified in terms of wet or dry yield, nutritional value or economic return.
Farm productivity	The use of water in a farm as a system implies a different level of productivity compared to individual crop productivity as the considerations of other constraints (land, labour, machinery, financial, risk) may influence the optimal allocation of water in a crop mix. Water may be a constraining factor during some months and may not be scarce in others. Accordingly, a global systemic view of the farm implies a 'farm value' for the water that may be different to the value when considering a single crop.
Basin productivity	Takes into consideration beneficial depletion for multiple uses of water, including not only crop production but also uses by the non-agricultural sector, including the environment. Here, the problem lies in allocating the water among its multiple uses and users. Priority in use involves the value judgement of either the allocating agency or society at large and may be legally determined by water rights.

[b] *Some authors define 'total water productivity' by including also effective precipitation water, but in this paper we focus on irrigation productivity and we do not enter into the discussion about 'green' and 'blue' water.*

The use of physical measures of the output is easier to apply than economic definitions of 'value'. Young (2005) criticises the frequent use of 'value added' or 'total production' for measuring socio-economic benefits of water use, opposing OECD recommendations (see Bergmann and Boussard, 1976, p. 59). The concept of added value (or total value of production) may lead to misleading results since 'value added' comprises of several factor incomes (labour, capital etc.). We recommend that the choice of the economic indicator should be taken with precaution corresponding to the level of analysis (micro, meso, macro) and that, in general, the selected variable should be a value generated by the water use. When economic analyses are done at a meso- and macro-level the priority in use may include objectives of rural development or social or territorial equity that may be in conflict with maximizing economic efficiency and diverting water to the most productive location and sectors against more traditional crops and less favoured areas. Therefore the macro level concept of efficiency may consider social targets (such as more jobs per drop) that are not necessarily compatible with the pure economic definitions (more value per drop).

4. Other aspects related to water use efficiency in Mediterranean systems

An important issue in Mediterranean systems is the use of 'deficit irrigation', defined as the application of water below full crop-water requirements (i.e. evapotranspiration). This is a crucial strategy to maximize water productivity and efficiency. Generally, the farmer's adaptation to water supply limitations in water scarce regions is to cultivate crops with supplementary or deficit irrigation. This is a strategy that is expected to be used more frequently as in the future irrigated agriculture will take place under increasing water scarcity. Therefore, to maximize food production under soil and water constraints, irrigation management will focus more towards maximizing the production per unit of water consumed (water productivity), against the old strategy of intensive water use in some areas maintaining the rest under rain-fed conditions. Deficit irrigation is widely practiced over millions of hectares for a number of reasons - from inadequate network design to excessive irrigation expansion relative to catchment supply. A review can be seen Fereres and Soriano (2007) who conclude that there is a potential for improving water productivity of many field crops; there is sufficient information for defining the best deficit irrigation strategy for many conditions; and the level of irrigation supply under deficit irrigation should be relatively high in most cases. This is a strategy that increases the efficiency of the use of water by crops, but can be applied only to certain crops at some growth stages.

IV – Concluding remarks

'*It is not the quantity of water applied to a crop, it is the quantity of intelligence applied which determines the result - there is more due to intelligence than water in every case.*'
Alfred Deakin 1890

The paper shows that the term RUW is of utmost relevance to the irrigation sector as water scarcity and pressures on water are increasing. The term is multi-faceted, depending upon what decision level scale of water use we refer to. At a micro-level (household, farm and community level), the definition includes to maximize profit, water use efficiency and productivity; at a meso-level (institutions, river basin, infrastructure) to achieve an equitable and economic efficient allocation that does not increase the conflict level between competing uses; while at a macro-level (legal, national and international policy) sustainability and food security appear to be core aspects of RUW.

The single dimensional indicators (ratios) presented could potentially be used to aid measuring RUW. Still, it is important to carefully define the economic terms, as the measured 'value' depends on the decision-level or policy context in which the estimate is developed (Young, 2005, p 221). For example subsidies to production are an income for the farmer but an expense for the government. Additionally, most of the measures do not specify if they refer to depleted water or to diverted water. At crop and field-level much of the 'apparent losses' remain inside the hydrological system and do not represent losses at a meso level as most of the water returns to the basin. This consideration is an argument that supports the notion that rationality depends on the scale of analysis. In view of the diversity of definitions on WUE and WP indicators there seems to be a considerable confusion around the interaction between the hydrological cycle and these concepts, which again could produce confusing results for planners and policymakers involved in addressing issues of water scarcity. Even irrigation professionals use various terms interchangeably and without due regard to the clarity of their recommendations (Perry, 2007).

Summing up, for calculating productivity we recommend to use biomass, edible crops, dry matter, profit, water value in case of an economic target or job creation in the case of social objectives. The economic value should take into consideration the level of analysis, as the private farm measure of success (profit) is different from the global public measure of value (where e.g. taxes or subsidies are considered differently than from the private viewpoint).

References

Barbier E.B. (1990). Economics for sustainable production. In: R.T. Prinsley, ed. *Agroforestry for sustainable production*, p. 389-404. London, Common-wealth Science Council.

Bazza M. (2006). Overview of the history of water resources and irrigation management in the Near East Region. FAO Regional Office for the Near East. 1st IWA international Symposium on Water and Wastewater Technologies in Ancient Civilizations. http://www.fao.org/world/regional/rne/morelinks/Publications/English/HYSTORY-OF-WATER-RESOURCES.pdf

Berbel J., Mesa-Jurado M.A., Pistón J.M. (2011a) (forthcoming). Value of irrigation water in Guadalquivir basin (Spain) by residual value method. Water Resources Management DOI: 10.1007/s11269-010-9761-2

Berbel J., Martín-Ortega J., Pascual M. (2011b). A cost-effectiveness analysis of water-saving measures for Water Framework Directive: the case of the Guadalquivir River Basin in Southern Spain. *Water Resources Management*, Published online: 3 November 2010. DOI: 10.1007/S11269-010-9717-6.

Berbel J., Gutiérrez C. (2004). Sustainability of European Irrigated Agriculture under Water Framework Directive and Agenda 2000. Ed. European Commission. ISBN: 92-894-8005-X.

Bergmann H., Boussard J. (1976). Guide to the economic evaluation of irrigation projects. OECD, Paris. 247 p.

Biswas A. K. (2004). Integrated Water Resources Management: A Reassessment A Water Forum Contribution. *International Water Resources Association Water International*, Volume 29, Number 2, P. 248–256.

Blue Plan (2008). The Blue Plan s Sustainable Development Outlook for the Mediterranean. Sophia Antipolis, France: Plan Bleu

Clemmens A.J., Burt C.M. (1997). Accuracy of irrigation efficiency estimates. *J.Irrigation and Drainage Eng*. 123:443-453.

European Commission (2009). Adapting to climate change: Towards a European framework for action. WHITE PAPER. Brussels, 1.4.2009.

European Commission (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23rd October 2000 establishing a framework for Community action in the field of water policy. *Official Journal 22 December 2000* L 327/1, Brussels: European Commission.

FAO (2003). Review of World Water Resources by Country. *Water Reports 23*, Rome, 2003.

Gómez-Limón J.A., Berbel J., Arriaza M. (2007). MCDM farm system analysis for public management of irrigated agriculture. In: *Weintraub, A., BjorndaL, T., Epstein, R., Romero Y. C., (eds.), Handbook on Operations Research in Natural Resources in International Series in Operations Research and Management Science*,Ed. Kluwer, Nueva York; Páginas: 93-114; ISBN: 978-0-387-71814-9

Fereres E., Soriano M.A. (2007). Deficit irrigation for reducing agricultural water use — *J. Exp. Bot*. (2007) 58 (2): 147-159.doi: 10.1093/jxb/erl165

GWP-TAC (2000). Integrated Water Resources Management. Global Water Partnership – Technical Advisory Committee. TAC Background Papers No. 4. GWP, Stockholm, Sweden.

Hackett S. (1998). Environmental and Natural Resources Economics. published by M.E. Sharp, Armonk, NY.

Kassam A., Smith M. (2001). FAO Methodologies on Crop Water Use and Crop Water Productivity. Expert meeting on crop water productivity, Rome 3 - 5 December 2001, pp. 18.

Kahneman D., Tversky A., 1979. Prospect theory: An analysis of decisions under risk. *Econometrica* 47 (2): 263–291. doi:10.2307/1914185. http://jstor.org/stable/1914185.

Kijne J.W, Tuong TP, Bennett J, Bouman B.A.M., Oweis T. (2002). Ensuring food security via crop water productivity improvement. Background Paper 1. *In: Challenge Program for food and water.* Colombo (Sri Lanka): CGIAR-IWMI. 42 p.

Kundzewicz Z. W., Mata L. J. (n.y.). Concept paper on cross-cutting theme: WATER.

Malano H., Burton M., Makin I. (2004). Benchmarking Performance in the Irrigation and Drainage Sector: A tool for change. *Irrigation and Drainage*, 53: 119-133.

Mehta A.V., Yang S. (2008). Precipitation climatology over Mediterranean Basin from ten years of TRMM measurements. *Adv. Geosci.,* 17, 87-91, doi:10.5194/adgeo-17-87-2008.

Molden D. (1997). Accounting for water use and productivity. SWIM Paper 1. Colombo, Sri Lanka: International Irrigation Management Institute.

OECD 2001. Environmental Indicators for Agriculture. Methods and Results. Executive summary

Pearce D.W., Turner R.K. (1990). Economics of Natural Resources and the Environment. Published by Harvester Wheatsheaf.

Perry C. J. (1996). The IWMI water balance framework: A model for project level analysis. Research Report 5. Colombo Sri Lanka: International Irrigation Management

Perry C. (2007). Efficient irrigation; inefficient communication; Flawed recommendations. *Irrigation and Drainage*, 56: 367–378 (2007). Published online in Wiley InterScience (www.interscience.wiley.com) DOI: 10.1002/ird.323

Rosegrant M.W. (1995). Dealing with water scarcity in the next century. International Food Policy Research Institute 2020 Brief 21, June 1995. http://ageconsearch.umn.edu/bitstream/16339/1/br21.pdf

Schoengold K., Zilberman D. (2004). Economics of Water Quality and Agriculture. Agricultural Water Quality and Water Use: Developing Indicators for Policy Analysis. Proceedings of an OECD Expert Meeting-Gyeongju, The Republic of Korea, October 2003.

Seckler D., Amarasinghe U., Molden D., de Silva R., Barker R. (1998). World Water Demand and Supply, 1990-2025: Scenarios and Issues. Research Report 19, International Water Management Institute, Colombo, Sri Lanka.

Seckler D., Molden D., Sakthivadivel R. (2003). The Concept of Efficiency in Water resources Management and Policy». Chapter 3 in *Water productivity in agriculture: limits and opportunities for improvement* edited by. International Water Management Institute, Colombo, Sri Lanka

Rockstrom J., Falkenmark M. (2000). Semi-arid crop production from a hydrological perspective: gap between potential and actual yields . *Crit. Rev. Plant Sci*. 19: 319-346**.**

Simon H. (1982). Models of Bounded Rationality . Volumes 1 and 2, MIT Press.

Smith M. (2000). Optimising crop production and crop water management under reduced water supply . 6th International micro-irrigation congress. SA National Council for Irrigation and Drainage. Cape Town, South Africa.

The World Bank (2007). Making the most of scarcity : accountability for better water management results in the Middle East and North Africa . MENA development report on water. DOI: 10.1596/978-0-8213-6925-8

UNEP/MAP-Plan Bleu (2009). State of the Environment and Development in the Mediterranean , UNEP/MAP-Plan Bleu, Athens, 2009.

Viets F.G. (1966). Increasing water use efficiency by soil management. In: *Plant environment and efficient water use*, ed. W.H.Pierre *et al.,* Madison, Wisconsin, USA: American Society of Agronomy.

Wallace J.S., Gregory P. (2002). Water resources and their use in food production systems. *Aqatic Sci* 64: 1-3

Wallence J.S. (2000). Increasing agriculture water use efficiency to meet future food production. *Agric Ecosystems Environment* 82: 105-119.

Willardson L.S., Allen R.G., Frederiksen H.D. (1994). Universal fractions for the elimination of irrigation efficiency. In: *Tech. Conf. of United States Committee on Irrig. and Drain.* (USCID), 13th, Denver, CO. 19–22 Oct. 1994. USCID, Denver, CO.

Young R.A. (2005). Determining the economic value of water: concepts and methods. Washington, DC. Resources for the Future. doi:10.1007/s10640-005-1956-2

Zoebl D. (2002). Crop water requirements revisited: The human dimensions of irrigation science and crop water management with special reference to the FAO Approach. *Agriculture and Human Values*. Doi: 10.1023/A:1019909704144

Zoebl D. (2006). Is water productivity a useful concept in agricultural water management? *Agricultural Water Management* 84, p265-273

Appendices

Annex 1 Abbreviation

CEA	Cost-effectiveness analysis
CBA	Cost benefit analysis
DEA	Data Envelopment Analysis
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GWP	Global Water Partnership
MAP	Mediterranean Action Plan
MCA	Multi-Criteria Analysis
MELIA	Mediterranean Dialogue on Integrated Water Management
OECD	Organisation for Economic Co-operation and Development
RUW	Rational Use of Water
SEMC	Southern and Eastern Mediterranean countries
SEMIDE	Système Euro-Méditerranéen d Information sur les savoir-faire dans le Domaine de l Eau
TAC	Technical Advisory Committee
UNEP	United Nations Environment Programme
WFD	EU Water Framework Directive
WP	Water productivity
WUE	Water use efficiency

Annex 2: Water demand, total and per sector, period 2000-2005.

Countries	Total demand (km³/year)	Drinking water (km³/year)	Irrigation (km³/year)	Industry (km³/year)	Energy (km³/year)	Drinking water (%)	Irrigation (%)	Industry (%)	Energy (%)
Spain	37.070	5.300	24.160	1.440	6.170	14.3	65.2	3.9	16.6
France	34.960	6.200	4.100	3.380	21.280	17.7	11.7	9.7	60.9
Italy	41.982	7.940	20.136	7.986	5.919	18.9	48.0	19.0	14.1
Greece	7.800	1.250	6.300	0.130	0.120	16.0	80.8	1.7	1.5
Malta	0.058	0.031	0.024	0.003		53.4	41.4	5.2	
Cyprus	0.253	0.067	0.182	0.004		26.5	71.9	1.4	
Slovenia	0.894	0.187	0.007	0.080	0.620	20.9	0.8	8.9	69.4
Croatia	0.375	0.314	0.001	0.050	0.010	83.7	0.3	13.3	2.7
Bosnia-Herzegovina	0.930	0.230	0.600	0.100		24.7	64.5	10.8	
Montenegro	0.050	0.050				100.0			
Albania	1.700	0.460	1.050	0.190		27.1	61.8	11.2	
Turkey	40.100	6.000	30.100	4.000		15.0	75.1	10.0	
Syria	16.690	1.426	14.669	0.595		8.5	87.9	3.6	
Lebanon	1.400	0.450	0.940	0.010		32.1	67.1	0.7	
Israel	1.950	0.712	1.129	0.113		36.5	57.9	5.8	
PalestinianTerritories	0.280	0.125	0.155			44.6	55.4		
Egypt	70.430	4.760	58.800	2.200	4.670	6.8	83.5	3.1	6.6
Libya	4.260	0.600	3.540	0.120		14.1	83.1	2.8	
Tunisia	2.457	0.406	1.918	0.133		16.5	78.1	5.4	
Algeria	6.270	1.330	3.940	0.800	0.200	21.2	62.8	12.8	3.2
Morocco	9.488	0.855	8.475	0.158		9.0	89.3	1.7	
Total/Average									
North Shore	126.072	22.029	56.560	13.363	34.119	17.5	44.9	10.6	27.1
South and East Shore	153.325	16.664	123.666	8.129	4.870	10.9	80.7	5.3	3.2
Mediterranean	279.397	38.693	180.226	21.492	38.989	13.8	64.5	7.7	14.0
Ratio									
North Shore / Mediterranean	45%	57%	31%	62%	88%				
South and East Shore / Mediterranean	55%	43%	69%	38%	12%				

Source: State of the Environment and Development in the Mediterranean 2009 (UNEP/MAP-Plan Bleu, 2009).

Notes:
- Total water demand corresponds to the sum of water directly abstracted, including losses in transport and use, and the production of non-conventional water
- Drinking water demand refers to water directly abstracted and water issued from desalination of sea water and brackish water for supplying the households, public services, commercial establishments and deserved industries.
- Water demand for irrigation refers to water directly abstracted and non-conventional production (desalination, clean wastewater reuse, drainage, etc.) for irrigated agriculture production.
- Water demand for industry refers to water directly abstracted for the industries not deserved by the public drinking water network.
- Water demand for energy refers only to the thermal power plant cooling.

Sources: Plan Bleu, from national source

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(1) Jordan is often also considered part of the region though it is not bordering the Mediterranean sea.
(2) A list of abbreviation is given in Annex 1.
(3) See e.g. Wallence 2000; Rockstrom and Falkenmark 2000 (rain-fed) and Wallace and Gregory 2002 (irrigated agriculture).
(4) A draft version of this paper served as a starting point for the thematic group discussion on 'Rational Use of Water' in the MELIA-project in 2007. The authors want to thank Laila Mandi for inputs on a draft version of this paper.
(5) Norway and Switzerland have also committed to the WFD.
(6) www.fao.org
(7) SEMIDE thesaurus: http://www.semide.net/portal_thesaurus
(8) WFD Glossery: http://www.euwfd.com/html/glossary.html
(9) FAO: http://www.fao.org

Conceptual Frame for Rational Use of Water Resources in the Mediterranean

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Abstract. Many countries in the Mediterranean region are located in the arid to semi arid regions of the world that are known to have limited water resources and suffer increasing water scarcity. Sustainable management of these resources will become increasingly complex in the future as climate change is expected to increase the frequency and intensity of drought and water shortages. There is an increasing concern about the effective and efficient use of water for agriculture, and water conservation in general. The promotion of effective water use and on-farm water management are identified as important contribution to management strategies to address problems of water scarcity and to promote intensive agriculture on environmentally sound grounds. The conceptual frame of rational water use is based on research papers and discussions during the second MELIA project workshop and on papers uploaded on the Melia website. Most of the contributing partners focussed on the solutions to local and regional issues for rational use of water resources. They have also identified instruments and measures that could be employed to contribute to the rational use of water, mainly in the agricultural sector.

Keywords. Water resources – Water availability – Water supply – Water use – Water management – Water policies – Water conservation – Water use efficiency

Cadre conceptuel pour une utilisation rationnelle des ressources en eau dans le basin Méditerranéen

Résumé. *De nombreux pays de la région méditerranéenne sont situés dans des zones arides et semi arides du monde avec des ressources en eau limitées et une pénurie d'eau croissante. La gestion durable de ces ressources deviendra plus complexe et difficile dans l'avenir à cause des changements climatiques qui augmentent la fréquence et l'intensité des sécheresses et de la pénurie d'eau. Il y a une préoccupation croissante actuellement au sujet de l'utilisation efficace et efficiente de l'eau en agriculture et la préservation des ressources en eau en général. La promotion de l'utilisation rationnelle de l'eau et la gestion des eaux agricoles ont été identifiées comme des contributions importantes à la stratégie de gestion des ressources en eau, nécessaires pour résoudre les problèmes de pénurie d'eau dans les pays méditerranéens. Le cadreconceptuel de l'utilisation rationnelle de l'eau est basé sur des documents de recherche présentés au second MELIA Workshop et/ou téléchargés sur le site Web du projet Melia. La plupart des partenaires et d'autres membres du projet MELIA ont mis en évidence les solutions locales et régionales pour l'utilisation rationnelle des ressources en eau. Ils ont également identifié les raisons et les mesures qui pourraient être prises pour contribuer à l'utilisation rationnelle de l'eau principalement dans le secteur agricole.*

Mots-clés. *Ressources en eau – Eau disponible – Pénurie d'eau – Approvisionnement en eau – Politique – Economie – Préservation de l'eau – Utilisation de l'eau – Efficacité d'utilisation*

I – Introduction

In the Mediterranean water resources are limited, fragile and very unevenly distributed over space and time. During the second half of the 20th century, water demand has increased twofold, reaching 280 km^3 /year in 2005. Agriculture consumes 64 % of total water demand: 45 % in the north and 82 % in the south and east. In numerous Mediterranean countries, water use is approaching the limit level of available resources. Momentary or structural water shortages are being observed. The number of '*water poor'* Mediterranean people, living in countries with less than 1,000 m^3 of water per person per year, extends to 180 million, 60 million of whom face shortage conditions with less than 500 m^3/capita/year. Twenty million Mediterranean people are still deprived of access to drinking water, particularly in the south and east (Plan Bleu, 2011).

Within the MELIA project, a debate and dialogue on the perspectives for rational use of water resources in the Mediterranean region was carried out to assess and promote schemes of water saving, or optimal water use and water conservation for different sectors (urban, industrial and agricultural). Important savings can be achieved in agriculture through a better use of both technical and economical tools, as well as institutional and human resources. Water saving can also be achieved in both drinking water and industry, but the most beneficial saving in terms of volume would be in irrigated agriculture.

The paper is based on research papers presented at the second MELIA project workshop and on papers uploaded on the Melia website (Karaa *et al.,* 2010; Mazahreh *et al.*, 2005, Munla, 2007; Dudeen, 2009; Abdin and Gaafar, 2009; Chimonidou *et al.*, 2009; Rana *et al.*, 2009; Omrani and Ouessar, 2010). We would like to thank all MELIA partners for their contributions. Most of the contributing partners focussed on the solutions to local and regional issues for rational use of water resources. They have also identified instruments and measures that could be employed to contribute to the rational use of water, mainly in the agricultural sector. After elaborating the issue of water scarcity in the region, we will present a number of lists of, among others, measures and instruments that are expected to contribute to developing the framework of rational water use for the Mediterranean.

II – Water scarcity in the Mediterranean countries

The Mediterranean is one of the regions to be affected most by climate change, facing water problems such as scarcity, pollution, conservation, sanitation and management of resources. Water is a scarce commodity in most Mediterranean countries and its availability is declining to a critical level.

Shelef and Azov (1996) list the following features and characteristics shared by Mediterranean countries:

- Warm, sunny and dry during a relatively long summer and a relatively long rainy season during autumn, winter and early spring.
- A general shortage of water, at least in certain regions of the respective countries.
- A threat of pollution of groundwater and surface water, due to the lack of dilution, dispersion and flushing out, which is a consequence of the general shortage of water.
- Ideal circumstances for intensive agriculture to grow crops that need a warm and dry climate. This results in the export of agricultural products to countries with a colder climate. In most regions irrigation is needed to sustain this intensive agriculture during the dry summer, however, in some countries irrigation is required almost all year.
- The occurrence of droughts, frequent or occasional, depending on the region. Droughts lasting several years occurred in the Middle East and southern Europe in the past two decades.
- Tourism is one of the most important economical branches. Tourism provided countries with hard currency (the economy in certain countries largely depends on this). Tourism requires high standards of sanitation, drinking water and food, and, furthermore, clean beaches and water to swim in.

- Relative susceptibility to disease outbreaks and even epidemics due to the sanitary conditions, the warm climate, the relatively high proportion of disease carriers and locally endemic diseases.
- Relative shortage of funds for both capital investments and operating costs in the municipal public sector.

We add the following features:

- Rapid population growth and significant rising of consumptive demands, especially as a result of migration from rural to urban areas.
- Trans-boundary water dependencies and challenging questions of overlapping political and administrative boundaries affecting shared water bodies.

According to Abdin and Gaafar (2009) other important factors contribute to the deteriorating water situation in most Mediterranean countries. These driving forces can be categorized in four subgroups: social forces (poverty, inequity, cropping patterns and consumer behaviour), physical variables, economic forces and political forces (for instance irrigation water subsidies).

In the Mediterranean region nearly 70% of the available water resources is allocated to agriculture. In the arid and semi-arid countries of the region agricultural water use accounts for as much as 80% of the consumed water. In the Northern countries this can be about 50% of the total available resources (Hamdy and Lacirignola, 1997). According to De Wrachien (2003), more than 16 million hectares are irrigated. As water resources in the eastern and southern Mediterranean are decreasing, they are expected to be the main limiting factors for agricultural development, particularly in the period 2000 – 2025. The water needed for irrigation is scarce and finding land suitable for irrigation is becoming more difficult (De Wrachien, 2001).

As said before, significant water savings are possible if better use is made of existing human and natural capacities. Therefore, governments have made great efforts, and have invested heavily, to improve water resources management through the application of new technologies in urban and agricultural areas. Such investments are intended to reduce water losses and to increase water availability at local levels. However, when entire river basins are considered, the issues become more complex (Duqqah *et al.,* 2010)

The situation clearly calls for a review of existing policies. This review should embrace an integrated view and should, regarding water resources, consider both demand management and supply augmentation (Sapiano, 2008).

Demand Management: Regulatory instruments must be formulated in order to adjust, limit or stop water uses or users who are utilizing the resource inefficiently and thus contribute to the degradation of the natural resource base. The underlying aim should be to give priority to the environment and water uses that have the highest social and economic value.

Supply Augmentation: A programme of measures must be developed which should wherever possible encourage incentives for the augmentation of the current water supply 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 options are selected that are most suitable in the local context.

III – Towards a conceptual frame for sustainable rational use of water resources in the Mediterranean

As a synthesis of debates, contributions, discussions, it was convened that sustainable perspectives on rational use of water resources in the Mediterranean region will be developed by taking into account the following aspects, strategies, tools, measures and so on:

Strategies for basin management improvement Basin management is a policy instrument that takes into account all water resources and all water uses in a basin, together with the physical, social and economic influences on these. To improve basin management by using the concept of sustainable rational water use, we propose:

- ✓ To set up public education and inform the users about their rights as well as their responsibilities.
- ✓ To elaborate guidelines on how to develop public awareness.
- ✓ To improve communication amongst stakeholders.
- ✓ To prepare users for the new concepts of ***"****Rational Water Use"* and the environmental dimension.
- ✓ To improve the water use of irrigation in the engineering and technical context.
- ✓ To make the farmers aware that they have to pay for water, though this is often complicated as some farmers think: *" if rain water is free, why must we pay for the water we use?"*
- ✓ To improve irrigation techniques (drip irrigation, sprinkler), use alternative sources of water such as treated wastewater or drainage water in irrigation, etc.
- ✓ To promote agronomic research and application of results such as:
    - selecting crop varieties with high yield per unit of water;
    - switching to less water intensive crops;
    - sequencing crops to maximize output under conditions of soil and water salinity;
    - selecting drought resilient crops where necessary;
    - introducing water efficient crop varieties.
- ✓ To look for a strategy in the whole Mediterranean for preserving water in agriculture
- ✓ To look for new sustainable technologies, regulations, cooperation between different stakeholders in water management.
- ✓ To increase farmers' awareness in water resource management and encouraging participatory approach.
- ✓ To finance and establish pilot projects for collective irrigation, especially in ground water resources.
- ✓ To get benefits from the investment projects that support national projects for irrigation modernization.
- ✓ To finance the rehabilitation of government irrigation projects with easy and grace period loans.
- ✓ To build capacity in the field of designing, operation, and maintenance in addition to preparing trainers to promote strategies for modernizing and managements of irrigation projects.
- ✓ To develop national standard specifications for all irrigation equipment.

- ✓ To develop industrial and research labs, and contribute to establishing labs to monitor the quality of produced irrigation equipment.
- ✓ To construct additional water works, such as new dams and expand irrigation networks.

Technical, economic, social and environmental aspects

- ✓ Special attention to water value as a pillar of water policy.
- ✓ More extension is required to reach end-users.
- ✓ Consensus is needed on indicators to assess water use and water scarcity.
- ✓ Special attention to the social dimension as well as the economic in water use.
- ✓ Assessment of the balance between private and public intervention in water sector.
- ✓ Emphasis on better bridge between research and extension.
- ✓ Fostering awareness of decision makers on real challenges in water resources management.
- ✓ Further studies on integration of water pricing and water affordability.
- ✓ Establishing water user organizations for increasing farmer involvement in the management and collection of water fees.
- ✓ Reducing irrigation subsidies and/or introducing conservation-oriented pricing.

Sustainable technological solutions for water treatment recycling and reuse

- ✓ Select the technology that best fits the local conditions and be aware that technologies successful somewhere are not necessarily successful somewhere else.
- ✓ Reuse of drainage water and treated wastewater in agriculture.
- ✓ Desalination of brackish and sea water.
- ✓ Enable all actors to be involved in experimental platforms development. Scientists and administrators have to work together.
- ✓ Promote the broad dissemination of successful scientific results to the public, end-users and all concerned agents (Translate scientific outputs into common language).
- ✓ Promote participatory approaches in decision making.
- ✓ Increase training opportunities for technical and non-technical staff.
- ✓ Enhance public awareness on a regular basis, not an ad-hoc basis. Institutional and economic support is needed.
- ✓ Create lobby groups to ensure that policy makers properly understand the problem and adopt the appropriate means.
- ✓ Use unconventional channels to convey the message to as wide audience as possible (e.g., use football teams, actors, etc.)
- ✓ Show the consequences of not taking any action.
- ✓ Develop a communication strategy with media involvement.
- ✓ Strengthen training and extension services to disseminate efficient technologies.

Efficiency and equity in water policies

- ✓ Water policies must be developed in an integrated fashion with other policies.
- ✓ All national policies should be revisited from time to time.
- ✓ Align national water policies with WFD principles rather than simply adopt WFD in a mechanical manner.
- ✓ No single national policy can be developed without the full participation of end-users after they have developed the required capacity through various tools such as extension services, training and others.
- ✓ National policies should follow a bottom-up participatory process to guarantee confidence, engagement and commitments of the end-users.
- ✓ Models should play an important role in supporting decision making processes, just us other technological tools do.
- ✓ Taking appropriate decisions is not simple, due to the different inter-connected aspects and the complexity of the issues. Decision Support Systems (DSS) and models can help the decision making process through iterative learning cycles.
- ✓ Indicators as well the results of DSS should support the development of a sustainable management plan.
- ✓ International technical cooperation needs political agreements and consensus on common objectives. This is specifically so for IWRM in the Mediterranean Region.
- ✓ Technical cooperation among countries needs legislation to identify rights, roles, and levels of cooperation regarding different water resources.
- ✓ Increased penalties for water miss-users or those who cause waste in different fields.
- ✓ Strengthening of “the polluter pays” principal.
- ✓ Encouragement of participation both at the low level through water users associations in old and new irrigated areas; as well as at the higher level of the distribution canal through the formation of the water federations.
- ✓ 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 in closed environment (greenhouses). This method is economic with land and water use, avoids soil salinization and produces high yields of exportable crops.
- ✓ Considering the use of brackish water for irrigation of salinity tolerant crops.
- ✓ Saving freshwater by switching to irrigation with treated wastewater.
- ✓ Shifting from high demand water crops to low demand water crops.

Developing tools for water quality-quantity monitoring for management of water resources

- ✓ Remote sensing is a complementary tool which can reduce the amount and costs of field measurements for integrated water management. However, ground truth data is required for validation.
- ✓ Active remote sensing (i.e. Radar and Interferometer are additional remote sensing tools for assessment of water quality and non traditional water resources. Developing computer models and computation of indices are used as indicators for water quality and water balance.

- ✓ Additional research should be established to enhance water use efficiency within farmers' parcels.

Improve knowledge sharing among practitioners

- ✓ Enable their participation in different scientific events as well as in the experimental work.
- ✓ Build their theoretical capacity to enable them to combine theory with practice
- ✓ Report on success and failure stories that they witness and lessons learnt.
- ✓ Provide communication venues.
- ✓ Enable exchange of expertise (remove barriers such as lack of funds, language, etc.)

IV – Conclusion

The enormous importance of water for the social and economic development of mankind and the conservation of our natural environment requires the mobilization of all of us, to take the necessary steps for the sustainable development of our natural resources and the raising of public awareness on the rational use of this precious commodity of nature.

However, it should be pointed out that water scarcity, due to growing demands coupled with the marked decline of rainfall attributed to climatic changes worldwide, makes the rational use of water and the reduction of wastage imperative. The more water we save today, the greater our chances are to have water in the future.

The improvement of strategies for basin management taking into account the technical, economic, social and environmental aspects, the use of sustainable technological solutions for water treatment recycling and reuse, the efficiency and equity in water policies, developing tools for water quality-quantity monitoring and the improvement of knowledge sharing among practitioners would be the key actions towards a sustainable rational use of water resources.

References

Abdin A., Gaafar I. (2009). Rational water use in Egypt, In: M. El Moujabber, L. Mandi, G. Trisorio Liuzzi, I. Martin, A. Rabi, R. Rodriguez (eds), 2009. Technological Perspectives for Rational Use of Water Resources in the Mediterranean Region - IAM Bari: CIHEAM, 2009. (Série A Séminaires Méditerranéens, N° 88, Options Méditerranéennes), p 11-28

Chimonidou D., Polycarpos P., Vassiliou L. (2009). Rational uses of Water resources in Cyprus. In: M. El Moujabber, L. Mandi, G. Trisorio Liuzzi, I. Martin, A. Rabi, R. Rodriguez (eds), 2009. Technological Perspectives for Rational Use of Water Resources in the Mediterranean Region - IAM Bari: CIHEAM, 2009. Série A Séminaires Méditerranéens, N° 88, Options Méditerranéennes), 109-118.

Plan Bleu (2011). Identification de critères de mise à l'examen de projets urbains durables dans le cadre de l'Union pour la Méditerranée PNUE. PAM. Plan Bleu, 50pp

De Wrachien D. (2003). Irrigation and Water Resources in the Mediterranean, A Strategic Action Plan for R&D, 6th Inter-Regional Conference on Environment-Water Land and Water Use Planning and Management Albacete, Spain, 3-5 September 2003

De Wrachien D. (2001). Irrigation and drainage. Trends and challenges for the 21st century. Proceedings of the 19th ICID Regional Conference on Sustainable Use of Land and Water. Brno, Czech Republic

Dudeen B. (2009). Driving Forces and Some Aspects of Water Policy in Palestine, MELIA 3rd Workshop entitled Water Value Impacts on the Mediterranean Water Policies Istanbul, Turkey 21-23 March 2009

Duqqah M., Mazahreh S., Shatanawi M., Fardous A. (2010). Water Use Efficiency And Water Productivity In Jordan, www.meliaproject.eu.

Hamdy A., Lacirignola C. (1997). Use of water in the Mediterranean. Sectorial distribution and prospects. Séminaires Mèditerraneenes, Série A n. 31, Valenzano, Italy.

Karaa K., Karam F., Raad R. (2010). Modernisation of irrigation systems: measures to reduce pressure on water demand in Lebanon. www.meliaproject.eu

Mazahreh N., Shatanawi M., Ghezawi S. (2005). Jordan Experiences In Water Saving And Participatory Irrigation Management. Options Méditerranéennes, Séries B, n° 48.

Munla Hasan A. (2007). Water Use Efficiency in Syrian Agriculture, NAPC, Working paper No 26, 2007

Omrani N., Ouessar M. (2010). Technical perspectives of irrigation efficiency improvement in the oasis systems-cases of southern Tunisia. www.meliaproject.eu.

Rana G., Katerji N., Mastrorilli M. (2009). Summary on the Water Use Efficiency of crops cultivated in Mediterranean region. . www.meliaproject.eu.

Sapiano M. (2008). Water Scarcity: Imbalances Between Resource Availability And Competing Demands In Malta, Malta Resources Authority; 2nd Workshop Pilot River Basins Phase III, Evrotas (Greece) - 8th October 2008

Shelef G., Azov Y. (1996). The coming era of intensive wastewater reuse in the Mediterranean region. *Water Science and Technology* 33 (10-11), 115-125.

Water Management Indicators - State of the Art for the Mediterranean Region

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Abstract: In the Mediterranean region physical water scarcity is an important issue, and consequently the management of water resources is of great relevance, in order to achieve sustainable development. However, big challenges in water management and the perception that current water management models do have deficits in integrating the views of important key stakeholders have increased the (especially international) pressure for implementing actions towards Integrated Water Resources Management (IWRM). As a consequence, an increasing interest in water resource assessment and water management indicators can be observed. This paper discusses existing water management indicators sets - SWAP, Aquastress Water Stress Index and UN Water – Water monitoring - with respect to their applicability in the Mediterranean region. For this purpose, the authors' perceptions were complemented with the knowledge of a group of experts which contributed by means of expert interviews. The main conclusion of the analysis is that so far no indicator set tailored for the Mediterranean has been developed. To develop the best-suited set a participatory, integrative and iterative process needs to be set up. The present paper constitutes the first iteration step in this process.

Key words: Water management – Indicator – Policies – Water availability – Water use

Les indicateurs dans la gestion de l'eau – État des connaissances pour la région de la Méditerranée

Résumé. *Dans la région de la Méditerranée, la raréfaction des ressources physiques en eau constitue un problème particulièrement important. Les grands défis qui s'offrent à la gestion de l'eau et la prise de conscience accrue que les modèles actuels de gestion de l'eau intègrent insuffisamment les points de vue de parties prenantes importantes ont récemment accentué la pression (en particulier internationale) pour la mise en œuvre de mesures favorisant une gestion intégrée de l'eau. On observe en conséquence un intérêt croissant pour l'évaluation des ressources en eau et pour les indicateurs dans la gestion de l'eau. Des interviews avec des experts de premier plan et une analyse bibliographique étendue permettent de comprendre les difficultés liées au développement d'ensembles d'indicateurs adaptés à la Méditerranée. Trois ensembles d'indicateurs de grande valeur sont examinés plus en détail : SWAP, Aquastress Water Stress Index et ONU Eau – Surveillance de l'eau. Ces ensembles d'indicateurs ont été analysés avec deux experts qui, chacun, mettent en avant des éléments différents du développement d'indicateurs. Nous pouvons conclure qu'il n'existe pas à l'heure actuelle d'ensemble d'indicateurs idéal. Le développement d'un ensemble d'indicateurs parfaitement adapté nécessite la mise en place d'un processus participatif, intégrateur et itératif. Ce document constitue la première étape de ce processus.*

Mots clés: *Gestion des eaux – Indicateur – Politique – Eau disponible – Utilisation de l'eau*

I – Shaping the aim

The purpose of the present paper is to compare existing approaches of water resources management which use indicators for the performance of an economic system, a country, a region, etc. and to identify or propose respectively a set of indicators best suited for the application in the Mediterranean region and to be elaborated throughout the MELIA project. Therefore, it appears useful to first try to define what exactly 'good', 'sustainable', or 'desirable' water resources management looks like. The following definition is certainly only an attempt as well as a basis for discussion. It shall serve to shape the frame that should be filled by the indicators to be chosen. An extensive literature review was performed. The detailed report can be found on the Melia website (http://www.meliaproject.eu/).

Sustainable water resources management consists of local and regional practices as well as political frameworks and directives steering these practices, which ensure that the actual requirements for drinking water, irrigation water, water for industrial use, as well as for the continuity of biotopes are fulfilled without constraining reaching the very same objective in the short-term, medium-term or long-term future. It is based on responsible, effective, as well as efficient water consumption, strongly related to traditional local knowledge and techniques, as well as modern technologies and political approaches targeted at different scales of time and space.

II – Introduction

Definitely: Water is one of the key issues of sustainable development. It is one of the basic elements for human survival and human well-being; it is an important production factor within the economies of societies and it is a habitat of biodiversity. Clearly: there is a social, an economic and an environmental dimension to the sustainability of water. Each dimension does have impacts on each other dimension, and these impacts do differ and change over time and depending on the scale.

In the Mediterranean region, where physical water scarcity is an important issue, the management of water resources is of great importance, in order to achieve sustainable development. However, big challenges in water management and the perception that current water management models do have deficits in integrating the views of important key stakeholders have increased the (especially international) pressure for implementing actions toward so-called 'Integrated Water Management'. Consequently, linked to the agreement on the Millennium Development Goals (MDG; http://www.undp.org/mdg/), an increasing interest in water resource assessment and water management indicators can be observed.

Beside the fact that a considerable number of water scarcity indicators already exists for the assessment of the level of water shortage in the different parts of the Mediterranean, they presently suffer from serious flaws. Related to this, in the technical annex of the MELIA project states the following:

First of all, they are limited to 'blue' water only, neglecting the important contribution that 'green' water makes to global food production.[1]*Secondly they are based on averages and hence hide the very important temporal and spatial variations of the water resources which are often the determining factors for water scarcity. They do not consider climatic differences, differences between primary and secondary uses or the effect of life-styles and citizens' perception. Much has to be said also to include the needs of essential ecosystems in the primary needs, as has been done implicitly in the new South African Water Act, where basic human needs and the needs of the environment are given priority above the other issues. Also water policies need to be formulated and assessed in relation to their level of adequate 'integration' with sustainability as well headline indicators (sector physical and non-physical indicators). This assessment is possible on the base of selected common indicators used to assess the process of integration of policies ('integration' indicators).*

The purpose of the present paper is to suggest a relevant indicator framework for water scarcity and management for the Mediterranean region. The framework will build on existing indicators sets which ideally consist of indicators which are simple, easy to understand, easy to measure, representative, well linked to social, economic and physical dimensions and to be used for a future benchmarking exercise. Furthermore, in order to ensure a high-level assessment of the state of the art in the area of water management indicators, we decided to complement our own perceptions with the knowledge of a group of experts which contributed by means of expert interviews. The experts to be interviewed were chosen in a way that the expertise of Mediterranean neighbours from the three different continents adjacent to the Mediterranean Sea would be represented. The experts interviewed are:

- Suhita Osório-Peters, CEIFA ambiente – Portugal

- Dr. Alaa El-Din Abdin, Ministry of Water Resources and Irrigation, Strategic Research Unit – MWRI – Egypt
- Basim Ahmad Dudeen, Land Research Centre – LRC – Palestine

The interviewees answered a set of questions prepared by the authors. The information gathered by that means was directly integrated (and where appropriate cited) in the paper. In the following the questions are listed:

- What is the role the resource 'water' plays in the Mediterranean?
- What are the main issues to be tackled to ensure sustainable water supply for all people throughout time in the Mediterranean?
- What are the main areas of interest with relation to water management in the Mediterranean?
- Three existing sets of indicators are described in chapter 9. Please comment on their appropriateness for the application in the Mediterranean. Do they reflect the identified areas? Would you suggest others?
- Is it feasible to gather this kind of data? How would you appraise the situation in your country/region in terms of data availability/quality?
- Who should take over the responsibility for data collection/creation responsibility?
- In how far can measurement results influence/have an impact on politics?

III – The role of the resource 'water' in the Mediterranean

In the Mediterranean, water resources are limited, fragile and very unevenly distributed over space and time. During the second half of the 20th century, water demand has increased twofold, reaching 280 km^3/year in all riparian countries in 2005. The number of people living in water scarce countries, with less than 1000 m^3/capita*year, reaches 180 million inhabitants, 60 million of whom face shortage conditions with less than 500 m^3/capita*year. Twenty million Mediterranean people are deprived of access to drinking water, particularly in the South and East. Water supply in several Mediterranean countries is endangered by the over-exploitation of a part of the renewable groundwater (Blue Plan; Benoit and Comeau, 2005).

Water can be seen as a vital resource; the key supporter for the development in the Mediterranean. As such it is essential for the improvement of people's quality of life. However, in the Mediterranean area 'water' is not only a life-supporting resource (domestic use), but also a very important production factor for the most relevant economic sectors: agriculture, agro-industries (food and beverages), tourism, pulp and paper production, etc. For instance, according to the 'National Water Plan', agriculture uses yearly 75 % of the total water consumption in Portugal, while energy production represents 14 % and the industry sector 4,4% (expert interview Suhita Osório-Peters).

Due to its social and economic relevance, governments have always had problems with imposing water prices. Agriculture remains a crucial issue, because it is a basic production sector, providing employment to many people in these regions, but it is also the sector that uses the largest quantity of water and requests water with minimal quality standards. Any quantitative or qualitative limitations on water supply can have dramatic consequences for the population. Due to climate change, the availability of water will probably decrease in the next decades and the strong seasonal variability of precipitation has strong impacts on soil quality, risk of erosion, draughts and flood. Water management must have a greater influence on land use planning in all countries in Southern Europe. Large projects of water transfer and dams are being built in many regions, but the long-term impacts of those interventions may be catastrophic (expert interview Suhita Osório-Peters).

IV – Ensuring sustainable water supply in the Mediterranean

The focus of the MELIA project is to establish a Mediterranean dialogue on integrated water management. The term ‘integrated’ is essential in this context, as it implies that the solution of the management problem cannot be found through a technocratic approach only, with top-down planned and implemented improved infrastructure, but needs to be multi-layered in terms of the theoretical approach as well as the incorporative (participatory) planning and implementation. Hence, the issues to be tackled to ensure sustainable water supply for all people throughout time in the Mediterranean can be divided into rather general and political issues and the technical issues necessary for a functioning supply.

In the course of the expert interviews, Basim Ahmad Dudeen emphasised that the question of water management is a political process of the first degree. The political/management issues were identified by the experts Suhita Osório-Peters and Basim Ahmad Dudeen as (with a contribution by Alaa El-Din Abdin):

- To assure the health and well-being of humankind the priorities for water use should be set at the national level and the international (WHO) standards on designated water allocation per capita adopted.
- The reallocation of water use for the benefit of the national economy, taking in consideration environmental preservation, should be prioritized.
- The agricultural economy is an area that should be addressed thoroughly to enable rationalization of water use. For example, the concept of virtual water should be taken in consideration.
- Raising awareness and education. Every person should feel responsible for efficient water management; it must be seen – like municipal waste management – as a collective task of citizenship.
- Change the current regional development paradigms, which do not regard water as an actually limiting and vital resource for sustainability. For example, it is not sustainable to give priority to golf courses in these regions, in order to develop tourism. Reuse of waste water should be developed.
- Water prices can stimulate efficient water management.
- Water bodies often cross land frontiers. A better cooperation between countries that share rivers, lakes and groundwater reservoirs is needed.

On the other hand, the technical issues are as follows (expert interview Alaa El-Din Abdin; Suhita Osório-Peters)

- water management improvement for infrastructures of water supply
- higher efficiency for supply networks
- minimise water losses
- improve technical capacity for water supply and management engineers
- reduce water demand through O & M utilising the best technology
- technological innovation leading to reduced water use can contribute to important water savings; RTD incentives can be used to spread best distribution and irrigation techniques.

V – Complexity of water resource management

'Inherent complexity' of water management as the main challenge

Assessing water resources and their management faces several difficulties (see Faures, 1996). First, *the type of water resource to be measured has to be defined*. In Mediterranean countries, the part of non-renewable water resources (water available from aquifers with a negligible rate of recharge) which is used for water supply can represent a significant share in the total volume; sometimes bigger than the share of renewable water resources. This is very critical especially from a sustainability point of view. Additionally, 'green water' represents an important part of the available water in arid countries. Another important source for irrigation is re-used wastewater and desalinated water. Therefore, water resources assessment simply on the basis of 'blue' water is of little use for planning purposes. Moreover, one must not forget wastewater, its treatment and the consequences for freshwater bodies.

A second difficulty arises from the *spatial variability of surface water and groundwater (see Faures, 1996)*. Both resources are usually computed separately although they are part of the same water cycle. Separate computation of surface water and groundwater usually leads to an over-estimate of the total amount of available water resources in a given area; an error frequently observed - even in specific water resources studies. Directly related to this issue is the problem of geographical boundaries used in assessing water resources. In order to maintain the integrity of the water cycle, surface water has to be computed on the basis of river basins, while groundwater has to be assessed on the basis of groundwater bodies (aquifers). These basins rarely have the same geographical extent, especially in arid countries, and they almost never correspond with political boundaries.

Although water resources are usually accounted for on an annual basis, and compared with yearly demand, large *seasonal/temporal variations* can be observed which can substantially reduce the amount of water actually available for use. In countries where agriculture heavily relies on water resources during the dry season, water availability may be significantly reduced if no storage capacity is available for regulation of wet-season flow.

Spatial as well as temporal variability are strongly related to the respective local climatic conditions. Therefore, regional approaches to water management have to take account of differences between specific countries, as the climate may affect countries in different ways and at different times.

With regard to the above mentioned challenges, an important issue is the question of *data availability and quality* respectively, as without comprehensive data of decent quality these questions will be difficult to be answered. Here the important question to be asked is which authority shall be responsible for the collection of these data. Suhita Osório-Peters explained that data availability about water is a very difficult issue in Portugal (and this situation may serve as representative for other Mediterranean countries). For example, traditionally, people consider groundwater on their land as their own property; thus, they do not accept government control over the wells they have on their land. Consequently, although legislation has changed, the implementation of the new water laws remains a very difficult issue.

A further complication lies in the concept of *'availability' of water (see Faures, 1996).* River runoff, for instance, is not fully available due to seasonal variations and the occurrence of floods. Additionally, part of the water flowing into a neighbouring country may be reserved by treaty or agreement and thus cannot be considered as available for use in the upstream country. On the other hand, the water use (and pollution) of upstream countries can have serious implications on the availability in the downstream country. The availability of groundwater is subject to the country's capacity to extract the water. In summary, the concept of availability, which is much more powerful than that of water resources, can hardly be applied systematically over all countries and has strong economic and political implications. Most of the limitations described above apply with a much higher intensity in regions where water is scarce, which at the same time are those regions where water resources present a limitation to development.

Certainly a very important issue is the question of *life style and the perception of water scarcity problems* by the local or regional population, as people may not be aware of the consequences of their own life style for the local or regional water situation. Consequently, in such an environment a need arises for good and considerate governance and education which aims at 'steering the public opinion' into the right direction.

Additionally, a very important aspect is the integration of all relevant stakeholders in the discussion about distributing available water resources. Here, it is essential to provide also the 'speechless' with a voice in the discussion process, e.g. when it comes to defending water requirements for the purpose of preserving ecosystems and their values and functions; but also with respect to stakeholder groups with weaker political representation.

VI – Indicators for water resources management

To use indicators for measuring and demonstrating a part of reality in a simplified manner is not a new concept. It has become especially popular as a tool for assessing progress with sustainable development objectives (Spangenberg and Bonniot, 1998).

In 1987 the World Commission on Environment and Development (Brundtland Commission) called for the development of new ways to measure and assess progress towards sustainable development. Consequently, in 1996 an international group of measurement practitioners and researchers from five continents got together at the Rockefeller Foundation's Study and Conference Centre in Bellagio to develop principles for the elaboration of indicators for sustainable development, the so-called 'Bellagio Principles'.

The four main aspects of assessing progress towards sustainable development are the following:

- Starting point of any assessment - establishing a vision of sustainable development and clear goals
- Content of assessment and the need to merge the sense of the overall system with a practical focus on current priority issues.
- Identifying the key issues of assessment process.
- Necessity for establishing continuing capacity for assessment.

These principles are seen as guidelines for the whole assessment process including the choice and design of indicators, their interpretation, and the communication of the results. They are understood as being interrelated and to be applied as a complete set. Furthermore, they are intended to be used in starting and improving assessment activities of community groups, non-government organisations, corporations, national governments, and international institutions.

The OECD (2001) proposes a set of questions that is to be answered for the interlinkage of social, economic and ecological dimensions of water management:

- What is the environmental impact of reducing subsidies to the agriculture sector?
- What are the environmental impacts of alternative agricultural policy instruments, such as direct payments versus market price support?
- What are the environmental impacts of extending current policies into the future?

- What are the economic implications for the agriculture sector of meeting environmental targets, such as those set out in international agreements?

Smith (2004) argues that for the development of an indicator set one first needs to pose the following relevant questions before indicators are defined and measured:

- What key questions must be answered to determine the degree to which the region and the single nations are on a sustainable course with respect to its use and management of water resources? What are the issues that involve water resources?
- What indicators would be most useful in addressing these questions and defining sustainability? How should sustainability be measured and monitored? For what purposes would indicators be useful?
- What water information and statistics are needed to develop indicators? How can this be done? What institutions should carry out these efforts?
- What sources of data or statistics should be considered for developing indicators of sustainable water resources in the Mediterranean? A compilation of possible sources for the US is e.g. maintained on the SWRR website (http://water.usgs.gov/wicp/acwi/swrr/).
- If new data should be collected for these indicators, what organizations should do it and why? What are the gaps in data collection that should be filled? What options exist for filling these data gaps?

In the context of development assistance, and here in the context of evaluating short, middle, and long-term projects, the development of an effective set of indicators is of great importance. Indicators are used for the monitoring and evaluation of development assistance projects, of their effectiveness and of the question to which extend a measure applied is leading towards sustainable development.

In this context, the principles and requirements which indicators have to fulfil can be largely applied in middle- or long-term projects concerning water stress and scarcity. These principles are:

- Validity – measure what they are supposed to measure
- Reliability (verifiable) – conclusions replicable if measured by different people at different times
- Relevance – to the project objectives & different information needs
- Sensitivity – to the situation observed and changeable over time
- Cost effectiveness – worth the time & money to apply them
- Timely – collect data reasonably quickly
- Targeted – specified in terms of quantity, quality, time, target group and location

In the realm of sustainable water management, Saeger (2001) gives a good overview of the characteristic that constitutes a good indicator in general, but especially for the water management. It should

- be representative
- be scientifically valid
- be simple and easy to interpret
- show trends over time

- give early warning about irreversible trends
- be sensitive to the changes it is meant to indicate
- be based on data adequately documented and of known quality
- be capable of being updated at regular intervals

Not all indicators of water can fulfil all these characteristics. In this context, especially the data collection and consecutive documentation is often considered as a big problem in terms of capacity, money, and time.

Many indicators used in current assessment models thus tend to use indicators that use data and statistics, already available. In such models, the focus is set on the question which available data can be used to get the best information, rather than what exactly to measure. The present paper deals with important water management areas to be assessed using indicators, and subsequently with issues of data availability, collection capacities, etc.

A good overview of the technical challenges that one has to face when developing a frame for water management indicators has been given by Smith and Zhang (2004), coordinators of the US-Sustainable Water resources Roundtable. The two most important are:

First, the **number of indicators** to be used: Too many indicators may impede getting an overview of the sustainability problem because of increased complexity. On the other hand, if too few indicators are used, the system may not be represented adequately and important linkages of system dynamics are lost.

The **scale** issue is of general importance in sustainability questions. For the Mediterranean region as a whole other indicators need to be used for the same issue as for the national or local level.

Saeger (2001) also argues that a gap exists in the information base needed to support current and future water management needs. The priority information needs are:

- Diffuse source of pollution
- Emerging issues on human and ecological health
- Relationship between socio-economic driving forces and environmental impacts
- Indicators of the contribution of water to the overall quality of life
- The ability to assess future outlooks and to assess long-term environmental change
- Effectiveness of policy and legislation concerning the water environment.

VII – Existing (sets of) indicators

For the purpose of this paper a broad spectrum of literature dealing with the topic of water resources management has been screened. In many studies different (sets of) indicators are proposed to tackle the different areas identified in chapter 6. Consequently, it seems reasonable to revert to these existing (sets of) indicators, to evaluate them and to identify which of them might be usable for an application in the MELIA context. On the basis of an assessment of different (sets of) indicators using a standardised form, in order to enhance clarity and to enable comparability, in this chapter we present three indicator sets which we propose as a basis for discussion – for the expert interviews as well as for the plenum of the MELIA colleagues:

1. SWAP

SWAP – the Mediterranean Dialogue on Framing Sustainability in Water Policy evaluation – was a project funded by the European Commission, DG Research, within the 6th Framework Programme {SWAP, 2009 #6209}. In the context of this project the experiences of different case studies were compared in terms of what positive or negative effects policies regarding water management had had on sustainable development especially of the water sector. The project involved representatives of various Mediterranean countries (Morocco, Algeria, Lebanon, etc.) and aimed for the exchange of experiences not only among the specific countries but also of the European Union with its Water Framework Directive.

In the SWAP project an indicator matrix was elaborated to be applied in the different participating countries in the Mediterranean region. The matrix was organised using different indicator topics, the main objectives within these topics, and related indicators; additionally specific objectives were defined, and related to them also a set of sub-indicators. The following topics were identified (the numbers in brackets represent the number of objectives, related indicators, specific objectives, and sub-indicators):

- Environmental (1-6-7-24)
- Economic (4-3-7-16)
- Social (3-3-9-12)
- Governance (3-5-3-3)
- Social-Environmental (1-0-4-2)
- Environmental Governance (0-0-3-6)
- Social-Economic (1-0-4-7)
- Social-Governance (2-1-3-4)
- Governance –Economic (1-1-1-0)
- Environmental-Economic (2-1-1-2)

In a next step the indicator set was presented to and discussed by stakeholder groups in three different case study areas. The final set of SWAP indicators was then selected by all local stakeholders through a participatory approach of all concerned in the context of promoting sustainable development. The structure of the final set was similar to the original, using different indicator topics, the main objectives within these topics and related indicators (numbers in brackets: number of main objectives and related indicators):

- Environmental (3-3)
- Economic (1-3/12)
- Social (2-4/2)
- Governance (1-1/2)
- Social-Environmental (1-3/2)
- Environmental Governance (1-8/1)
- Social-Economic (1-2/1)
- Social-Governance (1-2)

- Governance –Economic (1-1)
- Environmental-Economic (1-1/4)

The advantage of the SWAP indicator set is that it has been developed, and is already being applied, in the Mediterranean. The indicators reflect the state of the environment, economy, health, quality of life, social cohesion in a context of sustainable development at local or national level; yet they do not include system description indicators. Definitively, this set of indicators is worth considering when developing a MELIA indicator set.

2. Aquastress

In the Aquastress project ('an EU funded integrated project (IP) delivering interdisciplinary methodologies enabling actors at different levels of involvement and at different stages of the planning process to mitigate water stress problems'; Sullivan *et al.*, 2007) an integrated tool for the evaluation conditions of water stress was developed – the Aquastress Water Stress Matrix (AWSM), combining selected information regarded as relevant for water management decision making.

In addition to the core component, the Aquastress Water Stress Index (AWSI), the matrix includes maps, photographs, comments, and a 'warning system'. The significant range of issues relevant to identifying the causes of water stress was tried to capture by aggregating various indices within the AWSI, which then evaluates the level of water stress at a specific site.

Additionally, Aquastress suggests a set of indicators which enables the assessment of water stress in all the sectors using water - the domestic, industrial and agricultural sector as well as the environment. Each sector is subdivided into the four categories aspects of water quality and quantity, institutional and adaptive capacity, infrastructure, as well as society and equity. From all the collected indicators various were chosen for each category, following a ranking concerning the criteria relevance and data availability (number of indicators within the four different categories).

- Domestic sector (4-3-3-3)
- Agricultural sector (5-4-4-3)
- Industry-production (3-2-2-2)
- Industry-tourism/services (6-5-1-2)
- Environmental components for each sector (4-5-6-2)

The main idea of the list was to create an inventory of indicators that could be used in the test-sites of Aquastress. Also in this project, the water consumption component of a system to be managed seems to be adequately displayed by the indicators. However, the amount of water consumed should be contrasted with information related to the available water resources, including system information such as climatic circumstances, etc.

3. UN Water – Water monitoring

The scope of the study was voluntarily limited to monitoring initiatives which were global in scope and related to one of the following four dimensions: service, quantity, quality and governance. In so doing, the mapping discarded all local, national and even regional monitoring initiatives unless these were part of a systematic global monitoring effort (FAO, 2006).

A total of 44 initiatives were screened, of which 19 were classified as monitoring activities. Thirteen of these 19 initiatives refer more specifically to a narrower definition of monitoring based on compilation of country or point data or country surveys. The responsible institutions range from different UN organisations (e.g. UNEP, UNESCO, etc.) to the WHO, the FAO and many others.

The report suggests a list of Key Water Indicators for UN-Water, subdivided into various subcategories. It is based on work previously done in the framework of the World Water Assessment Programme. It contains a large number of indicators which are already available within UN-Water member databases, some of which are currently under development, and few newly proposed ones.

Target monitoring:

- Sustainable Development (5)
- Millenium Development Goals (2)
- IWRM and water governance (3)

System monitoring:

- Resources (6)
- Stocks and use (9)
- Other sustainability (5)
- Early warning (2)
- Production and use (7)
- Health and social aspects (7)
- Economic aspects (16)
- Quality aspects (10)

The suggested indicator set covers a wide range of fields related to water resources management and the majority of the ones discussed above. In contrast to the other sets described above it includes a sub-set of indicators which are dedicated to 'system monitoring'. These include 'resources' indicators such as precipitation quantity, as well as 'stocks and use' indicators (e.g. renewable water resources), etc. In their report, the UN also proposes a few new indicators which comprise, for instance, 'water distribution and delivery efficiency' or 'rain seasonality index'. Certainly, these two indicators would perfectly fill the gap in data on temporal and spatial variability in water availability. Yet, and this holds also true for quite a few already existing indicators, the big issue – especially in countries with a shorter tradition in (environmental) accounting – is the data availability.

VIII – Conclusion and recommendations

Conclusions

The purpose of the present paper is to give an overview over existing indicator (sets) for water resources management, in order to derive recommendations for the compilation of an adequate set of indicators for the Mediterranean region. To effectively analyse existing indicators sets and look for necessary adaptations for a specific region, it is necessary to understand the setting – the circumstances – in this region. That is why at the beginning we elaborated the role of the resource 'water' in the Mediterranean and the necessities for ensuring sustainable water supply in the Mediterranean. Like in other parts of the world also in the Mediterranean region the management of the water resources is exacerbated by the complexity of water management as such and special issues characteristic for the Mediterranean. In this context, one could name, for instance, the dissimilarity among countries adjacent to the Mediterranean Sea, and the variable conditions even within the specific countries, in terms of water availability, economic conditions, technical development, etc.

As identified in Chapter 4, the main issues to ensure a sustainable management of water resources in the Mediterranean are political as well as technical. What all of them have in common is that, in order to evaluate the current situation as well as to measure the progress towards specific goals, certain indicators are needed. 'You cannot manage what you cannot measure' is a saying fitting perfectly into this context. Despite the existence of well-elaborated indicator sets, one has to take into consideration that all of them have been developed either on a detailed level for a specific setting, or with less detail in order to make it applicable to different settings. Hence, a set of indicators for the Mediterranean will have to be a set tailored to the needs specific for the region.

As said above, political as well as technical measures to improve the sustainable use of water resources depend on the provision of reliable data. However, in this context some political steering is crucial. First, the necessity of comprehensive and reliable data has to be understood by policy makers and the responsibility for data collection needs to be allocated to the respective administrative bodies, in order to ensure continuous collection of the right data. Here, field, planning, and management engineers appear to be the most appropriate to be responsible in following up the data collection and processes. On the other hand, more collective awareness with regard to the problems at local and regional level should be created, as participation of the population is, in this context, a condition for the success of data collection.

Guest commentaries

As elaborated before, managing water resources is a complex task which is difficult to achieve. A comprehensive and well elaborated set of indicators is certainly a good tool to support this aim. To ensure that in the MELIA project we steer into the right direction we invited different experts to comment on the present report and to write a short guest commentary concerning specific questions related to indicator sets for effective water resources management. When inviting the following experts the focus was set on the coverage of different thematic areas related to IWRM in order to ensure the representation of different schools of thought:

Professor Tony Allan, Geography Department, King's College, London, UK – creator of the concept of 'Virtual Water'; a pioneer in the development of key concepts in the understanding and communication of water issues and how they are linked to agriculture, climate change, economics and politics.

Professor Laila MANDI, Environmental Sciences, University Cadi Ayyad, Marrakech, Morocco – since 2001 National Co-ordinator of the cluster of competences on 'Water and Environment'.

1. Tony Allan - main challenges in trying to create an indicator set for water management in the Mediterranean, especially with respect to the biophysical and political differences among sub-regions or countries in this region? What (groups of) indicators should by all means be included in such an indicator set?

Water allocation and management in the Mediterranean

Unfortunately there are no available indicators of the quality of water governance – certainly none that are operational – that would help society manage its water resources in ways that enable the sustainable intensification of water use.

The allocation of water to different uses is everywhere a political challenge. It is particularly a political challenge in a water scarce region such as the Mediterranean. It is necessary to understand the hydrological and economic underlying fundamentals which are relatively easy to identify. It is getting such information into the competing political discourses on water security that is the challenge.

Hydrological and economic indicators

Hydrological and economic efficiency indicators are important. But they will not be rehearsed here as they are academic unless they can have an impact on the political and social processes that determine how water is valued, allocated, managed, re-used and disposed. There are a number of useful approaches that help us communicate about these issues. Recent work on water footprints and virtual water trade by Allan (2003), Hoekstra and Hung (2002), Chapagain and Hoekstra (2003; 2004), Aldaya *et al.* (2009), Garrido and Llamas (2009) provide both approaches and numbers that are more comprehensive than those used in the past to both define and compare levels of water resource security. They include the previously ignored green water in the soil profile which in most economies is the majority water – although not always in the Mediterranean. Especially in its eastern and southern regions where economies such as Egypt (Zeitoun *et al.,* 2010) are almost totally dependent – albeit for only part of their water security – on surface blue waters – the Nile, or Libya which is almost totally dependent on blue groundwater. The northern Mediterranean economies all have substantial green water resources. France is one of the exceptional economies in the world that is a net exporter of virtual or embedded water. These new approaches developed after 2000 also capture the role of international trade in water intensive commodities. Over 80 percent of the economies of the world are net food and virtual water 'importers'. The Mediterranean is unusual in having a net food and virtual water 'exporter' – France.

Other approaches are helpful and provide ways of identifying and quantifying different indicators such as cost, price and value of water resources in the case of Moss (2004); and of the costs of addressing the essential challenges of mobilizing investment to increase water availability and productivity and the relative costs and impacts of these investments the case of (McKinsey 2010). It is useful to note that these indicators have been developed by private and corporate sector players in association with water and water policy scientists.

Indicators of environmentally sustainable management of green and blue water

The above approaches to the hydrological and economic contexts and to the production and productivity of water have been developed by water science and corporate professionals. The sustainable use of water resources and the protection of the environmental services have been promoted by international and national civil movement activists (Zygmunt 2007; SAB Miller and WWF 2009). Identifying and quantifying indicators of the extent to which water resources are being allocated and managed sustainably is at a very rudimentary stage.

Indicators of effective governance of sustainable intensification and national water security

Water security is achieved in all net food and virtual water 'importing' economies outside the water sector. Nearly all the Mediterranean economies are net food and virtual water 'importing' economies. Water security - beyond that which can be achieved by sustainable intensification of the water resources of an economy – is achieved through the diversification of an economy. Diversification is impeded by water scarcity but not determined by water scarcity. Diversification depends on the extent to which the human resources have been improved and the synergies of public and private investment and entrepreneurship have been nurtured and developed. Think Malta: it has less than ten per cent of the water resources – blue and green – for water self-sufficiency. It is water secure because of the quality of its human resources and the effectiveness of its public and private sector productive and regulatory institutions. The identification and measurement of the vast range of indicators that makes up the governance of water resources and the socio-economic contexts in which such governance operates is an elusive and possibly fruitless task. Good governance of water is integral to the good governance of a political economy.

2. Laila Mandi - What are the main challenges when trying to create an indicator set for water management in the Mediterranean region, especially with the aim of integrating gender issues?

In the Mediterranean region, and particularly in the arid, developing countries, water scarcity is very real, with implications for social, ecological order, regional peace and food security. Management of available water resources is therefore a priority. Recognition of the need of integrated water resources management is growing, which requires attention to the human aspects of the use, development and management of water resources. For that reason growing attention to gender is now advancing in most countries of the Mediterranean region. Nowadays, the so-called 'mainstreaming' of gender issues in water resources and the irrigation sector is a top priority on the agendas of international organisations (Minoia, 2007; Hamdy *et al.*, 2004).

Gender plays an important role in Integrated Water Resource Management (IWRM). Not just in the planning process but also through the stakeholder consultations and every other step in between. Gender mainstreaming or gender equality in IWRM is essential for two important reasons. One because women are just as much affected by decisions made with regards to water as men and because achieving gender equality is one of the millennium development goals. For these reasons the challenge is to take gender into account in an IWRM plan to give a balanced and equitable output with everyone's best interests taken into account.

For instance, research shows that the role of women in water management and decision-making is directly linked to other major socio-economic drivers, such as improved sanitation, health, education, (micro-) finance, economic growth, resilience to shocks, and recovery from social conflict, and in the wider issues of governance and basic human rights.

However, a profound gender analysis demonstrated clearly the considerable gap between positive policy intentions and their conversion into concrete actions. Such slow conversion of gender policies into practice, in particular in water resources management and irrigation are the results of the lack of analytical tools and appropriate concepts, the lack of comprehensive conceptual frameworks and appropriate implementation beside the absence of gender performance indicators and above all the vague and weak roles of water institutions and agencies (Hamdy *et al.,* 2004).

According to the outcomes of the Bari workshop (Hamdy *et al.,* 2004), the main problems that are limiting the integration of women in water management are:

1. **Legislation**: Legislation often does not sufficiently consider the access of women to land and water in most Mediterranean countries. Women are absent in the decision-making process, government agencies are not taking enough initiatives in educating women in water management issues. Legislation must be modified to be more gender-sensitive.

2. **Communication and Awareness of Gender Issues**: Education at primary and secondary school, vocational schools and universities in gender issues is of utmost importance for increasing the awareness of the public and the government bodies. Little is done in this important area compared to the actual needs.

3. **Inadequacy of Analysis:** There is a poor analysis of gender issues in water policies. New tools and guidelines are needed.

4. **Lack of Participation of Women in Water Governance:** Women are mainly absent in the management and policy making processes. Very few women are active in Water Users Associations and Water Cooperatives. The same applies to most irrigation and water supply agencies.

5. **Centralization of Water Management and Governance:** There is an excessive centralization of decisions and insufficient knowledge of local problems resulting in very poor technical assistance at local level.

6. **Institutional Capacity:** There is a lack of coordination mechanisms among relevant institutions and bodies within countries and more at regional level and limited skills related to participatory and gender approaches.
7. **Extension**: The extension services directed towards women are unsatisfactory. There are few female extension officers\gender specialists. Training material is rarely gender ensitive.
8. **Impact of Globalization**: Globalization is affecting social roles in rural communities and agricultural management, including irrigation. Many women are changing their attitude towards agricultural work.
9. **Cultural Heritage and Social Norms**: In most countries inequity and inequality are dominant because of social and cultural reasons.
10. **Poverty**: Most working women are engaged in agriculture and are the most disadvantaged group of their society. Due to lack of training and other reasons they remain unskilled workers.
11. **Lack of Access to Information:** There is insufficient knowledge among men and women about their own rights, and there is lack of access for needed information and technology.
12. **Lack of Gender-Sensitive Indicators**: There is an absence of institutional set up that is responsible for monitoring the process of gender integration into water management.
13. **Gender-disaggregated statistical information** A limited availability of statistics disaggregated by sex and therefore it becomes difficult to quantify the gravity of situations related to the access of women and men to land and water resources.

It is recognised that the outputs of the MELIA project will contribute to the future development of methods and tools which will enable important improvements in the capacity of women in developing countries to cope with changes in their environment. Women will be encouraged to participate in stakeholder engagement and capacity building activities. Environmental sustainability is enhanced when the priorities and demands of all stakeholders are addressed:

- Women should be recognized as central to the provision, management and safeguarding of water and environmental management
- Policies and strategies on water and environmental management need to respect gender differences
- Good understanding of gender equality issues is required for adequate implementation of policies and strategies

Recommendations – proceeding further

One of the aims of the MELIA project is to propose a set of indicators applicable in the Mediterranean region, in order to facilitate and improve the management of water resources. As the bottom line of this present review paper, taking into account the guest commentaries, we suggest proceeding further in the following way:

As a first step a general feedback round seems to be advisable in which the MELIA partners comment on the present paper giving input such as additional issues necessary to be covered, more existing indicator sets, etc. Last inputs will be collected at the 4th MELIA project workshop in March 2010 in Amman, Jordan.

The paper presents three specific existing sets of indicators which have certain potential of being applied in the Mediterranean. MELIA partners could build on the experiences made (many of them were already part of other projects elaborating indicator sets) and use the existing sets for a possible adaptation of an indicator set already applied nationally. An additional option could be to discuss the elaboration of a MELIA indicator set by means of a project workshop.

While it would be crucial for the workshop to invite also representatives of national institutions now responsible for the data collection, in order to get an insight in data availability and consequently the feasibility of the elaborated indicator set, in general, special caution has to be applied no to depend too much on indicators, as often specific indicators are based on weak assumptions leading to confusing results.

There is no one ideal indicator set for the management of water resources in the Mediterranean. The process to get to the best-suited set has to be understood as participatory, integrative and iterative. In this spirit the present paper constitutes the first iteration step in this fruitful procedure.

References

Aldaya M.M., Hoekstra A.Y. (2009). *The water needed to have Italians eat pasta and pizza.* Delft, the Netherlands, UNESCO-IHE.

Allan J.A. (2003). Virtual water - the water, food and trade nexus: useful concept or misleading metaphor? *Water International* 28: 4-11.

Allan J.A. (1993). Fortunately there are substitutes for water otherwise our hydro-political futures would be impossible. *Priorities for water resources allocation and management*, Vol. 13-26, ODA, London.

Benoit G., Comeau A. (2005). A Sustainable Future for the Mediterranean: The Blue Plan's Environment and Development Outlook. Mediterranean Action Plan (MAP) of the United Nations Environment Programme (UNEP). Earthscan. London.

Chapagain A.K., Hoekstra A.Y. (2003). *Virtual water flows between nations in relation to trade in livestock and livestock products*. Delft, the Netherlands, UNESCO-IHE.

Chapagain A.K., Hoekstra A.Y. (2004). *Water Footprints of Nations. Value of Water* Research Report Series 16, UNESCO-IHE, Delft, the Netherlands.

FAO (2006). *UNWater - Water monitoring. Mapping existing global systems and initiatives.* Background Document - August 2006.

Faurès J-M. (1996). Indicators for sustainable water resources development. In: *Proceedings of the Workshop 'Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development'* organized by the Land and Water Development Division FAO Agriculture Department and the Research, Extension and Training Division FAO Sustainable Development Department 25-26 January 1996

Feitelson E., Chenoweth J. (2002). Water poverty: towards a meaningful indicator, *Water Policy* 4, S263-281; Elsevier Science Ltd.

Garrido A., Llamas M. (2009). Water Management in Spain: An Example of Changing Paradigms. *Policy and Strategic Behaviour in Water Resource Management*: 1-25.

Hamdy A., Quagliariello R., Venezian-Scarascia M.E. (2004). Integration of Gender Dimension in Water Management in the Mediterranean Region; Bari's workshop review. – INGEDI carried out by CIHEAM IAM-Bari http://ressources.ciheam.org/om/pdf/a64/06002369.pdf

Hoekstra A.Y. (2008). Human appropriation of natural capital: A comparison of ecological footprint and water footprint analysis. In: *Ecological Economics* 68

Hoekstra A.Y., Hung P.Q. (2002). *Virtual water trade. A quantification of virtual water flows between nations in relation to international crop trade.* Delft, the Netherlands, UNESCO-IHE.

McKinsey (2010). Managing water strategically: An interview with the CEO of Rio Tinto. McKinsey Quarterly.

Minoia G. (2007). Gender Issue and Water Management in the Mediterranean Basin, Middle East and North Africa. FEEM Working Paper No. 49.2007.

Moss T. (2004). The governance of land use in river basins: prospects for overcoming problems of institutional interplay with the EU Water Framework Directive. *Land Use Policy* 21(1): 85-94.

OECD (2001). A*gri-environmental indicators*, Volume3. Methods and results. 400 p.

OECD (2008). *OECD Key Environmental Indicators*. Organisation for Economic Cooperation and Development, Paris.

SAB Miller and WWF (2009). *Water Footprinting. Identifying and addressing water risks in the value chain.* Report. http://assets.wwfza.panda.org/downloads/sabmiller_water_footprinting_report_final_.pdf

Saeger J. (2001). Perspectives and Limitations of indicators in water management, in : *Regional environmental change* - online publication Springer Berlin/Heidelberg http://www.springerlink.com/content/njqxt7tprnhr2n2h/

Smith E. (2004). Water Resources Criteria and Indicators, in: *Water Resources Update*, Issue 127, p59-67; Sustainable Water Resources Roundtables

Smith E., Swanson R. (2007). Developing national and sub-national sustainable water resource indicators, in: *Proceedings of the 2007 World Environmental and Water Resources Congress*, May 15-19, 2007, Tampa, Florida; Sponsored Environmental and Water Resources Institute (EWRI) of ASCE) http://cedb.

asce.org/cgi/WWWdisplay.cgi?0705618

Smith E.T., Zhang H.X. (2004). Developing key water quality indicators for sustainable water resources management; *Proceedings of the Water Environment Federation*, WEFTEC 2004: Session 41 through Session 50, pp. 583-603(21),Water Environment Federation

Spangenberg J., Bonniot O. (1998). *Sustainability Indicators – A compass on the road towards sustainability.* Wuppertalpaper 81

Sullivan C.A., Manez M., Schmidt S., Moors E., Preziosi E., Loubier S., Inman D., Tarnacki K., Wyngaert I. Van den, Olsthoorn A.F.M., Fröbrich J., Blümling B., Koundouri P., Panebianco S., Giacomello, A.M., Günther D. (2007). *Report on indicators for water stress*', AquaStress Deliverable D2.1-3, Centre for Ecology and Hydrology, Wallingford, UK.

SWAP (2008). *SWAP Evaluation Framework - objectives, goals, and indicators. First part: the consensus on problems, objective, actions (Deliverable 4.1, 4.2, 4.3)*. WP4 – Participatory Deliberation of Methodology.

Zeitoun M., Allan J., Mohieldeenet Y. (2010). Virtual water flows of the Nile Basin, 1998-2004: A first approximation and implications for water security. *Global Environmental Change, 20: 229–24.*

Zygmunt J. (2007). *Hidden waters. We consume a lot more water than we can even imagine, and our water footprints extend far beyond our nation's boundary*, Waterwise

(1) Note: 'Blue' water is water withdrawn from rivers, lakes, or aquifers, while 'green' water is water from precipitation.

Promotion of water saving policies and options for water use in improved areas in Egypt

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Abstract. The problem of water scarcity is complex, as it includes climate change, desertification, as well as increased demand by different water user sectors. The concept of sustainable water use is based on three main issues, economic efficiency, social equity and environmental integrity. The vision of the Ministry of Water Resources and Irrigation is that a new approach of water management is needed to consider the diverse range of resource-use features and its interactions to elaborate sustainable water resources management strategies. The study presented here concentrates on these aspects in general and gives some findings on water saving options in the improved areas of Egypt. It reflects on the actual approaches to water saving strategies. Therefore the current state of water management policies, indicator development and participation approaches was investigated. The implementation of an effective integrated strategy or policy for water management, and water saving, needs also to be based on a comprehensive and integrated assessment of the water bodies. At the same time, successful practices of water use need to be disseminated. It is essential to enable a quantification and qualification of system aspects for successful evaluation.

Key words: Water – Price policies – Water management – Water availability

Promotion de politiques et d'options d'économie des ressources en eau dans les régions en progrès d'Egypte

Résumé. *La raréfaction des ressources en eau est un problème complexe qui associe le changement climatique, la désertification et une demande accrue de la part de différents secteurs consommateurs d'eau. Le concept de l'utilisation durable de l'eau procède de trois enjeux majeurs : l'efficacité économique, l'équité sociale et l'intégrité environnementale. L'idée du Ministère des ressources en eau et de l'irrigation est qu'une nouvelle approche de la gestion de l'eau est nécessaire pour appréhender la diversité des aspects liés à l'utilisation des ressources et ses interactions, dans le but d'élaborer des stratégies de gestion durable des ressources en eau. L'étude présentée ici porte sur tous ces aspects en général et rassemble quelques résultats relatifs à des options d'économie d'eau dans les régions en progrès d'Egypte. Elle propose une réflexion sur les approches actuelles en matière de stratégies d'économie d'eau. A cet effet, l'état actuel des politiques en matière de gestion de l'eau, du développement d'indicateurs et des approches participatives a été étudié. La mise en œuvre d'une stratégie ou d'une politique intégrée efficace pour la gestion de l'eau et l'économie des ressources doit en outre se baser sur une évaluation étendue et intégrée des plans d'eau. Les pratiques d'utilisation de l'eau qui ont fait leur preuve doivent en même temps être diffusées. Pour une évaluation efficace, il est essentiel que les différents aspects du système puissent faire l'objet d'une quantification et d'une qualification.*

Mots clés: *Eau – La politique des prix – Gestion de l'eau – Eau disponible*

I – Introduction

During our participation in the WASAMED meetings and the discussion on the harmonization and integration of water saving options for the Mediterranean Countries, some of the presented theoretical techniques appeared to be applicable for the case of Egypt. This paper presents some of the relevant applications for the current Irrigation Improvement Project (IIP) in operational irrigated areas in Egypt.

Egypt lies in the north-eastern corner of the African continent, stretching over an area of about 1 million km² (fig.1). The total cultivated land estimated to be 3.5 million ha, or about 4% of the total area. About 88 % of the total cultivated area consisted of annual crops and 12% consisted of permanent crops.

Agriculture accounted for about 17% of Egypt's GDP and provided employment to 38% of the labour force (Ministry of Economic Development, n.y.).

In its long term agricultural strategy (until 2017) (Ministry of Agriculture and land Reclamation) the government emphasizes the need to considerably increase the water use efficiency. The agricultural sector uses more than 80% of the total demand for water.

Figure 1: Location of Egypt *(MOED-Egypt 2007*).

Water is one of the most precious resources in Egypt. Much has been done, but still a lot remains to be done in the field of water resources development and management. The water scarcity in Egypt is, most of the time, related to a lack of management capacity. In the case of Egypt the main constraint to agricultural development will not be the availability of land, but of water. The demand for water will increase in the near future while the physical availability of water remains constant. The major challenge facing water planners and managers will be to balance demand and supply of water. The rising demands of water have necessitated the improvement of the performance of irrigation systems and increasing water use efficiency. 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 deserts cover most of the country's area, except for a narrow strip of cultivated land and urban areas along the Nile river course and Delta.

Egypt needs to formulate water saving strategies and action programs at larger scale for irrigation projects. They need to be integrated with operational programs, to have the maximum benefit. The integration of water saving policies includes developing appropriate mechanisms of water management and the establishment of water resources authorities, or other institutional arrangements. National programs that improve the institutional capacity to manage water resources are likewise needed.

The Ministry of Water Resources and Irrigation, MWRI, formulated a water policy program to assist the ministry in identifying, evaluating, and implementing policy adjustments and institutional reforms that lead to improved water use in agriculture. The examined issues are diverse and complex, ranging from legislative reform and measures to protect water quality, to increased private sector involvement in the management of Egypt's irrigation systems.

Performance improvement of irrigation systems is not only accomplished by technical interventions. More importantly the institutional framework needs to be improved in to order improve 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 MWRI.

This paper highlights the efforts towards improving the water use policies and efficiency through harmonization and integration of water saving options and the promotion of water saving policies and guidelines in innovative projects in Egypt. One of the main goals of such projects is water saving through the introduction of the new techniques at all operational levels (tertiary, distribution, branch and main levels). At the same time, the research highlights the need to introduce the concept of integrated water management and the accompanying operational techniques at the district level in the command area of the project. The study investigated the state of policies and the possibilities for integrated approaches of water management and the required collaborative development. Moreover, it studied the selection process of indicators for the assessment of water saving options at different operational levels.

Irrigation History in Egypt

In the past, the problem of irrigation in Egypt was the large variation in water supply (fig.2). The amount of supply was more than enough, however, most of this supply comes during a short period (August- October) and so a large part goes to the sea. During spring and summer periods

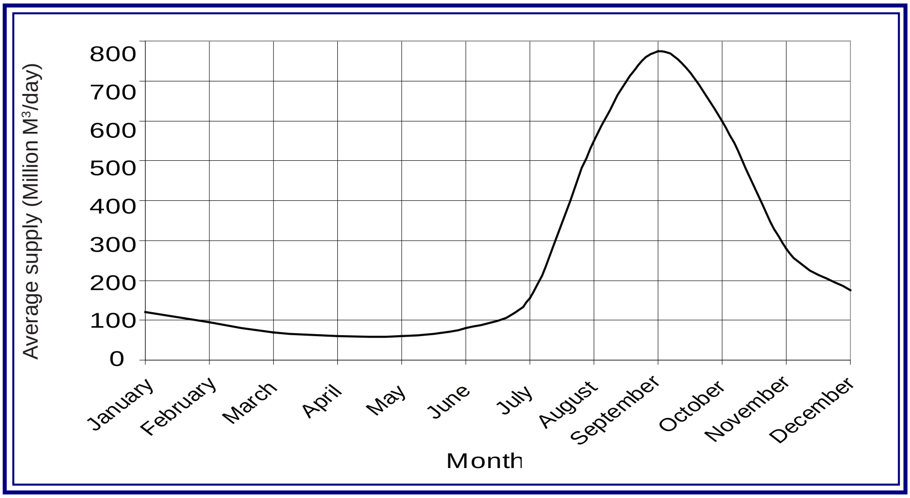

Figure 2: Average supply of Nile river *(WMRI Technical Report-2009)*

Even before constructing the High Aswan Dam (fig. 3), the main barrages on the river were built (Delta Barrage upstream of the two branches of the Nile and other barrage on the Nile itself in Upper Egypt) and many new canals were excavated. There was a big risk during high flood years and during low flood years, as the system did not enable the operator to control the excess of water during the high floods or to store the water to be used during the low flood year period. A better distribution between years was achieved by the construction of High Dam during the 1960's. Due to these efforts, cultivated land could increase from 3.05 Million acres in 1821 to 8.0 Million acres in 1997 and the cropping areas also increased from 3.05 Million acres to 15 Million acres. (WMRI Technical Report, 2009)

Figure 3: High Aswan Dam *(MWRI,2006).*

II – Water resources in Egypt

As water demand from sectors such as municipalities and industry is increasing, the development of Egypt's economy strongly depends on its ability to conserve and manage its water resources. The Nile River is the main source of water for Egypt. Under the 1959 Nile Waters Agreement between Egypt and Sudan, Egypt's share is 55.5 km³/year. Figure 4 shows the water balance for 1993-1994.

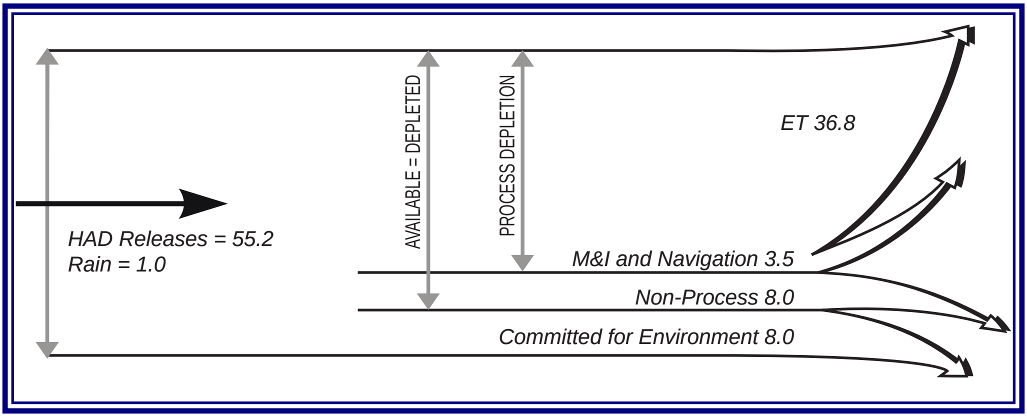

Figure 4: Water budget for Egypt's Nile River based on 1993/94 water balance data. *Source: Molden et al., 1998.*

The water resources include conventional and non-conventional water resources

- Conventional resources such as:
  - annual rainfall,
  - surface runoff and
  - groundwater
- Non-conventional resources such as
  - Shallow groundwater
  - Drainage reuse
  - Treated Sewage
  - Desalinated water

Figure 5 shows the shares of the various sources to Egypt's total water availability. Egypt has about 2,400 km of shorelines on both the Red Sea and the Mediterranean Sea. Desalination could, therefore, be used as a water source for domestic use in many locations. However, desalination of seawater in Egypt has been given low priority so far, because the cost of treating seawater is high compared with other sources, even unconventional sources such as drainage reuse. In remote areas where the cost of constructing pipelines to transfer Nile water is relatively high, desalination is sometimes feasible to provide domestic water.

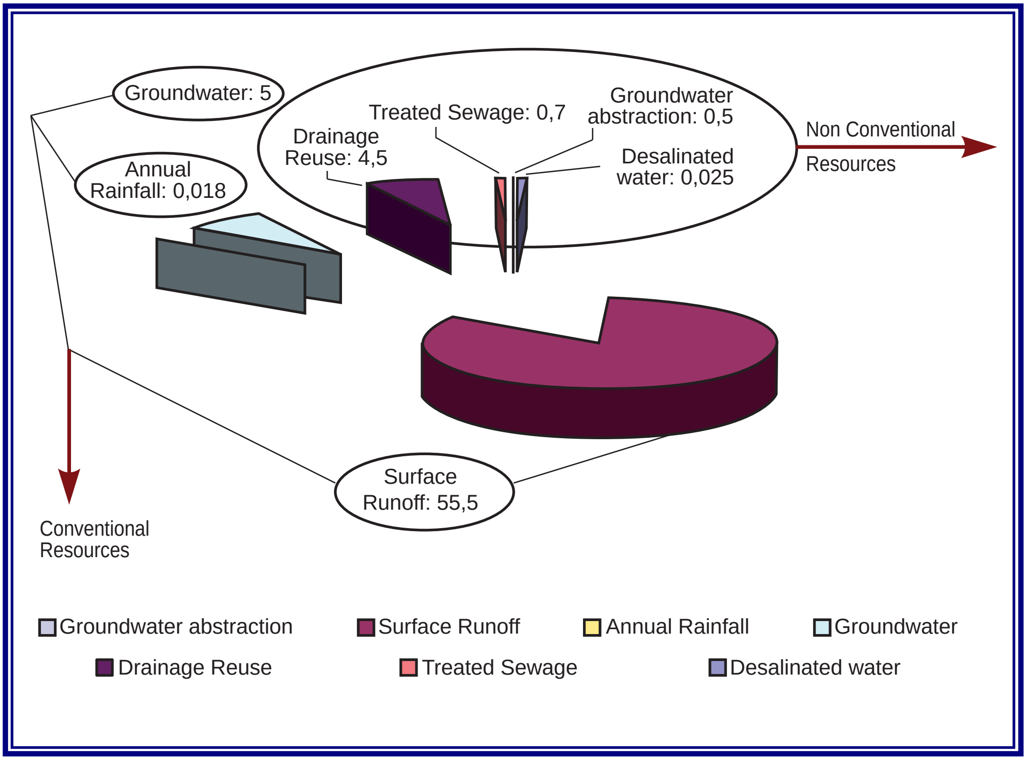

Figure 5: Conventional and non-conventional water resources in Egypt. *Source: Elkassar, G. 2008.*

The future use of such resources for other purposes (agriculture and industry) will largely depend on the rate of improvement in the technologies used for desalination and the cost of required energy. If solar and wind energy can be used as the source of power, desalination can become economic for other uses. It may be crucial to use this resource in the future if the growth of water demand exceeds the available other water resources. Brackish groundwater with a salinity of about 10,000 ppm can be desalinated at a reasonable cost and can have potential for use in agriculture.

Non-conventional Water Resources

Other sources of water can be used to meet part of the water requirements. These sources are called non-conventional sources, which include:

- The renewable groundwater aquifer in the Nile basin and Delta
- The reuse of agricultural drainage water
- The reuse of treated sewage water

These recycled water sources cannot be considered independent resources and cannot be added to Egypt's fresh water resources. These sources need to be managed with care and their environmental impacts evaluated to avoid any deterioration in either water or soil quality.

Water Challenges in Egypt

There are a number of government institutions engaged in the development of the water and land use in the country. The water and agricultural policies and strategies are affected by different natural conditions and human activities.

These challenges and gaps in the current operation of water and land sectors include:

- Securing water and food supplies
- Meeting basic needs
- Valuing water & land
- High population growth rate
- Increased industrial activities
- Lack of governmental funds to achieve proper maintenance and rehabilitation of system components
- Enforcement of water related laws and regulations
- Protecting the ecosystems
- Managing operational risks
- Lack of users' participation in system planning, design, operation, and maintenance

These challenges delay the improvement of the system management and result in low water use efficiency, and increase conflicts among water users to resolve these issues. The challenge of water management in Egypt is to convert the management approach from a single sector supply based approach to an integrated water resource management strategy which considers all different water use sectors, the different driving forces and their impacts. Furthermore, it should manage both the supply of water and the demand. Hence, water can only be managed effectively if all the uses of the resource become better known. Subsequently, it will be possible to implement water saving strategies and policies to implement them. The present policy approach reacts to increased demand by increasing the supply. In the future, the aim is to reduce the demand and introduce water saving policies at all levels. Figure 6 gives an overview of the main water policy domains and the related stakeholders and issues.

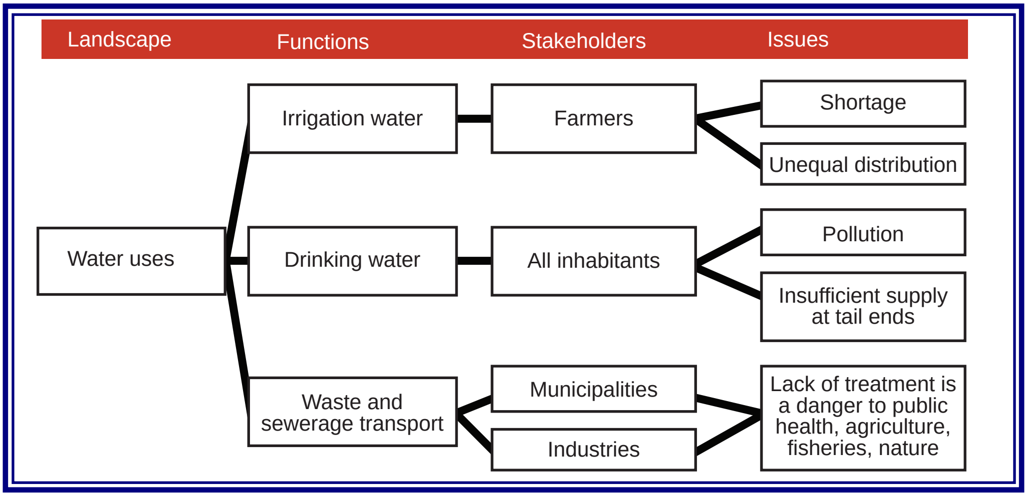

Figure 6: Water policy domains. *Source: Elkassar, G. 2008.*

III – Water use promotion policy

Agro and Hydro-Ecological Zones in Egypt

The rapidly growing population in the country puts considerable pressure on the scarce natural resources and there is an urgent need to develop agricultural production and water use systems that are more efficient and sustainable. These should be based on an initial assessment of the physical and biological potential of natural resources, which can vary greatly. 'The hydro-ecological zonation (HEZ) and the agro-ecological zonation (AEZ) approach present a useful preliminary evaluation of this potential, and ensures that representation is maintained at an appropriate bio-geographic scale for regional sustainable development planning' (Elkassar, 2008).

The Food and Agriculture Organization (FAO) produces this AEZ in each country to assess the crop production potential and length of the growing period zones. It is very useful as it describes the area within which rainfall and temperature conditions are suitable for crop growth for a given number of days in the year. These data, combined with the information on soils and known requirements of different crops, can be used to assess the potential water requirement and hence crop productivity.

Such an approach would facilitate the investigation and identification of appropriate techniques, capacity building needs, participating stakeholders, required legislation, economic tools, incentives, finance, as well as social implications. Egypt has a total area of about one million square kilometers, under arid and hyperarid climatic conditions, of which only a small portion (3% of total area) is agriculturally productive (source?) The country can be divided in 4 main agro-ecological zones having specific attributes of resources base, climatic features, terrain and geographic characteristics, land use patterns and socio-economic implications.

Such main zones could be identified as follows (see figure 7 and table 1):

1. North Coastal Belts: including North West Coastal Areas and North Coastal Areas of Sinai.
2. The Nile Valley: Encompassing the fertile alluvial lands of Upper Egypt and the Delta and the reclaimed desert areas in the fringes of the Nile Valley.
3. The Inland Sinai and the Eastern Desert with its elevated southern areas.
4. The Western Desert, Oases and Southern Remote Areas: including East Owenat Tock and Drab El Arabian Areas and Oases of the Western Desert.

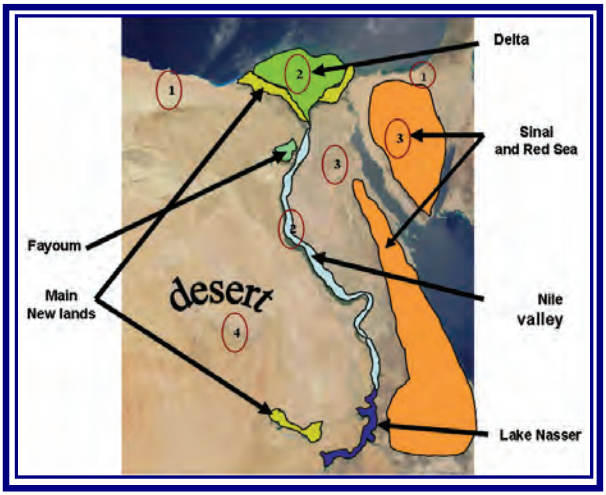

Figure 7: Map of Agro-ecological zones in Egypt. *Source: Elkassar, 2008.*

Table 1: Agro-Ecological Zone Parameters and water management issues in Egypt.

Name	Land parameters	Water parameters	Main management concerns
Lake Nasser	n.a.	• volume; • water level;	• storage and release of water; • spilling peak flow
Nile Valley	• rather flat • clay soils • impervious subsoil	• artificial water supply; • medium groundwater depth; • fresh groundwater;	• pump irrigation • Preventing drainage to river • new crop Varieties
Fayoum	• steep slope; clay soils	• shallow and stagnant groundwater; • inflow of surface irrigation water;	• irrigation by gravity • drainage to lake Qarun • water quality • environmental activities
Delta	• flat; clay soils	• fresh to saline groundwater • most surface water from Nile	• pump irrigation • improvement of old land • on-farm management • sub-surface drainage • water quality management • salinity control • water depth for navigation
New Lands	• flat to heaving • sandy soils	• saline groundwater • all surface water from Nile	• Irrigation practices and improvement of new land • on-farm management • sub-surface drainage and expected problems • water quality management
Sinai and Red Sea	• hilly to mountainous • steep slopes • sandy/rocky soils	• some rain • flash floods	• storage and release of water; • spilling peak flow
Desert	• sand dunes	• deep ground water • fresh or saline	• deep wells for irrigation; bottled water • Industrial activities

Source: Elkassar, G. 2008.

IV – Water distribution system improvement

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.
- Re-modelling the canal cross-section to improve the canal hydraulic characteristics and conveyance efficiency, and to bring the cross section back to the standards of the original design. The re-model-ed 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 (the ditch at tertiary level), pumps, pump stands, and pump sumps. Energy dissipation basins are also constructed at the head of each mesqa.

One of the main targets of this paper is to review and analyze water saving options included in the application of the Irrigation Improvement Project (IIP package), (MWRI, 1997). The IIP consists of a combination of physical and institutional improvements of the main irrigation delivery system and the farm level irrigation delivery and application systems. These improvements include renovation and improvement of canals, downstream water level control, conversion from rotational flow to continuous flow, mesqa improvements, organization of farmers into water users associations and technical assistance through the Irrigation Advisory Service (IAS) (Shalaby *et al.,* 2007).

There were significant improvements in mesqa conveyance efficiencies before and after IIP measures were implemented. Conveyance efficiencies appear to increase from an average of around 60-65% to around 90-95% as a result. These 'local water savings' are translated into reduced deficits of water supply at the farm level and reduced degradation of the water quality (Shalaby *et al.,* 2007).

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. As part of IIP, efforts were made to demonstrate precision land levelling on demonstration fields in each command area. The implementation of a full package of on-farm water management improvements is be expected to gradually result in additional 'local water savings'. These savings can be captured and distributed locally in the system. In addition, improved on-farm water management supports higher crop yields and crop quality. (Shalaby *et al.,* 2007).

Organizational and regulatory framework

The performance of the 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 organizational structures. They are characterized by the empowerment and delegation of responsibilities and the clarification of the line of command within an organization and between organizations. The water management organizations are mainly governmental (Shalaby *et al.*, 2007).

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', (MWRI, Irrigation Improvement Sector, 1997). Within the context of institutional reform in the 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 to manage parts of the irrigation system more effectively (Shalaby *et al.,* 2007).

In terms of administrating 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 to have the canals and other tertiary channels cleaned, maintained, and operated on 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 a representative for the farmers. 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 the relevant government agencies. They can provide such services by acting as a communication channel between the government and the farmers. (Shalaby *et al.,* 2007)

Water control and 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 provided either by rotational or continuous flow. Continuous supply requires stable water levels in the main and secondary canals (Elkassar, 2007). 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 (Shalaby *et al.,* 2007).

Irrigation automation is the use of mechanical gates structures, valves, controllers, and other devices and systems to automatically divert water in the desired amount and sequence. Automated systems can reduce labor energy and water inputs and maintainor increase farm irrigation efficiency, Labor saving and convenience are often major considerations in mechanizing irrigation. While convenience and labor saving are major consideration in many countries, better water control and increased farm irrigation efficiency may be the primary considerations in countries where labor is both plentiful and relatively low cost. Automation also enhances the use of tail water return or reuse systems and can reduce overall energy costs by making surface irrigation more attractive compared to alternative systems that use more energy.

Water Saving Strategy in IIP

Water saving has come to be seen as one of the main objectives of IIP, (Elkassar, 2007). It is expected that continuous flow will contribute to this by enabling and encouraging farmers to take water in a more rational way, without over-irrigation (although in the absence of conclusive evidence from a fully working example there has been a concern among operating staff that it might have the opposite effect). So far as it is a pre-condition for implementing mesqa improvement, continuous flow also contributes indirectly to water saving by eliminating losses from traditional low-level mesqas. However, it should be noted that the aim of improving equity implies that at least part of any savings will pass directly to tail farmers who suffer from water shortages at present. Many of these farmers re-use water which is ‘lost’ at present by irrigating from the drains. In some areas, there is also semi-formal re-use at secondary level, implemented by the Irrigation Districts. The overall saving at the branch canal level may therefore be rather limited. IIP interventions are relevant to all of these. The physical improvements should largely eliminate the possibility of direct losses from canals and mesqas (especially tail losses).

Harmonization and Integration of Water Saving Options

As presented in the paper by Shalaby *et al.* (2007), different water saving options could be integrated to save water in the water distribution system:

- 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.

In the meantime, different water saving options could be integrated to save water on the farm level by:

- Leveling the farm land,
- Improving of farm ditches and mesqas,
- Cultivating crops which are suitable to the climate of the area,
- 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,
- Enhancement of continuous flow strategies with night irrigation concept
- Establishment of WUAs and encouragement of private sector participation (Shalaby *et al.,* 2007).

The (MWRI, 2006) in its summary report for the National Water Resources Plan until 2017, has identified several specific situations that give rise to mismatching, which can be grouped into three general categories:

1. Under- or over-estimating crop water demands under free cropping choices, including cropping patterns and calendars.
2. System constraints, such as canal capacity, system storage capacity, and lag time.
3. External factors, such as climatic change and unanticipated drainage water reuse.

Water shortages have resulted from lack of information about cropping patterns and calendars. Furthermore, some cropping pattern and calendar choices by farmers were unsuited the Nile system delivery capacity. Information on crop selection and the dates of planting and harvesting is essential for good water management. However, there is no routine, accurate, and systematic transfer of this information from farmers or the Ministry of Agriculture and Land Reclamations (MALR) to the MWRI. Both ministries recognize that matching real-time irrigation water demands with water deliveries is an important step toward an efficient, demand-driven irrigation system.

Concept of Integrated Water Management at the Operational Level

The smallest management unit of the 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 introduce innovations for the improvement of performance of water allocation and management. MWRI is now implementing the integrated water management concept in a number of pilot districts. To implement this concept, reorganization at the district level is carried out. The new organizations are called Integrated Water Management Districts (IWMD) (see figure 8), which integrate all MWRI activities in each district (Elkassar and Abou ElFotouh, 2008).

The objectives of such policy were shown in the (USAID, 2008) report for the IWRM at District level and can be summarized 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.

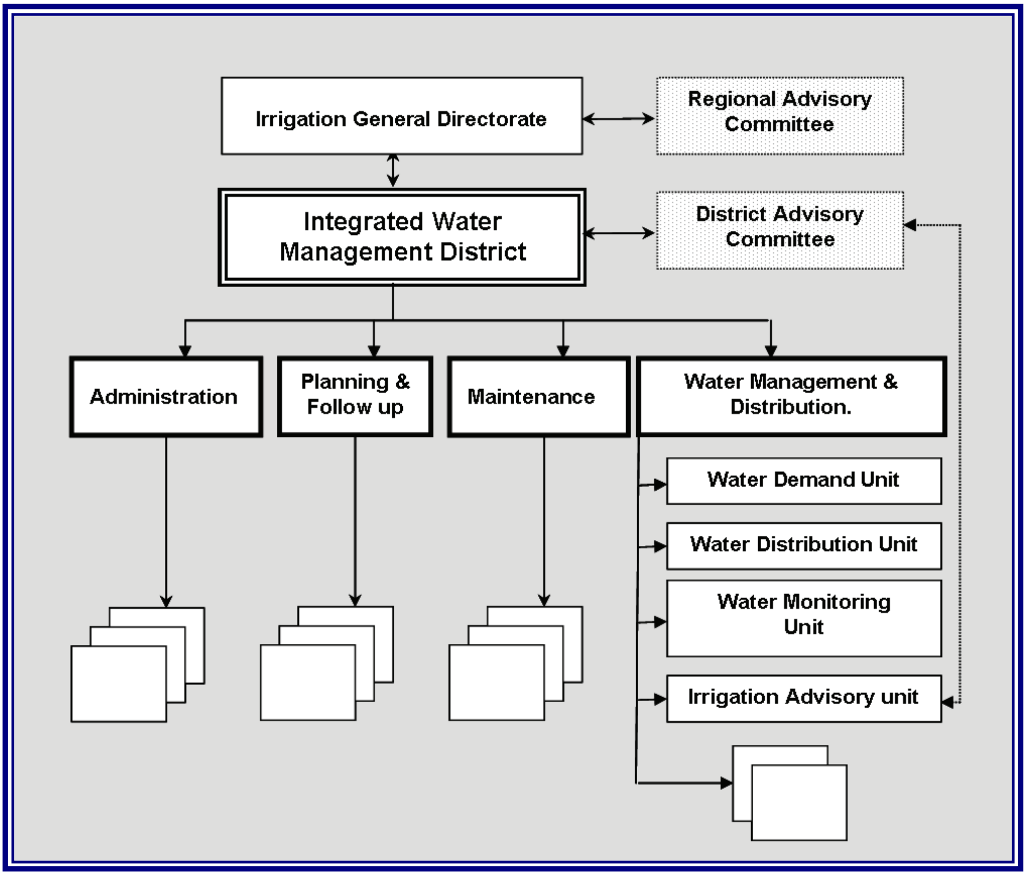

Figure 8: Organizational Structure of Integrated Water Management District *(Elkassar and Abou ElFotouh, 2008).*

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.

V – Main findings

The IIP may contribute indirectly to reducing surface run-off and percolation losses both by avoiding over-irrigation by farmers at the head of the system and by improving on-farm water management. Drainage re-use is not a core intervention of IIP, and it must be borne in mind that in general any increase in irrigation system efficiency reduces the scope for drainage re-use by a corresponding amount.

The IIP will not directly lead to reduced crop water consumption, but it is obvious that any changes in the agricultural system can be more easily implemented in a well-regulated irrigation system providing reliable, flexible and equitable water deliveries. The net overall effect of IIP in achieving water savings is difficult to predict. This is partly because the distribution of water losses in the existing system between the different components (e.g. canal tail losses, percolation losses etc...) is not well known. More importantly, any savings due to local increases in water use efficiency in IIP areas will be used to supply water to tail areas that suffer water shortages. At present they rely on direct irrigation from drains for part, or all, of their supplies. This substitution of water previously lost to the drains, for water previously taken from the drains, will be neutral in terms of overall water savings (FAO)

Action Plan Strategy and Expected impacts:

- Development of strategies to balance irrigation water demand with water supply.
- Establishment of better collaboration between farmers, the MWRI and MALR for determining actual real-time irrigation demands at the directorate and district levels.
- Establishment of a national policy for managing the transfer of real-time information about water supply and demand.
- Improvement of the Nile system operations, which are critical to the Egyptian agricultural economy.
- Movement toward a real-time, demand-driven water distribution system.

Reducing the water consumption by agriculture can be seen as an effective measure for increasing water productivity. The gradual replacement of sugarcane with sugar beets; the reduction of areas where rice is grown; the replacement of currently used varieties of rice with varieties that have a shorter lifecycle, higher productivity and less water requirements; the development of new crop varieties using genetic engineering that have higher productivity and less water consumption, and the design of indicative cropping patterns are effective means for increasing water productivity. The following diagram (figure 9) can assist in planning for securing water need and assessment of crop production, also illustrating different management levels. The following diagram illustrates possible interventions at each project stage to ensure obtaining the expected outputs and to have a sustainable project's benefits.

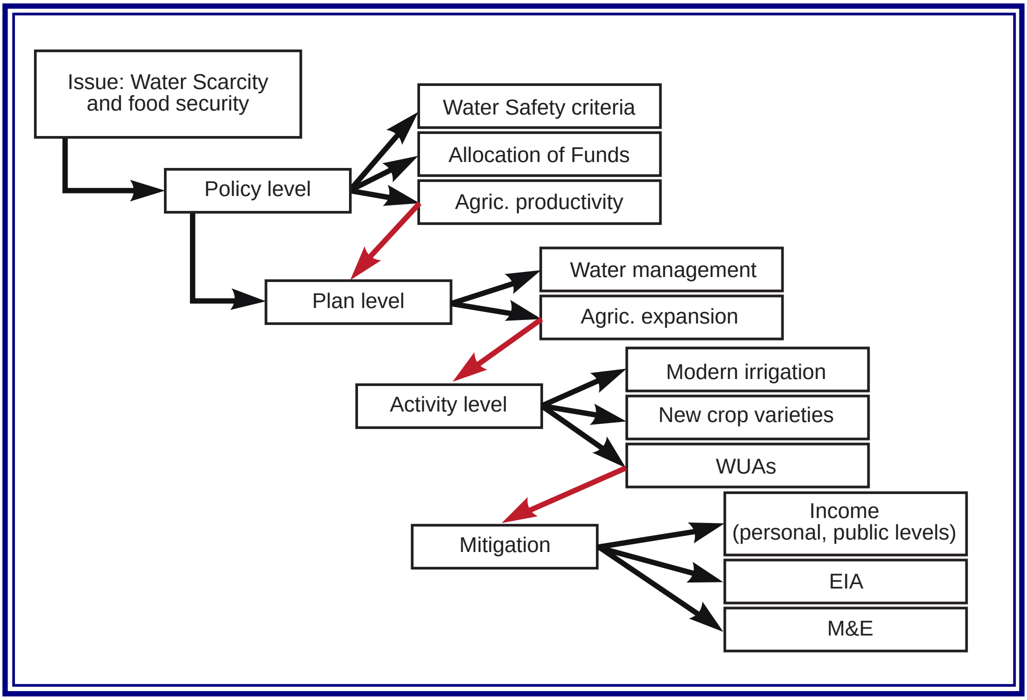

Figure 9: Layout of possible interventions at each stage of project *(Elkassar and Abou ElFotouh, 2008).*

VI – Conclusions and recommendations

The paper describes the integration of water saving measures into a water management policy by drafting a logical framework for future policies and new guidelines for water saving in the country. This logical framework aims at providing a tool for researchers and decision makers to enhance their capacity to analyze and evaluate the effectiveness of the current water saving policies, Furthermore, it also supports identifying measures and priority actions for strengthening and improving integrated management policies for water saving, in particular for the case of Irrigated Agriculture Projects in Egypt.

Different water saving options have been considered, and integrated, to stimulate optimal water savings and crop productivity at different operational levels. Integrating and harmonizing all the water saving options will result in optimal water saving and management on the national level. It could be concluded that implementing of the irrigation improvement project did not result in obvious water saving although the preliminarily results indicate that the application of continuous flow may amount to a large amount of water saving.

The proposed work focuses on the quantification of the changes that are anticipated by the technical interventions through a set of criteria at delivery and on-farm levels, e.g. equity of water distribution, water availability/sufficiency, agricultural practices, project management, agricultural productivity etc.

The following system management innovations could be addressed:

- Sustainability of water sources (durability, quantity and quality)
- Physical improvement of the delivery system
- Implementation of integrated water/land management

- Improve agronomic practices
- New operational techniques
- Farmers participation (WUAs), and institutional reform
- Decentralisation of decision making
- Improve socio-economic return and marketing
- Private sector participation

The study demonstrates that effective water saving policies, in the framework of an integrated water management approach, requires institutional changes and capacity building in the sense of an opening of participation processes to all relevant stakeholders. This can be reached relatively easily by allowing not only water users to participate in the water boards, but also other interested and affected stakeholders (private sector).

Integrated water-resources management should be linked to social and economic development and should address land and water uses and conservation. The results and recommendations presented can help in reviewing, coordinating and updating national water policy, legislation, and institutions to guide the preparation of water-resources assessments and to promote the use of sustainable management practices to meet the growing needs for water. The participation of all relevant stakeholders is essential for IWRM and also for an effective implementation of the necessary water saving strategies.

References

Elkassar G. (2007). Monitoring and Evaluation of Improved Irrigation Delivery System in w/10 Command area – Egypt

Elkassar G., Abou ElFotouh N. (2008). Concept of Integrated Water Management on the Command Areas of Irrigation Improvement Project. 3rd International Conference for Water Resources and Arid Environment, 16 – 19 November 2008, King Fahd Cultural Center – Riyadh, Saudi Arabia**,**

ELKassar G.M. (2008). Identification of Best Practices for Water Harvesting and Irrigation, Final Country Report, Nile Basin Initiatives, www.nilebasin/EWUAP.org.

FAO (2005). http://www.fao.org/countryprofiles/default.asp?lang=en

MWRI (1996). Final Report, 16th international congress on irrigation and drainage, 1996, 'Sustainability of irrigated agriculture', Cairo, Egypt

MWRI (1997). Activities and Achievements of the Irrigation Improvement Sector, Cairo, Egypt.

MWRI (1998). Water Policy Reform Activity, June 1998. Egypt's Irrigation Improvement program. Report No. 7, Ministry of Water Resources and Irrigation, Cairo, Egypt.

MWRI (2006). Water for the Future, Summary of the National Water Resources Plan 2017, November 2006, Cairo, Egypt.

Shalaby A.R., El-Gamal F., Moustafa H. (2007). Country Paper on Harmonization and Integration of Water Saving Options in Egypt. F. Karam, K. Karaa, N. Lamaddalena and C. Bogliotti (eds) *Harmonization and Integration of Water Saving Options.* Proceedings of 5th WASAMED workshop, Malta, 3-7 May 2007. Bari, CIHEAM.

Ministry of Economic Development, Arab Republic of Egypt. N.Y. Social and Economic Development , A Follow-Up Report for the Year (2006/2007)

WMRI, NWRC-MWRI. N.Y. Technical Reports for M&E of Irrigation Improvement Project in Egypt, 2004-2009

USAID (2008). Guidelines for Implementation of Integrated Water management Districts, Report No. 42, Life Project, January 2008, Cairo Egypt**.**

Lessons learned from the Tunisian national water policy: the case of the rehabilitation of oases

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Abstract. Tunisia, as a Mediterranean country, has an irregular climate. The country often suffers from local or general dry periods. To cope with this context of water shortage, Tunisia has adopted a rigorous water policy. This policy has lead to the development of the valuable hydraulic infrastructure in Tunisia today. The irrigated area evolved from 143,000 ha in 1976, to currently nearly 400,000 ha. To strengthen the performance of water policy across the country, three strategic water management plans (North, Centre and South) were instituted. Taking into consideration the diversity of water resources and the regional climatic and socio-economic conditions, complex irrigation schemes were built. In the south of the country, the rehabilitation of oases has been a major part of the national water policy. The strategic water management plan for the South (1979) was the prelude to successive projects. Challenging tasks to improve irrigation efficiency have been undertaken. Thanks to the development in techniques for drilling groundwater wells, the landscape of these irrigated areas has totally changed. In this paper, we discuss the relevant lessons learned from the Tunisian water policy. The case of the rehabilitation of oases in southern Tunisia is elaborated in more detail.

Keywords: Water – Policy – Irrigation – Oases – Efficiency.

Leçons tirées de la politique nationale de l'eau en Tunisie : le cas de la réhabilitation des oasis

Résumé. *Étant un pays méditerranéen, la Tunisie a un climat très varié. Le pays est souvent soumis à des périodes de sécheresse qui peuvent être locales ou générales. Pour faire face à ce contexte de pénurie d'eau, la Tunisie a adopté une politique rigoureuse concernant l'eau. A présent, cette politique a permis à la Tunisie de développer une imposante infrastructure hydraulique et d'accroître la superficie irriguée. Cette dernière est passée de 143 000 ha en 1976 à quelque 400 000 ha à présent. Afin de renforcer la performance de la politique de l'eau dans tout le pays, trois plans stratégiques de la gestion des eaux ont été établis pour le Nord, le Centre et le Sud du pays. Des schémas complexes des réseaux d'irrigation ont été mis au point, prenant en compte la diversité des ressources en eau et les conditions climatiques et socioéconomiques régionales. Dans le sud tunisien, la réhabilitation des oasis s'inscrit dans le cadre de la politique nationale de l'eau. Le plan stratégique de la gestion des eaux du sud (1979) a précédé de nombreux projets successifs, réalisés pour améliorer l'efficacité de l'irrigation. Grâce au développement des techniques de forage de puits pour le captage des eaux souterraines, le paysage de ces zones irriguées a totalement changé. Dans cet article, nous exposons les leçons tirées de la politique nationale de l'eau en Tunisie. Le cas de la réhabilitation des oasis du sud tunisien est plus détaillé.*

Mots clés: *Eau – Politique – Irrigation – Oasis – Efficience.*

I – Introduction

After half a century of water resources development, several lessons can be learned from the Tunisian national experience in managing water resources. For many decades, Tunisia has had a national water policy that defines the outline of water resources management. Despite the country's limited water resources, the accurate assessment of available water resources allowed Tunisia to satisfy the demand, without having to ration water even during periods of acute drought. This strategy was extended towards improved water demand management (Horchani, 2007). Indeed, the water saving plan aims to decrease the demand by 30% for all sectors. Major efforts are required in the irrigated sector.

Several reforms focused on the improvement of distribution efficiency. Moreover, significant financial incentives were directed at accelerating the introduction of water saving equipment (Hamdane, 2008). The many projects that concerned the irrigated areas, which were components of the water policy, induced a tremendous improvement of the development of the irrigated sector in oases in southern Tunisia.

This paper concerns the development of irrigation within the framework of the national water policy. The rehabilitation of oases in southern Tunisia is discussed as a case study. In the context of aridity and acute water shortage, the viability of agriculture in this region largely depends on the implemented strategies for rational management of groundwater resources.

II – Irrigation development : a key instrument of water policy

The irrigated sector in Tunisia has shown an accelerated development through the successive decades of water resources development. From nearly 143,000 ha in 1976, the irrigated area evolved to 380,000 ha in 2001. Furthermore, the hydraulic infrastructure target of 400,000 ha is expected to be achieved in 2010, when the planned surface water system will be fully operational (Hamdane, 2008).

More than 226,000 ha are irrigation systems under public management. The private systems, created around shallow wells, cover 175,000 ha. About 52% of the irrigated area is located in the northern part of the country, 31 % in the centre and 17% in the south (Fig.1). More than 40% of the irrigated area is used for fruit trees (40%), about 36% for vegetable (21% tomatoes and 15% potatoes) production. The cereal cultivation extends to over 14% of the irrigated area, while the feed crops cover 10%.

Figure 1: Location of the irrigated perimeters in Tunisia *(Aquastat, 2005).*

The contribution of the irrigated sector to the total value of agricultural production ranges between 30 and 35%. It contributes also 95% of vegetable production, 77.5% of fruit production, 30% of dairy products and 25% of national cereal yields. The irrigated sector also contributes 20% of the agricultural export value and employs about 26% of working forces (Al Atiri, 2007). Moreover, during the 11th national plan of social and economic development (2007-2011), the contribution of the irrigated sector is expected to reach 50% of the total agricultural production value.

The major Tunisian irrigation systems are collectives and have a regulated water service. They are managed by the public administration. About 62% of the irrigated area under public administration is supplied by water from dams, while 38% are irrigated from deep groundwater wells and treated waste water.

Listed by the nature of the water source, the irrigated perimeters under public administration consist of 142,000 ha irrigated from dams, 47,000 ha (only intensive) from groundwater abstractions, 30,000 ha are oases irrigated by deep groundwater abstractions and 8,000 ha from treated waste water. The private perimeters are supplied from shallow wells made by farmers (Al Atiri, 2007).

The Tunisian experience in developing the irrigated sector began after establishing the strategic water management plan in 1979. The irrigated perimeters were organized in three regions and a respective strategic water management plan was developed for the North, the Centre and the South.

This approach targeted more equity and efficiency in water management. An important strategy that was implemented was the promotion of rational water use. The approach emphasized the need to further involve farmers in water management. The principle of participatory management was often included in the projects concerning irrigation infrastructure rehabilitation.

III – The water strategy for southern Tunisia

The development of the oases in southern Tunisia is an important component of the development of the irrigated sector in Tunisia. These particular ecosystems constitute an intensively cultivated area, with three layers of cultivation (palm trees, fruit trees and vegetables). Palm tree production remains the main use of the irrigated area; it has the highest added value in the export sector while the two lower layers of cultivation are progressively disappearing. Water management in the oases faces several constraints: technical as well as related to farmers' behaviour. The water policy in those areas has a vital interest: it aims to maintain the balance between the available water resources and the development needs. There are three main aquifers that are supplying the oases in southern Tunisia: (i) Continental intercalary (CI); (ii) Complex Terminal (CT); and (iii) the Jeffara aquifer (Fig.2).

Because of their important reserves, the CI and CT aquifers that form the SASS (Système d'Aquifères du Sahara Septentrional or in English: North-Western Sahara Aquifer System) are the key resources for the development of the irrigated sector in these regions. In Tunisia, these reservoirs extend to over 80,000 km2 and are being exploited by more than 1,200 drilled wells (OSS, 2009a). The depth of the CT aquifer ranges between 30 and 500 m while the dept of the CI varies from 60 to 2,800 m. The CI remains the most important water reserve. It is, however, a non-renewable water resource. This aquifer is characterized by relatively hot water (30–75°C) at depths reaching 2,800 m. These geothermal water resources are located in a 600,000 km2 large reservoir, which covers the regions of Kebili, Tozeur, Gabes and the extreme south, and extends to Algeria and Libya. The CI aquifer is one of the largest confined aquifers in the world, comparable in scale to the great artesian basin of Australia. The principal areas of recharge are in the South Atlas mountains of Algeria and Tunisia, and the Dahar mountains of Tunisia (Edmunds *et al*., 1995). The mean salinity of both aquifers, varies between 2,5 to 5 g/l (Prinz and Loeper, 2008). The shared intensive use of these water resources from Tunisia, Algeria and Libya is now closely supervised in order to decrease their overexploitation across the three Maghreb countries.

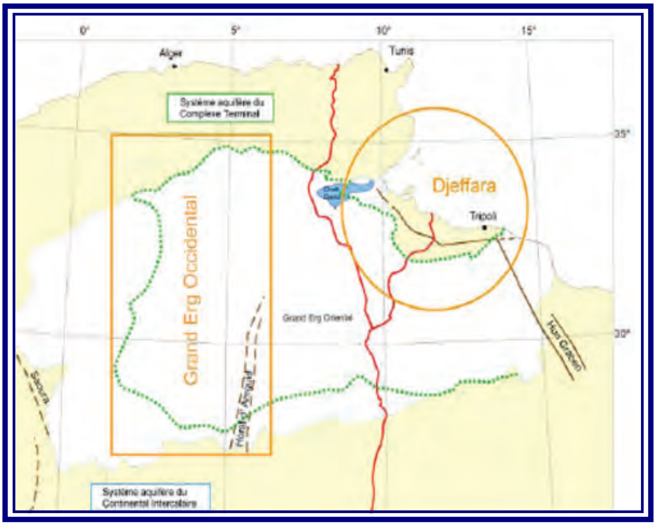

Figure 2: Location of the three main underground water resources in the Southern Tunisia *(Adapted from Schmidt et al., 2006).*

1. The rehabilitation of oases

Since 1972, Tunisia has undertaken an accurate assessment of the available underground water resources. To address the water needs of the expanding oases, the government instituted the strategic water management plan (1976) that defined criteria for natural resources exploitation. This plan aimed to address the growing social and economic needs. The main components are: (i) supplying drinking water, (ii) protecting the old oases that have survived in a context of acute water shortage (more than 129 oases on over 20,000 ha) and (iii) to satisfy the tourist sector, mainly in Gabes, Djerba and Jarjis (Seddik, 2009). The main interventions within the framework of the national water strategy were aimed at achieving agricultural development goals, following an integrated approach. The first step was water resources development. Across the whole southern country, considerable effort was made to rehabilitate hydraulic infrastructure. Deep abstractions were staged in order to increase the irrigated surface. Relevant irrigation and drainage networks were built. Furthermore, the implementation of storage reservoirs contributed to optimize water management, particularly during dry periods. The irrigated area extended through the creation of new oases in the regions of Djerid and Nefzaoua (3,500 ha).

The Tunisian government also promoted the development of irrigation in the oases by encouraging the intensification within farmer parcels. The common date palm varieties were progressively replaced by plantations with higher added value (e.g. *Deglet Nour* variety).

In order to optimize the water management in the southern oases, four specific water management plans were instituted in 1995 for the governorates of *Gabes*, *Gafsa*, *Kebili* and *Tozeur*. These plans aimed to reduce the water allocation shortage. In Kebili, 15 deep wells (up to 2,600 m) were drilled for the exploitation of warm water (72°C) from the CI aquifer. The CT aquifer was exploited by around 15 wells. Because of the increase in water availability, the irrigated area increased as well. More than 16,800 ha in the old oases were rehabilitated and, depending on the water availability, 700 ha of additional irrigated area was created.

In 1996, the project APIOS (***A***melioration of ***I***rrigated ***P***erimeters of ***S***outhern Tunisian ***O***ases) started. It focused on the rehabilitation of 153 oases. The intervention area covered 23,000 ha across the governorates of *Gabes, Gafsa, Kebili and Tozeur*. It was launched to tackle water mismanagement, mainly attributed to low efficiency of the irrigation and drainage networks. The prevailing situation demonstrated a high water loss ratio (40 to 60%) in major irrigated areas. The present situation shows a significant improvement in water management. As part of the rehabilitation works the old irrigation canals were replaced with watertight canals, the drainage networks were intensified. These efforts contributed to enhance water distribution efficiency with 25 to 30% and 7,500,000 m^3/ha/year were saved. Following the completion of the rehabilitation works in the concerned oases, the area productivity was enhanced by 38%, 19%; 23% and 39% respectively in *Gafsa, Tozeur, Kebili* and *Gabes* (Fig.3).

Furthermore, the cultivation intensity increased from 143% to 164%. The yield per unit of land has been improved respectively by 35%, 36% and 80% for dates, olives and fig trees as shown in figure 3 (SAPI, 2005).

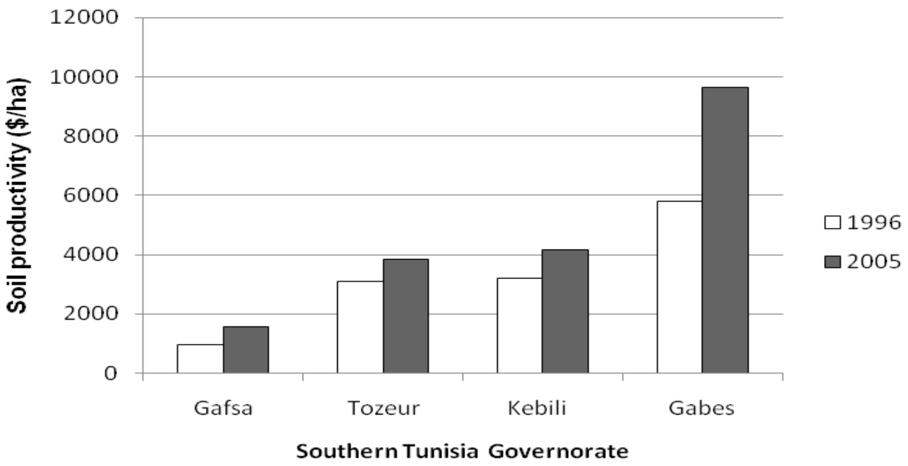

Figure 3: Impact of the rehabilitation works on the soil productivity in the oases in southern Tunisia *(Adapted from Sanyo, 2005*).

More than 90 oases were rehabilitated and a complementary phase of assessment was engaged. This assessment emphasized three highly important points: (1) water consumption on fields remains very high compared to the effective water requirements, (2) water pricing is still insufficient to fully recover real water costs and (3) introducing water saving practices will only be effective when the commitment of people to preserve their water resources is strengthened.

The southern oases have also benefited from the Project PISEAU (***P***roject of ***I***nvestment in the Water ***S***ector) that started in 2001. It focused on setting up pumping stations and building meshed irrigation networks. The introduction of reservoirs to better allocate the water supply, helped the common interest groups (GIC) manage their irrigation networks. After the final rehabilitation works undertaken within the framework of the project PISEAU I (2002-2007), the second phase started. This should be finalized after 2011. In southern Tunisia, the second phase will include not only the scarcity as well as the vulnerability of water resources to the risks of contaminations (salt, pollutants…). The recourse to non-conventional water resources should be strengthened by the installation of waste water treatment in the southern region. Public information campaigns will be increased and capacity building accelerated to further facilitate technology transfer (water treatment units, water saving equipment, underground water resources level and quality monitoring). Table1 shows the chronological succession of main interventions undertaken to promote irrigation in oases in southern Tunisia.

Table 1: The main rehabilitation projects in southern Tunisian oases from 1976 to 2008.

Date	Intervention aim
1976	Tunisian Government launched a wide study evaluating water and soil resources in southern Tunesia.
1979	The strategic water management plan for southern Tunisia was instituted.
1980	Start of 3,200 ha rehabilitation and the creation of 2,100 ha new irrigated area within the framework of the strategic water management plan for the south.
1983	*Djerid* water management plan concerned the rehabilitation of 3,300 ha in Tozeur regions.
1984	*Nefzaoua* strategic water management plan rehabilitating 4,300 ha and creation of 500 ha new oases.
1985	Strategic water management plan of *Gabes* regions: new irrigated areas created of 200 ha and 5,000 ha rehabilitated.
1986	Strategic water management plan of *Gafsa* regions instituted to rehabilitate 3,300 ha of existing oases.
1995	The study of improvement of oases in southern Tunisia concerned 23,000 ha distributed between *Gafsa, Gabes, Kebili* and *Tozeur*.
1996	Beginning of the rehabilitation works (irrigation and drainage network modernization).
2001	Project PISEAU (Investment in Water Sector)
2005	Measures implemented in 90 out of 153 projects (58,82%).
2008	Evaluation of the rehabilitation works impacts and decision to undertake the second phase that will concern 7,427 ha until 2016.

2. The geothermic water use strategy

Within the national water resources development strategy, the geothermic sector is definitely a relevant development and employment vector. After the exploratory drilling campaigns in the beginning of the 1976, important underground geothermal water reserves were identified and widely exploited.

In 1986, the government started to use geothermic water for heating greenhouses in southern Tunesia. Several demonstration projects were implemented across the southern country and the experience was favourable. The assessment of these experimental projects demonstrated a promising development alternative for this region and has led to a continuous extension of the covered area (Fig.4).

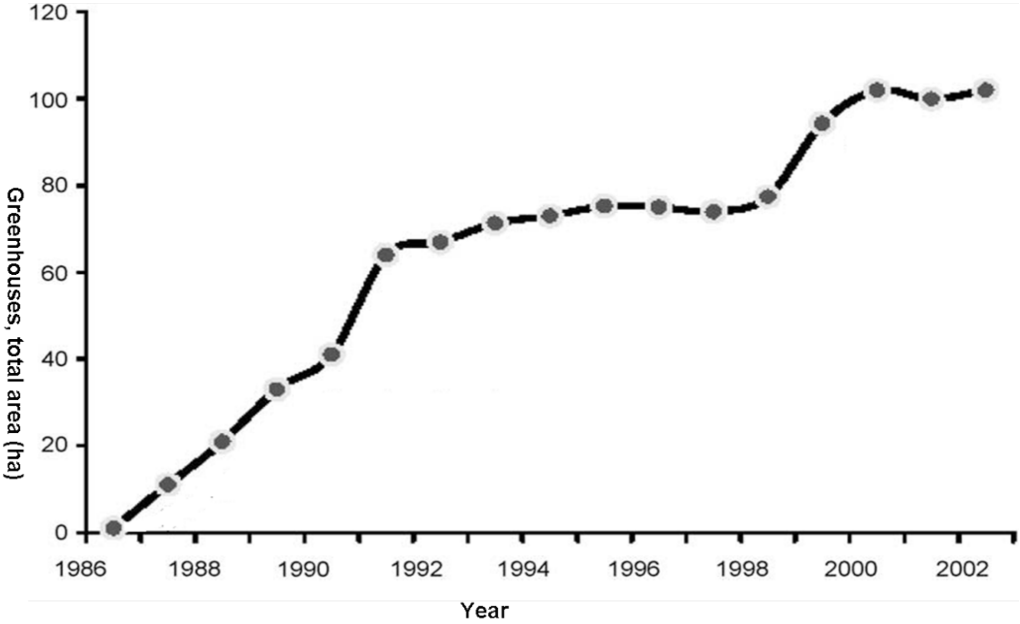

Figure 4: Development of the geothermic greenhouses area in southern Tunisia *(Adapted from Ben Mohamed, 2003).*

The total volume of geothermic water currently used is nearby 3,417 l/s, with 1,682 l/s in *Gabes*, 1,100 l/s in *Kebili* and 635 l/s in *Tozeur*. The irrigated areas supplied by this resource is for these governorates respectively, 100 ha, 105 ha and 100 ha (Seddik, 2009).

The enormous reserve that the CI aquifer provides, has led to the lightning development of the geothermic sector in those region. It is used to heat greenhouses before being allocated to irrigation. Such double use of the water contributes to its promotion. This production method has attracted many investors in the southern country and has allowed the irrigated areas to produce high quality products for the local markets as well as for export (Fig.5).

Figure 5: Geothermic greenhouse in the region of *Kebili*.

In 1993 an extensive work was commissioned to increase the geothermic agricultural areas across southern Tunisia. It allowed the development of further area of currently 215 ha, with respectively 88 ha in *Gabes*, 77 ha in *Kebili* and 50 ha in *Tozeur*. (Seddik, 2009)

To supply the required resources, about 77 deep groundwater wells were drilled to provide an amount of 2,360 l/s for both heating and irrigation purposes. The water quality of the used water ranges from 2,7 g/l and 3,3 g/l (Seddik; MAREH, 2009).

This salinity limits the yields but gives the vegetables a better taste, particularly the tomatoes and the melons. These products are in high demand in Europe and the Dubai Arab Emirates. The mean annual production from the southern part of the country approaches 8,000 ton/year, more than 45% of which is destined for export (MAREH, 1998).

In terms of employment, the geothermic sector supports the creation of 13 workplaces per hectare, while ordinary irrigated cultivation could not provide more than 3 workplaces per hectare. It provides 1,200 workdays per hectare while field cultivation could not provide more than 250 workdays per hectare. The expansion of this sector contributes also to reducing migration of the local population and has already become a pillar of the local development plan. (MAREH, 2009)

3. Water pricing policy

In 1991, a presidential decree outlined the water pricing policy related to the irrigated sector. It clarified the role of the stakeholders dealing with irrigation water management. The governmental development agencies as well as the farmers groups called GIC (groups of common interest) were called on to work closely together to establish water pricing and determine the mode of revenues collection, including the penalties rates in case defined rules are not respected. For this reason, three water pricing methods were recommended, as well as methods to collect the rates (Table 2): (i) the volume pricing method, based on actual water consumption, (ii) the global price method based on the irrigated area and (iii) the binomial pricing method that covers two proportions: a fixed part and a variable part dependent on actual use.

Table 2: The main water pricing and cost collect method followed in the public irrigated perimeters within the southern Tunisia *(Adapted from Sanyo, 2005).*

Water pricing method	Description	Water cost collection
Volume pricing method	This method is based on the actual water used. Reliable water meters in the irrigated area are required for this method..	The amount is paid directly after each irrigation turn.
Global price method	This method is applied in absence of reliable water meters in the irrigated areas. The water price is proportional to the irrigated area (fixed price/ha).	50% of the total cost is paid after planting, the rest is paid after harvesting.
Binomial method	This method includes a first fixed part based on the minimal annual consumption in the irrigated area. The second part is proportional to the surplus volume of water applied (m^3).	50% of the fixed amount is paid at the beginning of the agricultural campaign, the rest, including the price for the additional volume is paid after irrigation.

On the basis of these recommended water pricing methods, the governmental development agency and the farmers groups in close consultation define the suitable method to be followed according the circumstances in each irrigated area.

For the case of the oases in southern Tunisia, the water pricing volume method couldn't be applied in the same way as in the north of the country, where the irrigation networks are under pressure and the implementation of water meters is quite simple. Indeed, the water pricing in southern Tunisia is based on the total duration of irrigation (h/ha).

For this purpose, the assessment elaborated by SAPI (2005) showed that the volume method was chosen both in *Gafsa* and *Kebili*, while the binomial method was applied in *Gabes*. For the governorate of *Tozeur*, the three methods seemed to be applied; nevertheless the volume method was widely applied for the major oases.

Despite the strict commitment of the authorities to apply rigorous water pricing policy, there are many mismanagement practices that still represent a hindrance to a significant valorization of the resource.

Louhichi (1999) showed for the case of *Gabes* oasis, that reducing irrigation network losses by lining tertiary canals allows to economize 14,344 m3/year. The average total water cost reduction is 523 DT, which equals 0.036 DT/m^3. The unitary exploitation cost is 0.091 DT/m^3. The difference between both becomes more significant when the calculation takes into account several other exploitation costs (storage facilities, exploitation fees). Total exploitation costs amount to 0.416 DT/m^3, so 10 times the savings (0.036 DT/m^3). This demonstrates that it is more efficient to reduce water demand than to reduce the loss of .water in the system. However, the present method of water rate-making commonly used within the oasis is a fixed one and the amount to pay (DT/ha) takes only the irrigated surface as standard into account.

The current water pricing system doesn't take into account the investment costs the state provided to establish an imposing hydraulic infrastructure across the oases. Farmers pay only the exploitation costs (pumping fees, irrigation and drainage networks maintenance).

Sghaier (1995) claimed that such water rate marking doesn't valorise irrigation water. A water pricing policy recovering the full economic costs of water should be introduced. The water volume used by farmers each irrigation turn has to be the main standard of this water pricing policy. Moreover, the water price is now determined according to the budgets of farmers groups and shows an obvious stagnation. The development agency can hardly convince farmers to agree to increase the price of irrigation water, despite the growth of maintenance costs for irrigation networks.

4. Future challenges

At the national scale, it seems evident for the national policy to focus on water demand management as well as on improving the efficiency for both the drinking water sector and the irrigated agriculture (improving the distribution efficiency in irrigation networks from 66% to 80%). In absence of such improvements, the objective of 400,000 ha of total irrigated surface couldn't be met by 2010 (Treyer, 2000).

In the oases in southern Tunisia, the irrigated area is expected to increase from 46,000 ha in 1994 to 52,035 ha beyond 2030. For this purpose, the main objective of the long term national water strategy (EAU XXI) is to decrease the irrigation water demand. Indeed, this approach focuses on efficiency improvement and targets to reach the average of 365 million m^3 in 2030, while it was more than 506 million m^3 in 1996 (Sanyo, 2005).

Table 3: Water volume targets of southern Tunisia (*Adapted from EAU XXI, 1998; Sanyo, 2005).*

Year	1996	2010	2020	2030
Irrigated surface (ha)	46,000	49,000	50,490	52,035
Irrigation water consumption (m^3/ha/year)	11,000	9,500	8,167	7,022
Irrigation water demand (million m^3/year)	506	466	412	365

For irrigated agriculture in general, and in particular for the oases systems, the main challenge to meet is climate change. The impact of this phenomenon on water resources is expected to be very severe. Indeed, national studies predict a decrease of nearby 28% in non-renewable underground resources by 2030. The production in dry periods is expected to decrease with 50%, this equals 800,000 ha for rainfed agriculture. These impacts will be considerable also on livestock production which is predicted to decrease by 80%, both in the center and southern country (OSS, 2009b).

Facing these risks, Tunisia elaborated a national strategy to decrease the impact. The development of the mean climate indicators will be taken into account for the future natural resources management plan. The alert systems for both floods and droughts events are already established, with a network of climatic and hydrological stations across the country.

Water resources protection remains the focal point of such strategy, the enhancement of efficiency is supported by the implementation of several measures. In the drinking water sector, the hydraulic networks were subjected to an integral assessment that focused on the commitment of the population to water saving practices. In the irrigated sector, the intensification within farmers' parcels has to be enhanced in order to valorise the water resource. The cultivation of high added value crops should be intensified. Moreover, the contribution of the irrigated sector to the total agricultural production will be promoted. The objective is that this will reach nearly 50% on the long term.

For further economic efficiency, the government disengaged progressively from the management of water resources and required farmers groups to be more involved in protecting the hydraulic infrastructures as public facilities. The growing participation of the private investors, for example in the geothermic sector, calls for stronger promotion of water pricing and reduction of water wastage.

The national program of water saving was strengthened by the allocation of financial grants to introduce water saving equipment on farmer parcels. The percentage of costs covered by these grants are on average 40%, 50% and 60% to respectively extensive, middle and small farms (Hamdane, 2004).

It is evident that all these major efforts undertaken by the government would be sooner realized if farmers were committed to the same goals. Current practice of water use on parcels demonstrates that the applied water volume is more than the effective crop requirement. Traditional irrigation methods are still widely used within farmers parcels. The absence of any field levelling and the over application of water during irrigation, up to three times the actual crop requirements, cause relevant water losses (Mechergui and Van Vuren, 1998).

Ben Issa *et al.* (2006) showed the importance of salt inputs in case surplus water volume is applied. The problem of water wastage remains important in the oases in the southern part of the country. Another challenge that still is to be solved is the illegal extension of the irrigated area and the increasing number of private wells (Fig.6) that occurs in downstream oases. In these fields, the excess water supplies a shallow water table that rises to a rather inacceptable level and creates water logging and in longer term chronic salinisation (Prinz *et al.*, 2005).

Figure 6: Illegal well established in private parcel at downstream oases in the southern Tunisia oasis *(Region of Kebili).*

The first explorative studies conducted by OSS experts, predict a considerable decrease in artesian water in the extreme south of the country (Mamou, 2009). For the Nefzaoua region oases, Zammouri *et al.* (2007) three scenarios of pumping strategies from the CT aquifer were simulated. The main results demonstrate evident water quality deterioration across the whole *Nefzaoua*. In order to tackle these concrete changes, radical changes in the way the main stakeholders deal with water management in this country part should be considered. Furthermore, the regulations should be stricter in order to eradicate the phenomenon of illegal extension of oases.

IV – Conclusion

The rehabilitation of oases in southern Tunisia is a relevant component of the national water policy. In these arid regions (less than 100 mm in dry year), sustainable management of water resources is crucial to the accomplishment of the national development goals. Since the implementation of the strategic water management plan in 1979, the available water resources have been considerably exploited. The recent creation of oases with modern irrigation networks increased the production in irrigated areas. Furthermore, the rehabilitation of networks that sustained the old irrigated areas, notably within the framework of several projects (*PISEAU I, PISEAU II, APIOS*), improved the network distribution efficiency (25 to 30%).

The spectacular development of the geothermic sector is an important aspect of the national economy. The national efforts to develop irrigated agriculture in a severely arid climate, contributes widely to increase the productivity of the natural resources in these regions. It also provides job opportunities for the local population and enhances socio-economic variables. By achieving the water policy goals in the southern part of the country, the main stakeholders have capitalized a significant experience in managing water resources in a context of scarcity.

Despite the important success in the irrigated sector promotion in the south, the strategy of oases rehabilitation is being adapted to meet the futures challenges. Indeed, as water resources will become scarcer and less reliable, the population in this part of the country will experience evident difficulties in efficiently managing the resource. A major assessment of water management practices within the oases revealed that improvement of irrigation efficiency could not be carried out without complementary work informing the users about water saving practices. The term rehabilitation should also refer to making people more aware of water as a precious resource.

More rational use of water resources will no doubt be increasingly required from all involved stakeholders, especially in irrigation. Futures challenges will demand considerably more investments. Recourse to the extensive use of expensive modern technology, such as water treatment, desalination, aquifer recharge, seems to be inevitable. Furthermore, more research needs to be focused on crop water requirements. The ongoing prospective studies that will define the strategic outline of the water policy in the coming decade underline the priority of higher irrigation efficiency.

The Tunisian experience showed that integrated water management is definitely the key element in maintaining a balance between resources and demand. More close dialogue should therefore be instituted between stakeholders involved in water management. Such dialogue should be a decisive tool to resolve water conflicts (the problem is even more acute for farmers in oasis).

Particularly in southern Tunisia, where irrigated areas suffer permanent desertification risks, a deeper understanding and a better assessment of the management of available water resources is required. The collection of accurate data regarding this aspect will provide new possibilities for future water policy. It will also facilitate effective decision making in order to meet the various societal needs and overcome risks of degradation of water resources.

Moreover, reforming water policy in the oases in southern Tunisia towards a comprehensive approach will allow all stakeholders to cooperate closely and to increase the transparency of their roles. Such a situation ensures both the competent authority and farmers to reach their respective objectives.

References

Al Atiri R. (2007). Evolution institutionnelle et réglementaire de la gestion de l'eau en Tunisie. Vers une participation accrue des usagers de l'eau. In : Buarfa, S. *et al.* (editors) *Actes du séminaire ' L'avenir de l'agriculture irriguée en Méditerranée. Nouveaux arrangements institutionnels pour une gestion de la demande en eau.'* Projet Wademed. CIRAD, Montpellier, France, 13pp.

Aquastat (2005). http://www.fao.org/nr/water/aquastat/countries/tunisia/indexfra.stm

Ben Mohamed M. (2003). Geothermal resources development in agriculture in Kebili region, Southern Tunisia. *Geothermics* 32 (2003), pp. 505–511.

Edmunds W.M., Shand P., Guendouz A.H., Moulla A.S., Mamou A., Zouari K. (1995). Recharge characteristics and groundwater quality of the grand Erg Oriental basin. *British Geological Survey*, Wallingford. Final report, 9pp.

Hamdane A. (2008). *Tunisia: Reform of irrigation policy and water conservation*, 9 pp.

Hamdane A. (2004). La modernisation des systèmes irrigués en Tunisie. Note technique du Ministère de l'Agriculture et des Ressources Hydrauliques, 18pp.

Horchani A. (2007). Water in Tunisia: A national perspective. In: *Agricultural Water Management*: Proceedings of a Workshop in Tunisia (Series: Strengthening Science-Based Decision Making in Developing Countries) (2007): pp 88-89.

Louhichi K. (1999). *L'amélioration de l'efficience de l'irrigation pour une meilleure économie d'eau. Cas d'un périmètre irrigué en Tunisie*, Rapport Final. CIHEAM-IAMM, 59 pp.

Mamou H. (2009). *Ressources en eau et développement agricole dans le sud tunisien.* Workshop projet SIRMA 'Gestion des ressources naturelles et développement durable des systèmes oasiens de Nefzaoua '. Douz, Tunisie, 25-26-27.

MAREH (2009). *Revue de l'Agriculture* –N°110-Avril-Mai-Juin 2009. pp30-31.

MAREH (1998). EAU XXI. *Stratégie du secteur de l'eau en Tunisie à long terme 2030*. 97 pp.

Mechergui M., Van Vuren G. (1998). *Improved irrigation efficiencies in Tunisian oases.* ILEIA Newsletter July 1998.

OSS. (2009a). *The System Aquifer of Septentrional Sahara, the common management of a transborder basin.* Serie of drafts, N°1. 56pp.

OSS. (2009b). *Stratégies d'adaptation au changement climatique en Tunisie :* http://www.ossonline.org/index.php?option=com_content&task=view&id=915&Itemid=662).

Prinz D., Loeper T. (2008). *Nutzung fossilen Grundwassers in der tunesischen Oasenwirtschaft. Effizienz - Notwendigkeit – Sinnhaftigkeit.* Presentation 21.02.2008, BGR Hannover.

Prinz D., Chabani B. Kastl A. (2005). New Approaches in Oasis Water Management -Experiences from North Africa. In : *Proceedings, XII World Water Congress of IWRA – Water for Sustainable Development – Towards Innovative Solutions,* 22-25 Nov. 2005, New Dehli.

Seddik S. (2009). *Plan directeur des eaux du Sud. Note technique*, Ministère de l'Agriculture et des Ressources Hydrauliques, Tunis, 40 pp.

Schmidt G., Manfred H., Soeffner B. (2006). *Investigations on Regional Groundwater Systems in North-East Africa and West-Asia.* Technical Note of the BGR, Activities report in northern Africa, 18 pp.

SAPI. (2005). Assistance Spéciale pour l'Exécution du Projet. *Projet d'Amélioration des Périmètres irrigués des oasis du Sud de la Tunisie (TS-P10)*, Final Report.

Sghaier M. (1995). *Tarification et allocation optimale de l'eau d'irrigation dans les systèmes de production de la région oasienne de Nefzaoua (Sud de la Tunisie).* PHD Thesis in Applied Biological Sciences, University of Gent, Belgium, 235 pp.

Sanyo Consultants Inc. (1996). *The feasibility study on the irrigated area improvement in Southern Tunisia Oases.* Japanese International Cooperation Agency.

Treyer S. (2000). *Analyses des strategies et prospective de l'eau en Tunisie.* Rapport I Monographie, 270 pp.

Zammouri M., Siegfried T., El Fahem T., Kriaa S., Kinzelbach W. (2007). Salinization of groundwater in the Nefzaoua Region, Tunisia: results of a regional-scale hydrogeologic approach. *Hydrogeology Journal* N° 15, pp. 1357–1375.

Water management in the western Mediterranean basin: An archaeological approach (II)

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Abstract. This paper presents an approach to different aspects related to water management of the prehistoric societies in the Iberian Peninsula. It tries to evaluate and assess the water needs and the potentially exploitable water resources in prehistoric times: uses of water, drainage and water infrastructures, industrial water uses and water use in agriculture. The results provide a deeper knowledge of water management through analyses of the architectural and functional infrastructure designed to solve the problem of water supply and drainage. Water supply sources can be categorized in three main groups: underground water and springs, water courses and masses of accumulated water. Furthermore, the paper discusses archaeological evidence of water management from prehistoric times in the south-eastern Iberian Peninsula. The societies in that area already then had channelled water and probably had irrigation systems that channelled water from galleries cut into the rock to the cultivated crops. This is a sign of a true culture of water that has remained constant from the prehistory to the Hispano-Islamic culture and to the present day.

Keywords. Water management – Prehistoric human communities – Archaeological approach

La gestion de l'eau dans l'occident du basin méditerranéen: une approche archéologique (II)

***Résumé**. Cette étude constitue une approche des différents aspects liés à la gestion de l'eau dans les sociétés réhistoriques de la péninsule Ibérique. Il tente d'évaluer les besoins et les ressources hydriques potentiellement exploitables durant la Préhistoire: les usages de l'eau, le drainage et les infrastructures de l'eau, les usages industriels et l'utilisation de l'eau dans l'agriculture. Les résultats fournissent une connaissance plus approfondie de la gestion de l'eau qui inclut l'analyse architectonique et fonctionnelle des solutions infrastructurelles destinées à résoudre le problème de l'approvisionnement et le drainage de l'eau. Les sources d'approvisionnement en eau peuvent être résumées en trois groupes principaux: les eaux souterraines et les sources, les cours fluviaux et les masses d'eau accumulée. En outre, l'article met en lumière l'évidence archéologique de la gestion de l'eau, dès la Préhistoire dans le sud-est de la péninsule Ibérique. Les sociétés dans cette région à cette époque avaient déjà canalisé l'eau et ont probablement eu des systèmes d'irrigation qui transportaient l'eau de galeries creusées dans la roche aux plantes cultivées. C'est un signe d'une véritable culture de l'eau qui est demeurée constante de la préhistoire à la culture hispano-islamique et jusqu'à nos jours.*

***Mots-clés.** Gestion de l'eau – Communautés préhistoriques humaines – Approche archéologique*

I – Introduction

The availability of sufficient water was one of the factors that conditioned the choice of location for prehistoric human communities, especially in areas with unfavourable climatic and hydrological conditions. The fact that they were organised in urban or proto-urban areas also implies that they were not able to depend exclusively on the irregular and often insufficient rainfall for their basic needs. Thus, human settlements were located at sites with direct access to water or were provided with water collection systems. However, water management was not limited purely to guaranteeing a supply for the population; it was also concerned with removing excess water.

This paper constitutes the second half[1] of an exploration of different aspects of water management in ancient times in the west-Mediterranean basin. It tries to evaluate and assess the water needs and the potentially exploitable water resources in prehistory, and also to analyse the architectural and functional infrastructural solutions designed to solve the problem of water supply and drainage. While it is true that the lack of archaeological data and written sources for this period in relation to water constitutes a major difficulty, it is not impossible that certain issues can be explained based on existing evidence and comparison in order to elaborate and develop proposals to further the knowledge of this matter.

The paper discusses the uses of water in prehistoric Iberian societies. From examples observed at several archaeological sites in the Mediterranean Iberian Peninsula, we evaluate the structures of water supply and drainage and water removal infrastructures, aiming to understand the global urban networks and hydraulic methods used to exploit water resources and their subsequent management. The study concludes with an assessment of irrigation water use in agriculture.

II – The uses of water in prehistoric Iberian societies

Water use in prehistory would have been very limited in comparison to the periods immediately following it, such as the Roman era. Apart from domestic consumption, which was mainly limited to drinking and cooking, certain artisanal and industrial activities required water, particularly metal working, pottery manufacture, building and some textile and leather treatment processes. We also have to consider the water needed for livestock.

The aquatic world was a fundamental part of the Iberian idea of the universe. Water enables the eternal resurgence of vegetation, a never-ending cycle in which, in one way or another, human life and activity have to fit. Depictions of fish are quite common on Iberian vessels and they rarely appear alone, as they are closely linked to vegetation, making up two of the elements that symbolise the eternal rebirth of the natural cycle.

1. Water demand

So far we have little archaeological evidence of the domestic uses of water, although drinking and cooking obviously formed part of basic subsistence. As far as drinking was concerned, apart from water, there is evidence that people drank beer (made by fermenting certain kinds of cereals in water) and wine, which was mixed with water or mead (an alcoholic drink made by fermenting honey dissolved in water). Water was also needed to cook and prepare many foodstuffs and we have evidence of the pottery vessels used for cooking, as well as of certain plants (mainly cereals and legumes) that appear to have been consumed from Neolithic times. We also find animal bones from the Iberian period that show signs of having been boiled.

Artisanal and industrial uses included pottery manufacture, metal production and working, building materials, textile manufacture and probably also livestock management. In the case of pottery manufacture, water would have been needed to purify and model the clay. In pottery production centres we usually find manufacturing facilities, kilns and annexed rooms identified as decantation pools. This type of settlement was also usually in a place with easy access, good communications, nearby raw materials and, above all, plenty of water. In some settlements we also find evidence of areas dedicated to pottery production and storage. In areas where metal was produced and worked, we usually identify containers for holding the water used to cool the blacksmith’s tools and the metal objects that were hardened by tempering.

Water was also used to make and work with building materials. We have evidence of its use in making adobe and walls and in the direct application of earth, which was mixed with water in different proportions according to the manufacturing method. Water was also needed to obtain calcium hydroxide or slaked lime, for which it was mixed with limestone in a suitable proportion for the required purpose. At some archaeological sites there are signs of rooms or areas used for the production of this material, with the remains of lime in the process of being transformed or tanks (that may have contained water) used for slake lime manufacture.

Water is also linked to the production and treatment of textiles and was used in the different processes for transforming vegetable fibre (flax, hemp, etc.). We have evidence of structures associated with this activity, mainly water tanks in which the fibres were treated, soaked or dyed before being made into fabric, although it is also possible that some of these tanks were used for tanning hides or treating wool.

2. Potential water supply sources

Water supply sources for prehistoric settlements can be summarised in three main groups: underground water and springs, water courses and masses of accumulated water (lakes or lagoons).

As far as the first group is concerned, the use of surface water and the digging of wells in search of underground flows were rare in the Iberian societies (7th - 2nd centuries BC). In some cases we find wells that may have doubled as cisterns (as appears to be the case in the settlement of Els Vilars de Arbeca, Lleida) (Alonso *et al*., 2005). However, there are also some examples of true vertical wells of more than 1.5 m in diameter with depths of up to 9 and 11m in La Ciutadella de Calafell (Tarragona) and the settlements of Can Xercavins (Cerdanyola, Barcelona) and Castell (Rubí, Barcelona), structures that were abandoned between the 5th and the 3rd centuries BC (Sanmartí and Santacana, 2005). In the settlements of Ullastret (Girona) (Prado, 2008) and Ensérune (Languedoc, south of France) (Blétry-Sesé, 1986; Schwaller, 1994) well parapets have been preserved and a fountain has been identified in the settlement of La Muela de Arriba (Requena, Valencia), which is dates to between the end of the 4th century and the beginning of the 2nd century BC (Valor, 2004).

On the other hand, rainwater collection can be identified from reservoirs cut into the rock and the construction of cisterns. Such underground structures were a simple solution that had been used on the Iberian Peninsula since the Bronze Age. An example of this is an almost circular, stone-lined, 3.5-metre-deep structure with a 9-metre-wide mouth built at the end of the second millennium BC, in the post-Argaric phase of Fuente Álamo (Cuevas del Almanzora, Almería) (Schubart *et al.,* 2000).

The cisterns are large tanks that were located in the centre of the settlement, although they are also found in other areas. Covered cisterns (most of which had a flat roof made of large stone slabs) provided an optimum water storage solution, given that they maintained a constant cool temperature and protected the water from impurities. Despite this, prolonged stagnation of the water in the tanks would have inevitably led to its putrefaction[2].

The stored water came from collecting and channeling the rainwater that fell on the roofs of the houses and the streets into the cisterns. We also believe that they would have had some kind of system for filtering the impurities before the water was stored, although so far we have not found any evidence to confirm this.

The evidence shows that the use of cisterns for water supply was, without a doubt, one of the most important devices reserved for basic drinking water. However, despite their capacity in relation to a rainfall regime slightly greater than that of today, they appear to be insufficient to guarantee supply. Moreover, we cannot rule out that their main function was to provide water in the case of a siege, as appears to be the case in other parts of the Mediterranean, particularly in the areas of Greek (Hellmann, 1994) and Phoenician (Fantar, 1975) influence, although this was not a widely used tactic in Iberian conflicts (Moret, 1996). Apart from this collection system, the use of different types of vessel (such as jugs with spouts) to collect and store water for domestic use, leads us to surmise on one hand, that the rain water stored in cisterns was used for households purposes, on the other, that water was also collected from other sources than the local cistern.

The presence of cisterns appears to be common from the second millennium in the Ebro Valley, in settlements such as Zafranales (Fraga, Huesca) and El Regal de Pídola (Sant Esteban de Litera, Huesca). However, these structures built by the indigenous population survived for a long time, into the Iron Age and shortly before the cultural eclosion of the Iberian period, at other sites such as El Tossal de les Tenalles (Sidamon, Lleida), Roques de Sant Formatge (Serós, Lleida) and Jebut (Soses) (Moret 1994, 23-24). In the same region, the fortress of Els Vilars (Arbeca, Lleida) presents a monumental structure built at the end of the 5th century BC; it had a descending paved ramp and was used as a cistern to collect rainwater, at the same time as acting as a well, as it was deep enough to reach the water table, providing it with another water source (Alonso *et al.,* 2005, 29-30).

Cisterns continued to be used until the final days of the habitats on higher ground, a fact attested in the Ibero-Roman period. The cistern at El Pilaret de Santa Quiteria (Fraga, Huesca) belongs to this era; in it we can observe the transition to the elliptical form commonly found in the Greco-Carthaginian cisterns of the Western Mediterranean. During the full Iberian period we find this type in large settlements, although the most spectacular structure (built in the Ibero-Roman period) is at Azaila (Teruel), which was used to collect rainwater from the road network.

In the Catalan pre-coastal mountains, we know of cisterns in the settlement of Turó del Vent (Llinars del Vallès, Barcelona). These have wide mouths, are very deep and were built at the end of the 4th century BC. Further to the north, in the Empordà region, the Iberians also built perfectly elliptical cisterns with straight walls; these were cut into the living rock, lined with well-cut ashlars and finally plastered with lime mortar. Although they are not easy to date, they are probably from around the 3rd century BC. The meticulous technique used to build them shows Greco-Punic influences from the nearby Greek colony of Empúries. We know of a cistern of this type in the large settlement of El Puig de Sant Andreu (Ullastret, Girona), whose structure also includes a half-round lead conduit next to the opening to facilitate filling and an overflow channel on the other side to allow excess water to flow out (Fig. 1). We have also identified other smaller rainwater collection facilities at the settlements of Montbarbat (Vilà *et al*., 1992) and Puig Castellet (Pons/Llorens/Toledo 1989), which appear to date mainly from the 3rd century BC.

Figure 1: General view of the cistern nº 2 (Ullastret, Girona province).
Photo: courtesy Museu d'Arqueologia de Catalunya-Ullastret.

Despite numerous excavations of Iberian habitats in the Valencian Country, a cistern has only recently been located at one end of the settlement of El Molón (Requena, Valencia). However, it is in the south of the Iberian Peninsula where we have the least knowledge of Iberian cisterns, despite the fact that they were also common there and some were built to high quality standards. There are elliptical examples in the settlement of El Cerro de la Cruz (Almedinilla, Córdoba), where they are covered with stone slabs. These cisterns date from the 3rd and 2nd centuries BC and may well have Greco-Carthaginian influences. Undated elliptical cisterns, which could be either pre-Roman or Roman, are also found in the ancient towns of Acinipo (Málaga) and Cástulo (Jaén), sites with a continuous human presence.

As far as supply from water courses is concerned, rivers and streams near settlements would have been the main potential source due to the volume of the basin and the proximity. However, we have to bear in mind that the water courses in the Mediterranean area are mainly of a torrential nature. This means that their surface flow depends largely on rainfall and diminishes notably, and even completely disappears, in some stretches during dry periods.

Finally, bodies of standing water have to be taken into account on various levels: on the one hand, as a possible water supply and, on the other, as a possible agricultural resource by taking advantage of the rise in the level of the lake or the flooding of the land on the shores of the area occupied by the body of water.

III – Drainage and water removal infrastructures

Architecture and town planning in the Iberian period were governed by organisational and planning criteria that we can see exemplified in the degree of complexity they were able to attain in rainwater drainage infrastructures. In some Iberian settlements the solutions documented are not limited to the construction of drains, but demonstrate a global concept that takes into account factors ranging from the orientation and configuration of the roofs to the discharge of the water from the settlement itself.

This concept responds to two interrelated needs: on the one hand, the necessity to remove the water from structures and buildings into adjacent streets and other open communal spaces and, on the other, to channel this water via these areas to a point outside the settlement.

As far as the first of these needs is concerned, the building roofs were of vital importance. Archaeology provides us with little evidence of these structures, although experimental reconstructions carried out in recent years appear to point to a type of wooden beam structure covered by a layer of plant matter, with single pitch and gabled roofs. Likewise, it is also widely agreed that the structure would have had a perimeter border that channelled the water to wooden gargoyles. Once collected, the water would have been directed towards the street and, in some cases, to cisterns where it would have been stored. In this way, the roofs had a primary function of protecting the interior of the buildings and a secondary purpose of collecting rainwater.

We know of few examples of rainwater drainage systems, but in the settlement of Ullastret (Girona) a structure from the second half of the 5th century BC has been identified (Fig. 2); it consists of a base of stone slabs with a channel in the middle bordered by worked stone and paved with small stone slabs (Prado, 2008). It was used to collect the rainwater that fell on the roofs of the rooms and subsequently to channel it to the street. Another example of a drain has been described at the fortress of Els Vilars (Arbeca, Lleida); this dates to the 8th – 7th centuries BC (Alonso *et al.,* 2005, 30).

Figure 2: Detail view of example of rainwater drainage systems (Ullastret, Girona province).
Photo: courtesy Museu d'Arqueologia de Catalunya-Ullastret.

The streets were one of the basic elements in the second objective described above: channeling this water from inside the buildings to outside the settlement. As well as performing their primary function of linking the different parts of the settlement, the streets were also part of the drainage system and by arranging their inclines they were able to channel the rainwater away from the inhabited area. The drainage systems in Iberian settlements were linked to the main street that collected the water from inside the buildings, as well as that from the side streets that led into it.

The last of the drainage elements were the gates and openings in the walls that allowed the water to flow to the outside. Known as barbicans, they were built on slopes where the walls blocked the flow of water and would have undermined their foundations (Moret 1996). In the studied cases, channels have been identified that transversally cross the walls and, although they have not been preserved in other cases, we assume that similar structures existed in the settlement entrance gates.

There is a final element that crosses the wall on its interior. This is a channel located at its base with a kind of gargoyle on the outside designed to prevent water from pouring out along the wall.

IV – Water in industrial uses

Once harvested, certain plants used to make textiles, such as flax, hemp and esparto grass, needed a process known as retting, which consisted of soaking it in water to separate the fibre from the stalk.

There is little evidence of this activity in the prehistoric archaeological record of the Iberian Peninsula, although the excavations carried out at the settlement of El Coll del Moro (Gandesa, Tarragona) brought to light a flax retting workshop from the second half of the 3rd century BC (Rafel *et al.,* 1994). It has two adjoining, symmetric tanks measuring 1.80 by 1.60 m with one meter high walls; the floor and walls were made of adobe and the floor was paved with small stone slabs with the joints sealed with purified clay, which also covered the partition walls, making them waterproof. The presence of flax was also confirmed by an analysis of the preserved organic sediment and the phytolite technique.

Another recently identified industry practised by the Iberians, which also required large amounts of water, is wool dyeing. At one end of the settlement of Olérdola (Barcelona), in an area bordered by the wall, an artisanal area was built around the second half of the 4th century BC that included a dyer's and a blacksmith's (Fig. 3). This zone had a small channel that drained the excess rainwater from the hill and channelled it outside the walls. The dyer's area, reconfirmed by the analysis of the recovered residues, contained channels cut into the rock with small stone slabs and various tanks for soaking and washing the wool and had fires to heat the liquids (Molist *et al.,* 2005).

Figure 3: Detail view of an artisanal area used by a dyer (Olèrdola, Barcelona province).
Photo: courtesy Museu d'Arqueologia de Catalunya-Olèrdola.

In the settlement of El Oral in Alicante channels were also found that passed through the thickness of the surrounding walls, although the fact that they only originate from certain rooms leads us to believe that they were used to drain the water resulting from the industrial activities carried out in those rooms (Abad and Sala, 1993).

To the manufacture of textiles from plant fiber and wool dyeing, we have to add a third industrial activity: the extraction of iron from ferruginous clay dug in open-cast mines. In order to be used, the clay first had to be washed and subjected to a decantation process that separated the heavy mineral before it was crushed and reduced in a furnace. This process needed a sufficient water supply. An open-air decantation pool has been documented in the Iberian settlement of Les Guardies (El Vendrell, Tarragona), which was active around the 3rd century BC.

V – Irrigation and water use in agriculture

Although cereals, basic agricultural products in the Iberian diet, depended on rainfall, analyses of the plants consumed appear to show in some cases a major presence of water. It remains to be shown whether water was transported to irrigate a limited plot of land or whether they knew how to use channels to carry out more widespread irrigation. A Latin text designed to be displayed in public was found in the Celtiberian town of Contrebia Belaisca (Botorrita, Zaragoza). It contains the orders of a Roman provincial governor who ratified a sentence issued by the local town senate. This body had acted as a court in a case brought by a community known as the Alavonenses over the ownership of land that an Iberian town, Salduie, had purchased from another Iberian community, the Sosinestanos, for digging an irrigation channel. This is proof that such a practice existed in the north of Zaragoza, at least at the time the text was written, on 15 May 87 BC, to be precise.

The most interesting example of water resource management in the Bronze Age is linked to the control of water in the emergence and development of complex societies in the southeastern Iberian Peninsula. It is associated primarily with the Argaric society (2200/1400 BCE) and the studies undertaken have been based on two fundamental circumstances: the climatic and environmental conditions and the interpretation of certain structures supposedly related to water management, most of which have been found at Los Millares and Cerro de la Virgen (Lull, 1983; Buxó, 1997; Castro, *et al.,* 1999, 2001).

Gilman and Thornes' model (1985) was based on the supposition that the climatic and environmental conditions had not changed and that the arid or semi-arid conditions were identical to those existing today, suggesting that an agricultural economy would have favoured the development of irrigation to combat the aridity of the environment. The emergence of social stratification in the third millennium would have been associated with the intensification of subsistence production: the exploitation of secondary livestock products, forestry and irrigation, among others. Chapman's studies (1991), like those of Gilman (1987), were based on the same supposition, although the former believed that the control of water was one of the factors in the intensification process, although not necessarily the most important. Both Gilman and Chapman sought to explain the social development of the area as a result of the responses to adapting to an unfavourable environment; they agreed that, given the arid conditions of the southeast, the intensification of farming came about through the use of irrigation as the only way of building a productive agricultural system.

The arguments put forward by Chapman to justify the need for water in southeastern farming were based on the studies carried out by Helbaek (1969) at sixth millennium BCE sites in the Near East and Anatolia. According to these studies, certain cereals, such as barley and flax, need more water when they are grown in arid zones. Barley needs it because it suffers more from the effects of evaporation and flax cannot grow without an artificial water supply in areas with an annual precipitation of less than 450 mm a year. Chapman (1991) used these requirements to point out that the success of these crops was not guaranteed without water control. He argued that wheat, barley and flax would have been growing in a hostile environment and that to achieve a normal yield it would have been necessary to use water control technologies.

The current data obviously differ in part from the interpretations that can be deduced from the earlier research. The availability of specialised palaeoecological studies and systematic documentation on landscape reconstruction and climate change allows us to reconstruct the dynamic and evolution of the ground cover, together with the influence of human intervention on the modification of the area.

Firstly, palaeoenvironmental studies show that the characteristics of the third millennium landscape differed (and were changing), from those of the second millennium, suggesting wetter climatic conditions than those of today. From the beginning of the Holocene, the pollen register and anthracological analyses reflect a marked thermophilic nature for the zone, with mild bioclimatic parameters, although with abundant indications of water resources available in the area's hydrographic network (Yll *et al*., 1995; Rodríguez Ariza, 1992; Pantaleón-Cano *et al*., 2003; Fuentes *et al*., 2005). Likewise, the isotopic discrimination of carbon in the seeds of different cereal and leguminous plant species reveals that the current climatic conditions of eastern Andalusia are more arid, in other words with less rainfall, than those calculated for recent prehistory (Araus *et al*., 1997).

The most significant changes in the ground cover come about between the Chalcolithic and the Bronze Age. The palaeoenvironmental data support the general notion that the Chalcolithic marked the last period of forestation in the semi-arid southeast, which was followed by a decline clearly related to increased anthropic pressure on the environment and an intensification of the trend towards aridity. The establishment of new environmental conditions, together with the extension of open spaces is linked to an intensification of farming and pastoral activities, although with variations in the environmental framework. Nevertheless, if aridity existed or spread over the area, it was not generalised over space and time as it did not cause the immediate disappearance of the wetlands, which continued to exist during the Bronze Age. Thus, it appears that neither for this period large scale irrigation was necessary in the region.

Secondly, the diversity of the exploitation system could have included rainfed agriculture on the low-lying plains and in the interior, although agricultural specialisation may have been linked to the monoculture of certain cereals in the two periods.

Thirdly, there are data that indicate a process towards an intensification of production during the Copper Age, which did not necessarily include the practice of irrigating some of the crops, which were mainly cereals. On the other hand, leguminous plants or flax, for which it is assumed more water is needed, can take advantage of the fertility of easily-flooded lands or those with sufficient water. The high values registered for the broad bean in the region's archaeological sites are indicative of the importance of that crop from the Late Neolithic onwards. Considering the argument that defends different environmental conditions to those of today, broad bean cultivation could only have taken place under two circumstances: firstly, that there was sufficient water to grow them during this period, and secondly, that specific actions were taken to encourage their development, such as the use of irrigation. Isotopic studies of carbon in the seeds of different species found at Chalcolithic and Bronze Age sites in the southeast indicate that leguminous plants were cultivated in conditions with more water than cereals (Araus *et al*., 1997).

In general, with the exception of the models proposed by Gilman and Thornes (1985) and Chapman (1991), the most recent studies show that most of the cereals were grown in rainfed farming conditions and that if irrigation was practised, it was limited to small scale watering of leguminous plants on plots of land with favourable soils, perhaps using simple irrigation mechanisms (Castro *et al*., 1999, 2001; Cámalich and Martín Socas, 1999).

VI – Conclusions

The evaluation of the water needs of prehistoric settlements on the Iberian Peninsula is still based on relatively incomplete data. The construction of cisterns or reservoirs for rain water in the region can be dated back to the Bronze Age. These reservoirs in the villages retained a water reserve, but the periodic transport of other water to the living quarters remained necessary. The presence of artificial facilities or sources, organized by a distribution set or a single contribution as we find in the Greek and Roman world, were not documented in any Iberian sites.

However, capturing rainwater is not the only source of supply; we must consider that the supply of water was necessarily based on the use of other resources at their disposal, in a proportion we can not determine. Potable water from rivers and lagoons could be a key factor in understanding its possible use. Regardless of the quality of the water, its use is understandable for non-domestic artisanal, industrial or even agricultural purposes.

The early onset of the cisterns or reservoirs tanks occurs in places where the weather is more severe, which could indicate a possible environmental stimulus (the water demand) that would be stronger than other regional circumstances. In prehistory, the climatic conditions of the Mediterranean area of Iberian Peninsula were different from those found today. The agricultural systems of prehistoric societies may have different effects on the environment, increasing the depletion of aquifers, and probably the soil salinity. However, the degradation processes in areas that possibly suffered from floods and erosion in the region, take place over time, and it is also shown that more severe disruptions (although not the first) of the landscape are typical of this period. Although cereals, the basic agricultural food in prehistoric times, depended on rainfall, the other studied crops required in some cases, a significant presence of additional water.

Looking at the different social considerations of water management during this period we have been able to define the construction of infrastructures, tanks or cisterns for supplying the population and for draining off excess rainwater. These are examples of collective utilitarian structures and, like the settlement walls, show the existence of a strong social structure (Moret 1994). In this respect, the structures linked to supply become strategic elements for the survival of the group and correspond to a desire to undertake joint planning that was, apparently, supervised by elite.

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References

Abad L., Sala F. (1993). *El poblado ibérico de El Oral* (*San Fulgencio, Alicante*). Trabajos Varios del SIP, 90, Valencia.

Alonso N., Junyent E., Lafuente A., López J.B. (2005). *Arbeca: la fortalesa dels Vilars.* Museu d'Arqueologia de Catalunya, Guies del Museu d'Arqueologia de Catalunya, Barcelona.

Araus J.L., Buxó R., Febrero A., Molina F., Rodríguez O., Cámalich M.D., Martín D., Voltas J. (1997). Identification of Ancient Irrigation Practices based on the Carbon Isotope Discrimination of Plant Seeds: a Case Study from the Southeast Iberian Peninsula. *Journal of Archaeological Science* 24: 729-740.

Blétry-Sébé S. (1986). La maitrise de l'eau sur les *oppida* du Languedoc oriental. *Revue Archéologique de Narbonnaise* 19, 1-29.

Buxó R. (1997). *Arqueología de las plantas. La explotación económica de las semillas y los frutos en el marco mediterráneo de la Península Ibérica*. Crítica, Barcelona.

Cámalich M.D., Martín D. (1999). *El territorio almeriense desde los inicios de la producción hasta fines de la Antigüedad. Un modelo: la depresión de Vera y cuenca del río Almanzora*. Monografías Junta de Andalucía, Consejeria de Cultura, Sevilla.

Castro P.V., Chapman R.W., Gili S., Lull V., Micó R., Rihuete C., Risch R., Sanahuja M.E. (1999). Agricultural production and social change in the Bronze Age of southeast Spain: the Gatas Project. *Antiquity* 73: 846-856.

Castro P.V., Chapman R.W., Gili S., Lull V., Micó R., Rihuete C., Risch R., Sanahuja M.E. (2001). La sociedad argàrica. In: M. Ruiz-Gálvez Priego (coord.) *La Edad del Bronce ¿primera edad de oro en españa? Sociedad, economía e ideología*, Barcelona, Crítica, 181-216.

Chapman R. (1991). *La formación de las sociedades complejas. El sureste de la península ibérica en el marco del Mediterráneo occidental.* Ed. Crítica, Barcelona.

Fantar M. (1975). Le problème de l'eau potable dans le monde phénicien et punique: les citernes, *Les Cahiers de Tunisie* XXIII: 9-18.

Fuentes N., García-Martínez M.S., González.Sampériz P., Fernández S., Carrión J.S., López-Campuzano M., Medina J. (2005). Degradación ecológica y cambio cultural durante los últimos cuatro mil años en el sureste ibérico semiárido. *Anales de Biología* 27: 69-83.

Gilman A. (1987). El análisis de clase en la Prehistoria del sureste. *Trabajos de Prehistoria* 44: 27-34.

Gilman A., Thornes J.B. (1985). *Land, Use and Prehistory in South-East Spain*. Allen & Unwin, London.

Helbaek H. (1969). Plant collecting, dry-farming and irrigation in prehistoric Deh Luran. In: F. Hole, K. Flannery (eds.) *Prehistory and Human Ecology of the Deh Luran Plain*, University of Michigan (Memoirs of the Museum of Anthropology) 1, Ann Arbor, Michigan: 244-383.

Hellmann, M.-C. (1994). L'eau des citernes et la salubrité: textes et archéologie. In : Ginouvès, R., Guimier-Sorbets, A.-M., Jouanna, J., Villard, L. (Eds.) *L'eau, la santé et la maladie dans le monde Grec, Actes du Colloque organisé à Paris du 25-27 novembre 1992, Bulletin de Correspondance Hellénique*, supplément XXVIII: 273-281.

Lull, V. (1983). *La "cultura" de El Argar. Un modelo para el estudio de las formaciones económico-sociales prehistóricas*. Akal, Madrid.

Molist, N., Enrich, J., Bosch, J.M., García, M., Gómez, M., Mestres, J., Sales, J., Senabre, M.R. (2005). Adobatge i tintura en època ibèrica. Elements estructurals, analítics, químics i materials per a la identificació d'una instal·lació artesanal. El cas d'Olèrdola. *Actes del XIII Col·loqui Internacional d'Arqueologia de Puigcerdà (Puigcerdà 14 i 15 de novembre de 2003)*, Puigcerdà, Institut d'Estudis Ceretans, 821-837.

Moret P. (1994). Alguns aspectes del desenvolupament de l'hàbitat organitzat a l'àrea ibèrica. *Cota Zero* 10: 19-26.

Moret P. (1996). *Les fortifications ibériques. De la fin de l'âge du bronze à la conquête romaine*. Casa de Velázquez, Madrid, Collection de la Casa de Velázquez 56.

Nordon M. (1991). *L'eau conquise. Les origines et le monde antique*. Masson, Histoire de l'hydraulique 1, Paris.

Pantaleón-Cano J., Pérez-Obiol Yll E,R., Roure J.M. (2003). Palynological evidence for vegetational history in semi-arid areas of the western Mediterranean (Almería, Spain). *The Holocene* 13 (1): 109-119.

Pons E., Llorens J. M., Toledo A. (1989). Le hameau fortifié du Puig Castellet à Lloret de Mar (Girona, Espagne). Un bilan de recherches. *Documents d'Archéologie Méridionale* 12: 191-222.

Prado G. de. (2008). La gestió de l'aigua a l'oppidum del Puig de Sant Andreu (Ullastret). *Cypsela, 17.* Girona, 185-200.

Rafel N., Blasco M., Sales J. (1994). Un taller ibérico de tratamiento de lino en el Coll del Moro de Gandesa (Tarragona). *Trabajos de Prehistoria*, 51/2,: 121-136.

Rodriguez Ariza M.O. (1992). Human-plant relationships during the Cooper and Bronze Ages in the Baza and Guadix Basins (Granada, Spain). *Bulletin de la Société Botanique de France* 130: 451-464.

Sanmartí J., Santacana J. (2005). *Els ibers del nord*. Rafael Dalmau, Barcelona.

Schubart H., Pingel V., Arteaga O. (2000). *Fuente Álamo. Las excavaciones arqueológicas 1977-1991 en el poblado de la Edad del Bronce.* Arqueología Monografías, Junta de Andalucía, Sevilla.

Schwaller M. (1994). *Ensérune. Carrefour de civilisations protohistoriques*. [s.l.], Imprimerie Nationale & Ministère de la culture et de la franchophonie, Guides archéologiques de la France; 28.

Valor J.P. (2004). *El jaciment ibèric de La Muela de Arriba* (*Requena, València*). Archivo de Prehistoria Levantina, 25: 263-300.

Vilà M. Del V., Barrachina C., Martín S., Negre M.M., Ramón E. (1992). El poblat ibèric de Montbarbat (Lloret de Mar, la Selva), *Tribuna d'Arqueologia 1990-1991:* 107-114.

Yll E-I., Perez-Obiol R., Pantaleon-Cano J., Roure J.M. (1995). Dinámica del paisaje vegetal en la vertiente mediterránea de la Península Ibérica e Islas Baleares desde el Tardiglaciar hasta el presente. In: T. Aleixandre, A. Pérez González (eds.) *Reconstrucción de paleoambientes y cambios climáticos durante el Cuaternario*. Centro de Ciencias Ambientales, CSIC, Madrid: 319-328.

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(1) Part one was published in Option Méditerranéennes A, 83: Buxó, 2008. 'The water management in an ancient Greek-Roman city: an example in the North East of Spain'

(2) For this reason the classical Greek authors expressed a unanimous preference for water in motion originating from springs, although they endorse the use of water from cisterns in cases of necessity. (Hellmann 1994, 274).

Potential groundwater contamination by toxic metals around an abandoned iron mine, Bekkaria (Algeria)

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Abstract. This study evaluates potential groundwater contamination with toxic metals in and around an abandoned iron mine in Algeria. The studied mine is situated in East Algeria near the frontier with Tunisia. The exploitation of the iron mine terminated in 1967, however, our present interest is the impact of the mine's waste heaps on the groundwater and surface water in the area. Two aquifers are present, the first is situated at three metres under the ground and is connected with the wadi Oued el Kebir; the second is situated at 20 metres deep. The traces of water in the mine waste dump indicate that during the period of peak stream flow, as a result of snowmelt runoff, a losing stream exists that facilitates the displacement of pollutants. The performed analysis permitted us to study the presence of Metal Trace Elements (MTE) in the first aquifer and the wadis. The electrical conductivity near the mine is very high, this is explained by the high concentrations of sulphates, chlorides, calcium and sodium. The spatial variation of the chemical concentrations observed is probably related to the transport of dissolved chemicals from the iron mine waste. The graphs of the results show high concentrations of MTE reducing with the distance to the mine. The neural network modelling performed, confirms this conclusion.

Keywords: Iron – Algeria – Contamination – Water

Contamination des eaux souterraines par les métaux toxiques d'une mine de fer abandonnée : Cas de la région de Bekkaria (Tébessa).

Résumé. *La mine de fer est située dans l'extrême Est algérien. Son exploitation s'est arrêtée en 1967. Nous nous intéressons à l'impact de cette mine abandonnée sur les eaux souterraines et les eaux de surface. Ce qui revient à l'évaluation de la contamination potentielle des eaux par les métaux toxiques dans la zone de dépôt des terrils. La zone d'étude recèle deux aquifères, le premier très proche du sol et est en relation avec le wadi Oued el Kebir, le second est situé à 20 mètres de profondeur. Ainsi les précipitations entraînent le déplacement des terrils et des polluants, contribuant ainsi à la pollution des eaux et des sols. Les analyses réalisées montrent l'évolution des ETM (Elément Trace Métallique), dans les deux aquifères. Nous remarquons que la conductivité électrique est très élevée près de la zone de dépôts des terrils, elle est induite par les fortes concentrations en sulfates, en chlorures, en calcium et en sodium. Les concentrations observées sont générées par dilution. Les teneurs en éléments traces diminuent en s'éloignant de la zone de dépôt des terrils. La modélisation par la méthode des neurones artificiels confirme les résultats obtenus par l'hydrochimie.*

***Mots clés**: Fer – Algérie – Contamination – Eau*

I – Introduction

Tébessa is a city on the frontier with Tunisia. It is located in the extreme North-East of Algeria (fig. 1), at the edge of the desert, approximately 230 km south of Annaba on the Mediterranean coast. The area is limited to the south by the sector of Biskra, to the west by that of Constantine and in the east by the Tunisian border. The climate is semi-arid.

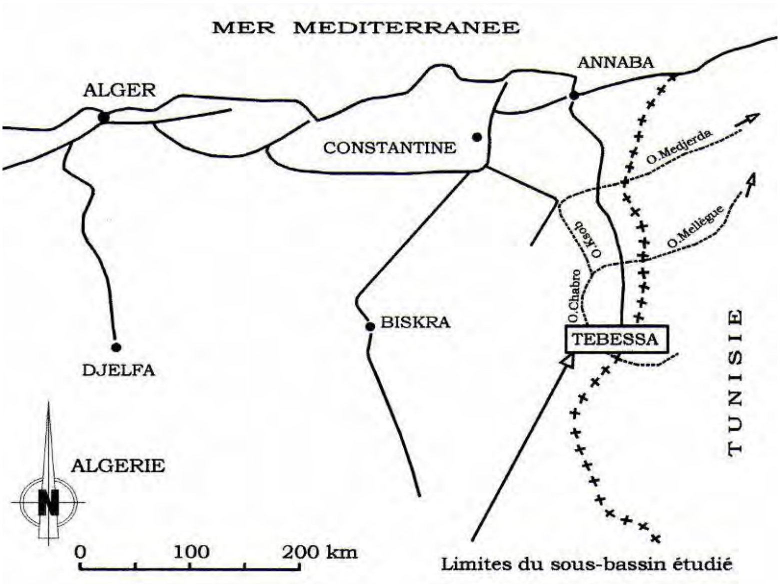


Figure 1: Situation of the study area.

In the studied zone the outcrop formations are of the sedimentary type. They are characterized by the presence of triassic formations, on which we will focus our interest. In the Tébessa area the most important triassic outcrops are those of Djebissa, Ouenza, Boukhadra, Mesloula, Boujaber, northern Hameimat and southern Hameimat. These outcroppings are saliferous and have developed a structure of several mineralogical zones. These formations contain different concentrations of metals such as lead (Pb), Zinc (Zn), Barium (Ba) and Strontium (Sr). Djebissa mountain contains traces of poly-metalic ores and iron. A layer of this iron comes from the iron mine of Khanguet which does not form part of our study area. The Pb-Cu index are in close contact with Cenomanian-Turonien on the South-East side, carbonated rocks (limestone) contains a mineralization with crystals either spread, in veins, or in nests. The products of epigenese can also be encountered: cerusite, limonite and hypogene minerals of copper represented by grey copper ore and digenite hypergenes represented by malachite and azurite.

II – Research outline

As climatic factors contribute to the propagation of the pollutants, the study of climatic factors proves to be essential. In order to study the climatic influence we considered two extreme years. The first is the year 1972-1973, which is considered to be very wet with a precipitation of about 625 mm. In this year the wet season was spread out over ten months. Conversely the year 1996/1997, with only 207 mm precipitation is a very dry year; the wet season is spread out over two months (December and January) and the rain started again mid-March until mid-May.

The shallow aquifer (less than 10 m deep) and the wadi are directly exposed to pollution, in contrast to the deep aquifer which is supplied by infiltration, in other words after a stay of water, allowing reactions between water and soil. They are therefore studied in this work.

The piezometric map of July 2006 shows that, in general, the piezometric surface (fig.2) has the same morphology as the topography. The flow comes in from the south-east as well as the north-west. The appearance of a steep depressed zone located in the north of Ain Chabro can be noted.

This situation is caused by the exploitation of drilled and natural wells in this area; more than thirty exploited wells are listed in the study area.

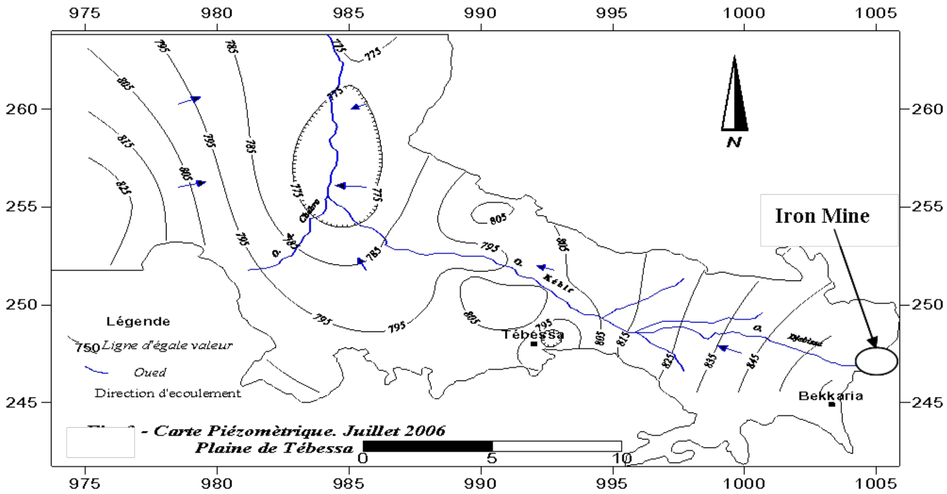


Figure 2: Piezometric map of the shallow aquifer (July 2006).

After the mining in the area was stopped (fig.3), no initiative for environmental protection was taken. This has reflected negatively on the environment. Indeed, for many years the spoil heaps remained deposited on the soil surface upstream of the wadis and the aquifer, directly exposing them to possible pollution. To demonstrate the effects of these spoil heaps on the water quality of this area, we will study the quality of water of both the wadis and the wells. The research will mainly focus on the analyzed metals and on the saliferous outcroppings upstream of the study zone.

Figure 3: Mount Djebissa and the abandoned mine.

The chemical components of the surface waters were the first part of this study. The analyses related to 8 points (fig.4), being distributed on the two wadis; wadi Djebissa and Oued el Kebir, according to the direction of the flow determined by piezometric map.

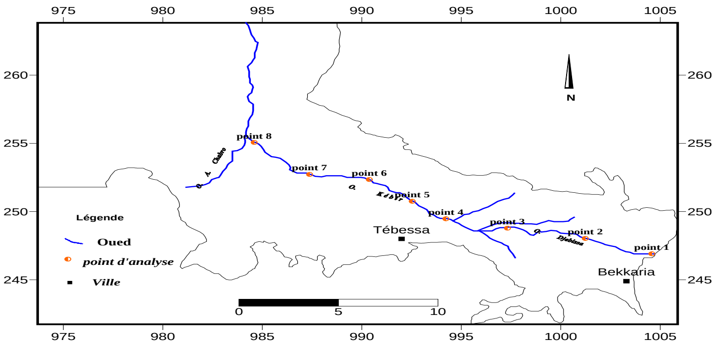


Figure 4: Distribution of sampling points of surface water.

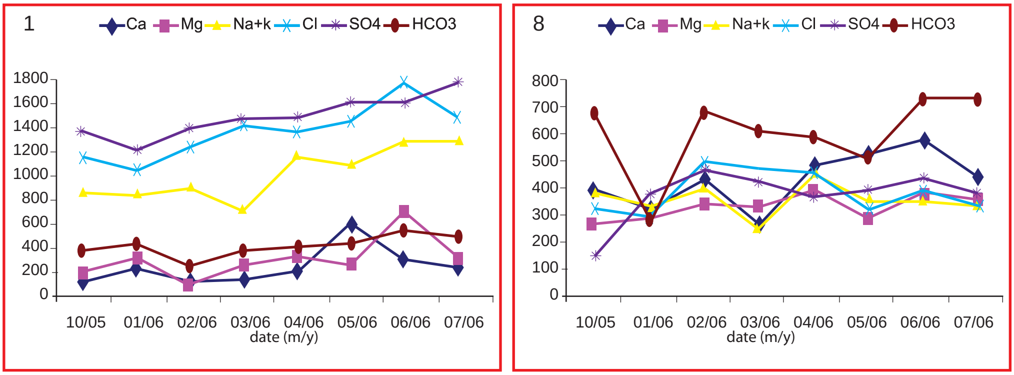
The analyzed elements are: major cations and anions (Ca, Mg, Na+K, Cl, SO_4, HCO_3), trace elements, and the Sr^{2+} /Ca^{2+} ratio.

III – Results of measurements and analysis

Concentration of major elements and MTE in surface waters

The graphs show the concentration (mg/liter) of major elements present in the surface water over time (month, year). Figures 5 & 6 show that important concentrations of sulfates (1000 mg/l) and chlorides (800 mg/l) are present. These two elements move simultaneously. This is aggravated by the climate; indeed during the wet period the dissolution of gypsiferous formations introduces sulfate in the water. During the dry season the evapotranspiration increases the concentrations of chemicals by decreasing the dilution. Furthermore, chlorides are added. Sodium evolves in the same way as chlorides and sulfates. The other elements are more or less stable (table 1).

In the centre of the plain we notice an increase in Ca (400 mg/l) and HCO3 (700 mg/l). The concentrations of other substances such as Mg (250 mg/l), sulfates (400 mg/l) and chlorides (400 mg/l) decrease, but remain important during the dry period. The bicarbonates show an increase for the last points; this is explained by the contribution by the carbonate border.



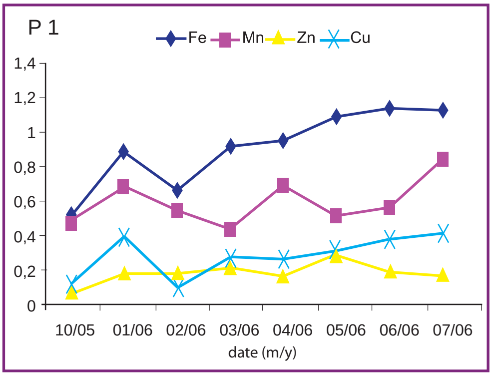
Figures 5 (point 1) & 6 (point 8): Spatial and temporal variation of concentration (mg/l) of major elements in surface water

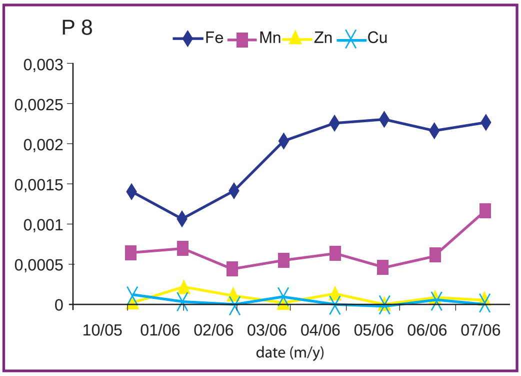
Table 1: Concentrations of the major elements in point 1 and 8 in surface water in wet and dry periods.

	Periods	Ca	Mg	Na+K	Cl	HCO3	SO4
P1	October2005	129	160	833	1128	367	1343
	January 2006	200	271	725	967	360	1137
	February 2006	153	134	725	1160	260	1352
	March 2006	251	376	609	1320	466	1360
	April 2006	258	304	1040	1128	412	1272
	May 2006	537	295	940	1182	421	1280
	June 2006	226	573	967	1451	466	1280
	July 2006	223	296	1040	1272	537	1549

	Periods	Ca	Mg	Na+K	Cl	HCO3	SO4
P8	October2005	386	260	380	350	720	111
	January 2006	340	271	330	302	369	341
	February 2006	390	295	382	430	669	411
	March 2006	251	300	235	420	560	369
	April 2006	430	382	420	383	571	320
	May 2006	478	295	334	320	550	355
	June 2006	494	314	326	317	664	418
	July 2006	430	314	291	296	730	400

The variation of the metal trace elements in the surface water is irregular. Iron and manganese evolve together especially during the wet period. The contribution of these two elements is probably due to the dissolution of iron from the abandoned mine. Copper especially presents a light increase for the dry period; zinc has certain stability for the whole graphs. The observation of the graphs demonstrates a decrease in the concentrations of the trace elements away from the mine (fig.7 & 8), (Table 2). This tendency highlights a probable trapping of the MTE by the soil.





Figures 7 & 8: Spatial and temporal variations of MTE elements in surface water at points 1 and 8 (Fe, Mn, Zn , Cu)

Table 2: Distribution of the trace elements in surface water in wet and dry periods.

	Periods	Fe	Mn	Zn	Cu
P1	October2005	0,55	0,52	0,018	0,051
	January 2006	0,98	0,764	0,12	0,388
	February 2006	0,72	0,579	0,149	0,086
	March 2006	0,99	0,44	0,107	0,215
	April 2006	0,97	0,6	0,167	0,227
	May 2006	1,08	0,49	0,209	0,245
	June 2006	1,12	0,484	0,12	0,275
	July 2006	1,12	0,716	0,09	0,24
P8	October2005	0,0017	0,0008	0,0001	0,0002
	January 2006	0,0012	0,0008	0,0003	0,0001
	February 2006	0,0015	0,0006	0,0002	0,0001
	March 2006	0,0024	0,0007	0,0001	0,0001
	April 2006	0,0025	0,0008	0,0002	0,0001
	May 2006	0,0024	0,0007	0,0002	0,0001
	June 2006	0,0023	0,0008	0,0001	0,0001
	July 2006	0,0024	0,0014	0,0001	0,0001

Concentration of major elements and MTE in Djebissa wells:

The second part consisted of analyzing the water of wells. The points taken are distributed in the plain near the mount Djbissa (fig. 9)

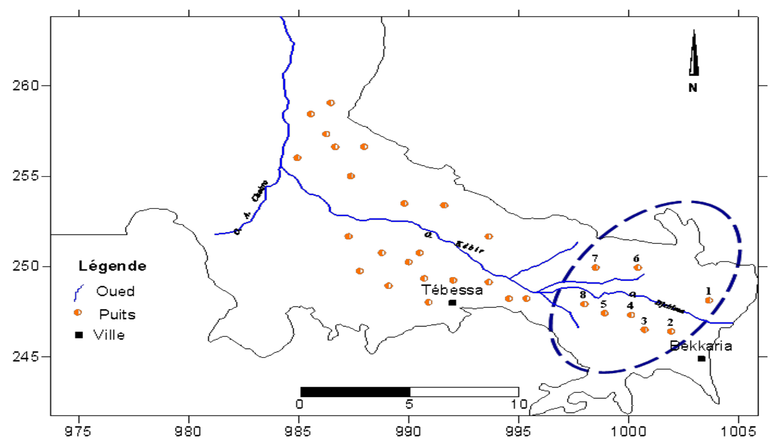


Figure 9: Distribution of the sampled water wells.

The examination of the graphs carried out (fig.10), shows that water is characterized by high concentrations particularly of chlorides, sulphates and sodium. At well N°1, the concentrations for the three elements oscillate between 700 (Na+K) and 1600 mg/l for chlorides. In well 8, we noted a very steep fall of these concentrations, the maximum reached is about 700 mg/l and the minimum borders 400 mg/l.

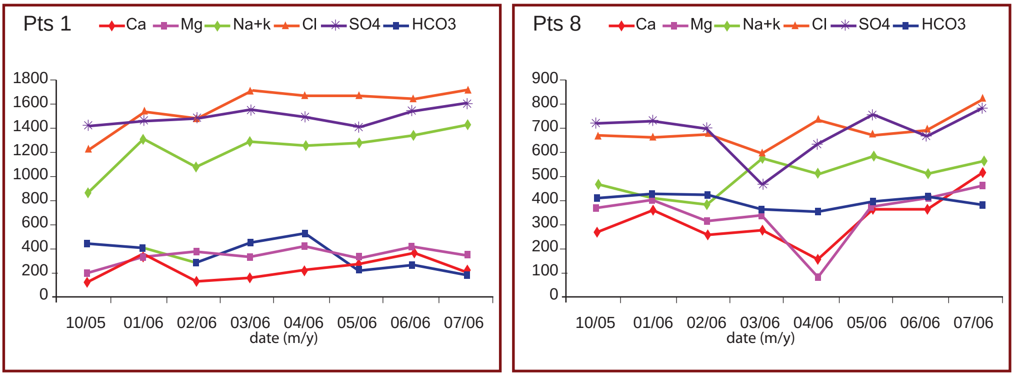


Figure 10: Spatial variation of major elements, in groundwater.

The concentrations of MTE in the groundwater samples collected from wells of the first aquifer, (fig.11), remain low. However, the iron concentrations are about 0.2 mg/l indicating water pollution. For the well 8 located far from the mine, the concentrations decrease to reach 0.05 mg/l.

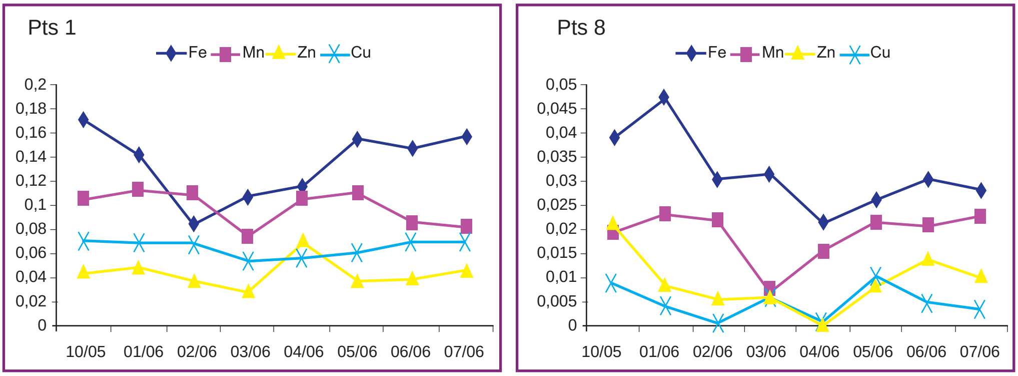


Figure 11: Spatial and temporal variation of presence of MTE in groundwater at points 1 and 8.

The interpretation of the results highlights a double variation of the concentrations:

- The first, the horizontal direction, indicating a decrease of the concentrations away from the mine. This distribution is generated by the flows that transport chemical elements.

- The second, the vertical variation, showing that water of the aquifer is not contaminated, which highlights a trapping of metals by the sediments.

Confirmation by Sr^{2+}/Ca^{2+} ratio :

The study of the Sr2+/Ca2+ ratio gives an indication of the influence of sorted gypso-saliferous on the water salinity. Strontium is related to the evaporites. The strong contents of Sr2+ in water are explained only by the dissolution of celestite (Sr SO4); a mineral associated with gypsum, it thus serves as a good marker of the presence of the evaporites.

In surface water (fig.12) the Sr^{2+}/Ca^{2+} ratio reached important values highlighting the influence of sorted gypsiferous substances on the quality of water. Indeed the dissolution of minerals contained in the formations enriched water in elements traces.

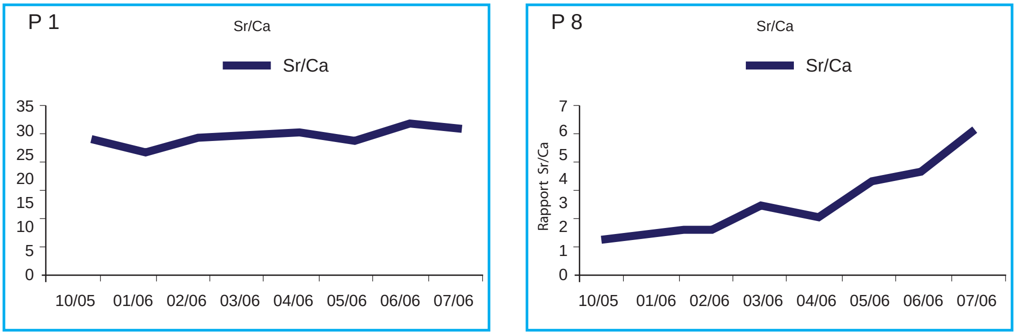


Figure 12: Sr2+/Ca2+ ratio over time in surface water at points 1 and 8.

IV – Neural networks analysis

Modeling constitutes another tool for the description of the impact of the iron mine on the quality of water. To complete our work we chose a model based on networks of artificial neurons.

Presentation of this method

A network of artificial neurons (RNA or ANN) is a nonlinear empirical model. It is composed of inter-connected elements of treatment (neurons) working jointly to solve a specific problem. Hecht Nielsen (1990) gives the following definition: a network of neurons is a system of calculation made up of strongly inter-connected simple elements of treatment, which process the data by their change of dynamic state in response to an external entry.

Connections between the neurons

The networks of neurons (fig.13) are organized in layers; these layers are composed of a certain number of inter-connected neurons which contain a function of activation.

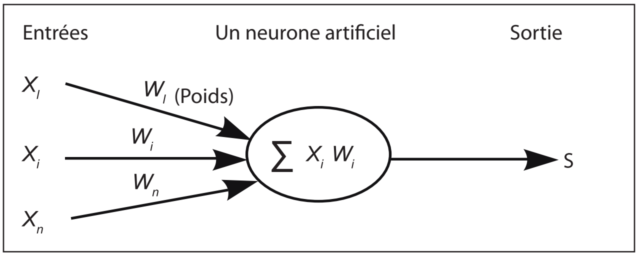


Figure 13: Neural network

Creation of the model

In this work, a multi-layer network of Perceptron was selected as model of the system where the network treats a vector of input being composed of the variables including Ca, Mg, Na, K, Cl, SO4, HCO3, NO3, pH, M, and Sr/Ca. These vectors of input produced a vector of output (left) which is electric conductivity (EC). The network of MLP can be represented by the following compact form: {EC} = ANN [Ca, Mg, Na, K, Cl, SO4, HCO3, NO3, pH, mineralisation, Sr/Ca].

Choice of the execution criteria:

The data for the quality parameters of subsoil waters analyzed for the year 2006 were employed to create the model of the RNA by using STATISTICA software, neural network version 4.0. The parameters of water quality include: concentration of calcium (Ca^{2+}) ions, magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), sulfate ($S0_4^{2-}$), bicarbonate (HCO_3^{-}), nitrate (NO_3), hydrogen (pH), mineralization (M), and the strontium ratio on calcium (Sr^{2+}/Ca^{2+}). These parameters which represent the quality of water are regarded as input variables while the output variable (left) is electric conductivity (EC). The statistical parameters used in this work are: the Root Mean Square Error (RMSE) and the coefficient of R2 determination

Results and discussion:

The types of networks considered are: MLP (3 and 4 layers), RBF, GRNN and linear. During the analysis, 697 networks were examined. The best optimal model of the found RNA is the MLP (3 layers) with 6 hidden nodes (figure 3). The minimal error of 0.3125517 is compared with the other types of networks RNA (table 3).

Type of Network	Error (RMS)
GRNN	3.31
RBF	3.08
Linear	2.14
MLP (4 layer)	1.16
MLP (3 layer)	0.31

Table 3: Error RMS in various neural networks.

The model has an excellent performance in the checking with a report/ratio of regression of 0.016 and a correlation coefficient higher than 99% for the training. The sensitivity analysis of the water quality variables of RNA in phases of the training and of checking indicates that mineralization (M) and the strontium on calcium ratio (Sr^{2+}/Ca^{2+}) are the most important factors influencing electric conductivity in groundwater.

V – Conclusion

The work carried out concerns the effects of the spoil heaps deposited upstream of two wadis and a system of aquifers. The measurements carried out demonstrate that water of both the wadis and the sub-surface aquifer are charged with MTE. The concentrations observed in water of the wadis are, however, very high compared to the water of the wells. This would be due to the trapping of the MTE which takes place in the soil layer separating the two levels of water. The study of the ratio Sr^{2+}/Ca^{2+} shows the influence of the gypsiferous formations on the water quality. The results obtained by the mathematical model confirm this relation well.

References

Djabri L. (1987). Contribution à l'étude hydrogéologique de la nappe alluviale de la plaine d'effondrement de Tébessa. Essai de modélisation. Thèse de Doc.Ing. Univ. Franche Comté. Besançon.176pages.

Djabri L., Hani A., Mania J., Mudry J. (2001). Mise en évidence du processus de salinité des superficielles. Vérification par l'ACP dans le secteur de Annaba-Bouchegouf et Guelma. *Revue Tribune de l'eau*. Vol, 54.N° 610.pp29-43.

Ghreib L. (2007). Impact des formations triasiques sur les eaux d'une plaine en zone semi-aride : cas de la plaine de Bekkaria-Tébessa (Extrême Est Algérien). Mémoire de Magister de l'Université de Annaba. 114 pages.

Jung M.C. (2001). Heavy metal contamination of soils and waters in and around the Imcheon, Au-Ag mine, Korea. *Appl. Geochem*. 16, 1369–1375.

Lee J.Y., Choi J.C., Yi M.J., Kim J.W., Cheon J Y., Choi Y.K., Choi M.J., Lee K.K. (2005). Potential groundwater contamination with toxic metals in and around abandoned Zn Mine, KOREA. *Water, Air, and Soil Pollution* N° 165: 167–185.

Lallehem S., Mania J. (2002). A linear and non linear rainfall-runoff model using neural network technique: exemple in factured porous media. *Journal of Mathematical and computer Modelling*. N° 1, Vol. 55.

Second part

Water value and water price

Valuing water from social, economic and environmental perspective

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Abstract. The increasing demand on water due to the growth of both the population and economy has put strong pressure on water quality and quantity. Water is therefore increasingly being valued as an economic resource. The price of water depends on quantity and quality as well as on the behavior of people and market. The value of water for society, people's health and the environment are important factors that should be considered in the valuation process. Water in sufficient quantity and good quality for drinking and sanitation to meet basic needs, is a human right. Water has been treated as an economic good as stated in the 1992 Dublin statement: 'water has an economic value in all its competing uses and should be recognized as an economic good'. This is different from water pricing when pricing is intended to recover the full costs of infrastructure, management and operation. This may lead to economic pricing of water, which will damage the interests of the poor and will make irrigated agriculture unfeasible. Valuing water for domestic purposes in Egypt using different valuation techniques has shown the limits of the end-users' willingness to pay. Water pricing policy in Jordan is aimed at recovering the cost of operation and maintenance and at the same time at water conservation.

Key words: Water – Value systems – Price fixing – Price policies – Costs – Human rights

Valoriser l'eau de la perspective social, économique et de l'environnement

Résumé. *La demande croissante en eau due à la croissance démographique et économique a mis la pression sur la qualité et la quantité de l'eau et est donc de plus en plus apprécié en tant que ressource économique. Valoriser l'eau dépend de la quantité et la qualité ainsi que le comportement des personnes et du marché. Les valeurs sociales, la santé et l'environnement de l'eau sont des facteurs importants qui devraient être pris en compte dans le processus d'évaluation. Fournir de l'eau aux personnes en quantité suffisante et de bonne qualité pour la boisson et l'assainissement pour répondre aux besoins de base est le droit de l'homme. L'eau a été traitée comme un énoncé économique de bonne Dublin selon à 1992: «L'eau a une valeur économique dans toutes ses utilisations concurrentes et doit être reconnue comme bien économique». Ceci est différent de tarification de l'eau lorsque le prix doit couvrir les coûts de l'infrastructure, la gestion et l'exploitation. Cela peut conduire à des prix économique de l'eau, qui peuvent porter préjudice aux intérêts de l'agriculture du pauvre et rendra irréalisable l'agriculture irriguée. Valoriser l'eau à des fins domestiques en Egypte et en utilisant différentes techniques d'évaluation a montré les limites des prêts à payer par les utilisateurs finaux. La politique de tarification de l'eau en Jordanie vise à la conservation de l'eau et le recouvrement des coûts de fonctionnement et d'entretien.*

Mots clés: *Formation de prix – Système de valeurs – Coût – Prix – La politique des prix – Droits de l'homme*

I – Introduction

The issue of water is ranked high on the global political agenda as water scarcity has become a threat to human survival and sustainable development. Human activities and development processes have exerted huge pressure on the already exhausted water resources. World leaders, scientists and policy makers have realized that unsustainable management and inequitable access to water resources cannot continue. In many parts of the world such as the Middle East, demand far exceeds supply while in some countries in Africa access to fresh water is limited. According to the UN World Water Assessment Programme (WWAP) (UNDP, 2006) about 1.4 billions people worldwide have no access to clean and drinkable water, while about 2.5 billions including almost one billion children have no or poor sanitation.

The growth in population has created greater pressure on water resources by increasing water demand and pollution. During the last century, the world population has doubled while water consumption has increased five times. Demographic changes like migration and urbanization have increased the demand for water and created a higher need for water services. Social changes such as the improvement of life style and the rise in living standards have influenced the peoples' perception and their attitude toward water. This is illustrated by changing patterns of consumption and production. Furthermore, the changes in global economy and the growth of the international trade of goods and services have increased water stress in some countries, while relieving it in others through the flow of virtual water.

Many countries experience water scarcity, water pollution and the increase of other environmental problems that will hinder the sustainable development and threaten peace and continuity for human beings. Therefore, people have to be aware of the value of water, the environment and healthy ecosystems. In the context of water shortage and lack of access to water, it is important to discuss the issue of valuing water, including its economical, social, cultural and other values. The value given to water is explained with a short sentence 'water is life'. Water is a human right. Therefore, priority has to be given to satisfying human needs. After the basic need is met, water should be allocated to the use that has the highest value or water should be treated as an economic good.

The values of water are many and the economic value is just one of them. The perception of the value of water varies from culture to culture and from individual to individual. For many people, the non-economic values are paramount and they find that charging for water is very difficult to accept. This can be found in the policies of many governments as they do not charge for or price water for political, cultural and social reasons. People living in an arid climate place a higher value on water that those living in wetter countries. The range of value perspectives includes culture, social circumstances, environment and religion. The value of water has been addressed in nearly all religions where it is attributed important symbolic and ceremonial properties.

According to UNESCO (2006), the range of value perspectives varies to some extent on a case-by-case basis and on the stakeholder group involved. Moss *et al.* (2003) has listed the following value perspectives: environmental, social, public health, economic, production, political and gender-related.

II – Global perspective on water value

According to fourth principle of the Dublin Statement on Water for Sustainable Development (2002), 'water has an economic value in all its competing uses and should be recognized as an economic good. Within this principle, it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price. Past failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources'.

Agenda 21, chapter 18 (UNCED, 1992) has concluded that: 'Water should be regarded as a finite resource having an economic value with significant social and economic implications regarding the importance of meeting basic needs'.

The ministerial declaration of the 2nd world Water Forum (The Hague, 2000) said: 'to manage water in a way that reflect its economic, social, environmental and cultural values for all its uses, and to move towards pricing water services to reflect the cost of their provision. This approach should take account of the need for equity and the basic needs of the poor and the vulnerable'.

Also, the ministerial declaration of the 3rd World Water Forum (Kyoto, 2003) stated: 'funds should be raised by adopting cost recovery approaches which suit local climatic, environmental and social conditions and the «polluter-pays» principle, with due consideration to the poor. All sources of financing, both public and private, national and international, must be mobilized and used in the most efficient and effective way'. Similar statements were issued after 4th and 5th world forum in Mexico (2006) and Istanbul (2009).

In Europe, water pricing reform is also on the table as part of the EU Water Framework Directive's drive to recover the costs of water services, including the costs imposed on the downstream users by users upstream and the environment. The main objective of the EU Water Framework Directive (WFD 2000/60/EC) is the achievement of the "good" ecological and chemical status of all waters by 2015. As part of WFD implementation, the economic valuation of water can play two specific roles. (i) The WFD requires water utilities in Member States to set water prices to cover the costs of water services (art.9). But it allows for exceptions in order to provide affordable water to poor users. Studies of willingness and ability to pay can determine when full cost recovery water pricing is feasible. (ii) River Basin Authorities are also required to implement cost-effective programs of measures (art. 11) to reach the WFD objectives. However, if the costs of measures are disproportionate to the benefits of achieving the good status, "derogations" can be allowed (art. 4). River Basin Authorities can then implement less costly measures. Economic valuation may be used to determine how large the economic benefits are, and so justify, or not, further measures.

III – Water as a basic need

This part was taken from a presentation by Shatanawi (2009) to the international conference: 'Water and Peace' that was held in the European Parliament, Brussels (12-13 Feb., 2009). 'Water is the source of life and it is the first element of every living thing. Without water there will be no life because human beings, animals, plants, etc… need water every day for their continuity and survival. As water is a common resource, everybody has the right to use it, but water availability is limited to resource constraints. Giving such constraints on water availability, how much water is needed to satisfy this right? The answer to this question came out from discussing the human right issue and the understanding of human needs and uses for water'.

One of the concepts of the 'new world thinking about water' states that water is a human right, but this right to water does not imply a right to unlimited amounts of water, nor does it require that water be provided for free. The concept of meeting basic water needs was strongly reaffirmed during the 1992 Earth Summit in Rio de Janeiro. 'In developing and using water resources, priority has to be given to the satisfaction of basic needs...'.(Gleick 1998) In 2002, water was recognized as a fundamental human right where a General Comment on the right to water was developed by the UN Covenant on Economic and Cultural Rights (CESCR,). This covenant was realized and ratified by 145 countries ensuring that every one has access to safe and secure drinking water, equitably without discrimination. General Comment 15:2, states that: 'the human right to water entitles everyone to sufficient; affordable; physically accessible; safe and acceptable water for personal and domestic uses'. It required governments to adopt national strategies and plans of action, which will allow them to 'move expeditiously and effectively towards the full realization of the right to water.' 'These strategies should be: (i) based on human rights law and principles, (ii) cover all aspects of the right to water and the corresponding obligations of countries, (iii) define clear objectives, (iv) set targets or goals to be achieved and the time-frame for their achievement, and (v) formulate adequate policies and corresponding indicators' (CESCR 2003, GC 15:47).

Generally, governmental obligations towards the right to drinking water under human rights laws broadly fall under the following principles: respect, protect and fulfill (CESCR 2003, GC 15:20).

Respect: Governments must refrain from unfairly interfering with people's access to water like disconnecting their water supply.

Protect: Government must protect people from interference with their access to water by others. This includes stopping pollution or prohibiting unaffordable price increases by corporations.

Fulfill: Governments must, within available resources, take all possible steps to realize the right to water including passing appropriate legislation, implementing programs and monitoring their progress.

CESCR general comment 15:2 also says that: ‘An adequate amount of safe water is necessary to prevent death from dehydration, reduce the risk of water-related disease and provide for consumption, cooking, personal and domestic hygienic requirements.’ This amount has been defined by the WHO as 40 liters per capita per day. In addition, CESCR, GC 15:1 has stated that: ‘water is recognized, not only as a limited natural resource and a public good, but also as a human right’. At the international level this constitutes decisive progress, in terms of the legal protection of the right to water, although it is not a legally binding document.

IV – Value, price and cost

The value of water is measured in terms of its benefit to its users; the price of water is the charge levied from the consumers; while the costs to supply water are defined as the capital and operating costs of abstracting, treating and transferring water to the point of use. Full cost recovery is when users pay the full cost of obtaining, collecting, treating and distributing water, as well as collecting, treating and disposing of wastewater. Defining exactly what should be included in this cost is still an issue of some contention (WWAP).

In addition to the economic values, it is necessary to recognize what values actually fall within the economic analysis and what values are beyond economics. Matthews (2001) has illustrated the different concepts in Figures 1 and 2. A distinction is drawn between efficiency analysis and beyond efficiency (Figure 1). Within the category of efficiency, there are two broad concepts of goods that are valued. Those that are traditionally traded in the market place (private goods: apples, oranges, etc.) and others, which are not typically traded in the market place (non-market or public good: air quality, watershed preservation, etc.). The sum of these can be referred to as full economic value. In addition to the economic value, it Matthews recognizes that there some values are above and beyond those within the domain of economics. These would include, amongst others cultural and religious values.

Figure 2 presents the subject of cost analysis. Full economic costs include aspects such as capital costs and operation and maintenance costs (OM), as well as technological externalities. Technological externalities are described as costs that can be attributed to actions by others; individuals or firms. For example if a factory pollutes the water upstream the downstream users will have to clean the water before using it as drinking water. ‘Pecuniary externalities’ are those that arise through the price system. ‘Complete economic costs’ therefore include both ‘pecuniary’ and ‘full economic costs’ (Matthews 2001).

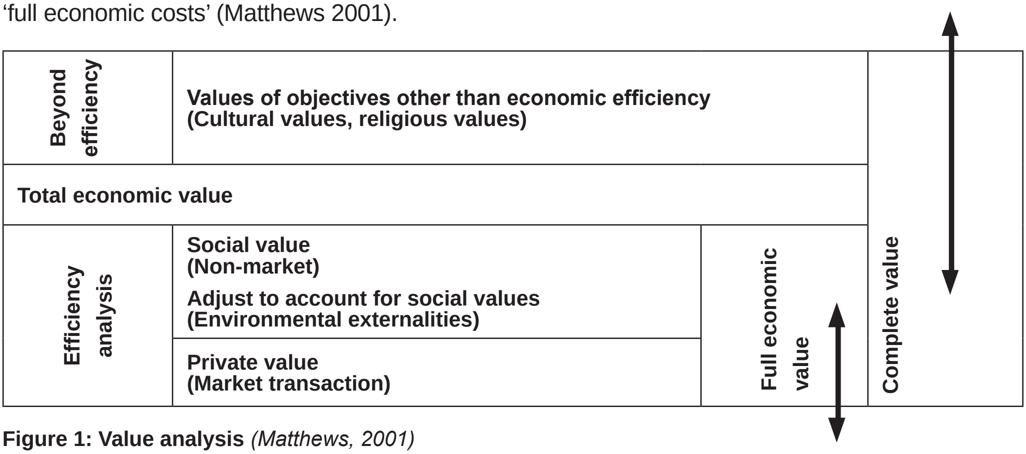

Figure 1: Value analysis *(Matthews, 2001)*

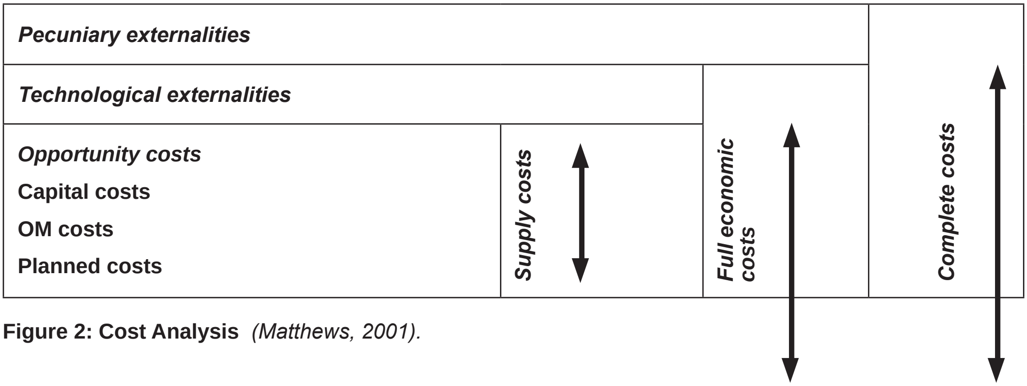

Figure 2: Cost Analysis *(Matthews, 2001).*

V – Value versus valuation

Value and valuation can have more than one meaning. This results in the fact that valuing (giving value to) a resource is not the same as the valuation of resource. Some people believe that water can not or should not be «valued» economically. Value has both a qualitative and quantitative connotation while the valuation of water is usually an indicator, a kind of economic measurement. When the word «value» is used in a subjective sense, it may mean that water is so important (valuable) that is beyond economic measurement. The subjective importance (value) of water is sometime measured by looking at indicators such as people's preferences which can be useful in determining the relative importance of water (Mattews, 2001). Acknowledging that some values can not be taken into account in the valuation the following sections will discuss the economic value and methods to establish this value.

Economic value

It is necessary to value water economically because it provides critical information to decision makers about efficient and equitable allocation of water among competing uses. Allocation can be either within the present generation or between present and future generations. Economic valuation can also provide information on the design of economic instruments such as water pricing, property rights, tradable water rights, markets, resource tax, etc.

Economic value signifies that people are willing to pay for a commodity, rather than go without it. Willingness to pay refers to the maximum amount an individual would be willing to pay, or give up, in order to secure a change in the provision of a good or service (OMB, 1992). Water is an essential commodity and people would pay any price for the basic amount for survival. However, after basic needs are met, people buy water based on its price and compare water with other goods they might buy. Water should be allocated to the uses that have the highest value.

At this point, many questions arise. How much will a household be willing to pay for drinking water? How much will a farmer pay for irrigation water, or a factory for clean water? There are two types of values and benefits from water, namely; use value and non-use value. The use value involves the commodity benefits (such as drinking, irrigation, etc.) and associated benefits (like wastewater services and navigation). The non-use values include recreation, ecosystem preservation and social and cultural values. These values are, however, difficult to measure.

Valuation Techniques

There are two main methods for the valuation of natural resources, namely (i) direct valuation which is based on survey of willingness to pay and is called 'Stated Preference Technique' and (ii) The indirect method of valuation which is based on observed market values and is called 'Revealed Preference Techniques'.

1. Stated Preference Technique

The direct approach, also called the contingent valuation method (CVM), is used to estimate the value of water by asking people how much they are willing to pay for a resource or service. Conducting questionnaires and surveys to give rank or value are used for this. It is used to estimate the value of water use for households, agriculture, industry and recreation. In this method people are directly asked to reveal how much they are willing to pay for good quality water with assured supply for domestic use, as an example. Using this method, Hoehn and Kriager (2000) conducted a survey and analysis for household services in Cairo, Egypt, and found that connection to water services was worth more than the improved reliability of services. They also found that recovering project costs through fixed tariffs, can lead to charges for water and wastewater services that are higher more than people are willing to pay.

2. Revealed Preference Techniques

The indirect method is based on observed market values. The following approaches can be used for evaluation:

Residual value: this is the easiest and most commonly applied valuation techniques. It considers the marginal contribution of water to output. However, this technique requires that the quantity of water used is measured accurately, as well as labor costs, value of land, capital costs and other inputs. The prices of all inputs and output must reflect the true economic value.

Production function approach: This technique requires conducting experiments from which a production function is obtained. The marginal contribution measures the change in output from a unit increase in water input while keeping other input variables constant.

Optimization model: This method is used to estimate the value of water for all users in an economy and involves modeling. The marginal contribution is measured as the change in sector output across the entire country, by the allocation of water. The technique involves using modeling techniques such as linear programming, computable general equilibrium (CGE), GAM and other economic modeling instruments.

Opportunity cost: This approach is based on the difference in costs of production so it is a good technique to estimate water productivity of available alternatives. It calculates the price differential for alternatives such as replacing hydro-electric power plants with thermal power plant.

Demand curves for water: The relationship between the price of water and the quantity demanded can be shown using the economic technique called the demand curve that has been described by Fortin *et al.* (2001). Harris (2002) demonstrates that in typical water demand curves, price and quantity are inversely related. The relation between price and water can be found by determining the variations in the slope of the two demand curves. The use of demand curves in water resources, however, has some restrictions. Demand curves were developed based on the principle of “perfect markets”. In such markets, no individual consumer or no individual producer is large enough to dominate the market. Another assumption is that consumers and producers all have perfect knowledge of both the price and the cost of the goods in the market. To a large degree this holds for most goods and services in a market economy, however, there are notable exceptions, such as a situation of monopoly, in which an individual producer can dominate the market (Harris *et al.*, 2002).

VI – Valuing water in Jordan

Water situation

Jordan is ranked among the countries of the world with limited water resources where demand is far exceeding supplies. The per capita share of water of renewable water resources is 150 m^3/year and is expected to reach less than 90 m^3 in 2020 (MWI, 2007). Meeting Jordan's water demands, including water supply to the major centers of consumption will require expensive development and conveyance projects, because the most accessible sources and feasible projects have been already developed. No single action can remedy the country's water shortages; rather a program of measures is necessary to increase the overall water availability. The limited options focus on increasing the supply of usable water by improving the amount and quality of treated wastewater; or reducing water demand by adopting water conservation programs and improving water use efficiency. Supply augmentation options might include desalinization of brackish groundwater that is present in different locations.

Water pricing policy

The implementation of water pricing policy as an incentive to improve water management was only very effective when it was coupled with public awareness programs. The government of Jordan has undertaken a package of measures and policy reforms to strengthen the water sector and to assure financial viability (Shatanawi *et al.*, 2006). One of these measures is the application of water-pricing policy to cover the cost of operation and maintenance, and also part of the capital cost, using it as an instrument for the efficient management of water. So recovery of supply costs is the intention. The policy states that water is managed as an economic commodity that has an immense social value. At least, a water price is set. Differential prices are applied to account for irrigation water quality, the end users, and the social and economic impact of prices on the various economic sectors and regions of the country. Due to the increase in marginal costs of collecting and treating wastewater, charges, connection fees, sewerage taxes and treatment fees shall be set to cover at least the operation and maintenance costs. It is highly desirable that part of the capital costs of the services shall be recovered.

Water is relatively expensive in Jordan because of the scarcity and the high cost involved in acquiring, treatment, transporting and distribution. The actual costs of delivering water to consumers are estimated at 1.14 \$/m^3 for municipal purposes and 0.32 \$/m^3 for irrigation in the Jordan Valley. Cost analysis show that the government of Jordan has been subsidizing these water services. Water in Jordan Valley is charged according to the principle of price discrimination. The block water rates structure is divided into four steps depending on the level of water usage. The farmer's payment depends on the total water consumption. It ranges from 0.0114 \$/m^3 to 0.05 \$/m^3 with an average of 0.027 \$/m^3. The same principle applies to the charges of water delivered to households, which is also based on a block rate structure. The first block (up to 10 cubic meter per month) is priced at 0.3 \$/m^3 while the last block is 1.42 \$/m^3. This means that rich people pay the highest cost, which implicitly means that they support the poor who consume less. To control groundwater pumping and reduce over-abstraction, the government has passed a by-law charging resource taxes on groundwater withdrawals exceeding 150,000 m^3/year. (MWI, 2002).

In the future, the cost of securing additional supply will be higher because all inexpensive resources have already been exploited. Therefore, future options will rely on desalination of brackish and sea water and the transport of fossil water. The medium term plan is to exploit and transport the fossil water of Disi Aquifer over a distance of 325 km at a cost of about 1.20 \$ / m^3 before the network. This will increase by almost 50% due to system losses and pumping cost. Short-term plans consider water desalination at some locations. The long-term plan involves mega-projects such as the Red-Dead Seas conveyor which intends to use the difference in level between the Red Sea and Dead Sea to desalinate some 850 million m^3 of water annually by diverting 60-80 m^3/s of open sea water (about 1700 million m^3 annually). The second aim of the project is restoring the drying Dead Sea to its historical elevation. The feasibility and environmental studies will be finished in 6 months, with initial costs estimates ranging between 6 and 7 billion US dollar. This high cost can be justified by securing such a huge quantity of water and restoring the drying lake that has been considered as an international heritage (Shatanawi, 2008).

Economic value return

In the past, social values were the main drive for water allocation. People tended to allocate water to traditional crops such as wheat, olives and forage crops, aiming at self-sufficiency. With the growth of the international market and the implementation of global trade agreements, the trend has become to take into consideration the economical productivity of water. In the process of water allocation within the agriculture sector (related to the cropping pattern), the water production function is used. In an attempt to analyze the relationship between the productive process and the economic trade with water resources, Jabarin and Karabliah (2004) have estimated the amount of water embodied in export crops. The results showed that Jordan utilizes significant amounts of water (50%) to produce certain vegetables and fruits for export. The policy has to be modified in such a way that cash crops with low water consumption are produced while importing water intensive crops.

Environmental value

During the last thirty years, the damage to the environment has been significant due to over-pumping of renewable groundwater aquifers to the extent that many springs have dried out, as the case of Azraq Oasis. The drop of discharge in the springs has affected the ecosystem and the base-flow of some rivers. Over-pumping has caused a significant decrease in water levels, in the yield of many aquifers as well as in water quality. So far, the economical value for such damages has not been calculated, but the water and environmental agencies are carrying out a project to measure the cost of damages and water quality deterioration. The initial estimate of the cost of damages and rehabilitation was estimated by Soir (2009) to range from 320 to 450 million US dollars.

VII – Conclusion

The ways in which water is conceived and valued, allocated and managed, used or abused are embedded within the economic, social, cultural and environmental context of a society. Therefore, the values are the sum of weights assigned to the outcomes of the above factors and their specific policies. Providing water to people in sufficient quantity and good quality to meet the basic needs of drinking and sanitation is a human right.

In some countries, such as Jordan, the implementation of water pricing policy as an incentive to improve water management was only very effective when it was coupled with public awareness programs. The policy of water allocation based on economic and social equity principles was successful. The ratio between financial and opportunity costs is usually quite different for different water uses. If water is to be allocated appropriately and used efficiently, the emphasis for municipal supplies must be on financial costs, and for irrigation on opportunity costs.

References

CESCR (2003) *Substantive issues arising in the implementation of the international covenant on economic social and cultural rights* (2002). http://www.unhchr.ch/tbs/doc.nsf/0/a5458d1d1bbd713fc1256cc400389e94/$FILE/G0340229.pdf

Fortin M., Slack E., Loudon M., Kitchen H. (2001). *Financing water infrastructure.* Toronto. Commissioned by The Walkerton Inquiry.

Gleick P. (1998). The human right to water. *Water Policy* 1 (1998) 487-503

Harris J., Tate D., Renzetti S. (2002). *Economic principles and concepts as applied to municipal water utilities.* Final report. GeoEconomics Associates Incorporated. http://www.ontla.on.ca/library/repository/mon/5000/10311443.pdf

Hoehn J., Krieger D. (2000). Valuing water in a desert city: economic analysis of infrastructure investment in Cairo, *Journal of Water Resources Planning and Management*, 126 (6): 345-350.

Jabrin A., al-Karablieh E. (2009). *The water prospective in the export competitiveness: an analysis of the Jordanian agricultural product.* Presented at the 14th national scientific week (3-8 May 2009), the Higher Council of Science and technology, Amman, Jordan

Mathews D., Brookshire D., Campana M. (2001). *The economic value of water: results of a workshop in Caracas, Venezuela* (November 2000). Publication NOWRP-4, Water resources program, the University of New Mexico, Albuquerque, NM.

Moss J., Wolff G., Gladden G., Gutieriez E. (2003). *Valuing water for better* governance. How to promote dialogue to balance social, environmental and economic values? CEO Panel, Business and Industry.

MWI (2008). *National Water Master Plan. Ministry of Water and Irrigation* (MWI). www.mwi.gov.jo, Amman, Jordan.

MWI (2002). *Groundwater protection by-law. Ministry of Water and Irrigation.* Amman, Jordan.

OMB (1992). Guidelines and discount rates for benefit-cost analysis of federal programs, Circular No. A-94. Office of Management and Budget. Washington D.C., USA.

Shatanawi M. (2009). *Human rights to water.* Presented at the World Political Forum: international meeting on water and environment «Peace with Water», Brussels, 12 and 13 February 2009.

Shatanawi M. (2008). *The status of water resources in Jordan.* Presented at the scientific day of the Faculty of Agriculture, University of Jordan, Amman, Jordan

Shatanawi M., Duqqah M., Naber S. (2006). Agricultural and irrigation water policies toward improved water conservation in Jordan. in: *Options Mediterranean*, Series B: Studies and Research, No. 59, CIHEAM, Bari, Italy.

Soir G. (2009). *The deterioration of water resources quality in Jordan and what to do about it*, presented at the 14th national scientific week (3-8 May 2009), the Higher Council of Science and technology, Amman, Jordan.

UN (2006). *United Nations World Water Development report 2*, http://www.unesco.org/water/wwap/

UNESCO (2006). *Water a shared responsibility*. United Nations World Water Development Report 2 (WWDR 2), UNESCO, Paris.

What is covered by water fees, prices and costs?
Examples of water policies in Turkey

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Abstract. The paper discusses what is understood as water price in Turkey, the components it comprises of, the methods of pricing and the advantages and disadvantages of these methods. The methods used for pricing drinking and irrigation water in Turkey are explained with examples. The structure of financing, construction, operation and maintenance is described. The question is raised whether the price for water should always cover all the costs. International organizations promote full cost recovery, but the paper demonstrates that economic, social and geographic conditions should be taken into account when setting the price. Full cost recovery can severely hinder public access to clean drinking water, specifically for the poor, because the water price may be too high compared to their income. In irrigated agriculture it can lead to the abandonment of irrigation when the water is too expensive compared to the value of the crops produced. Therefore the use of a socio-economical development index is proposed. This index helps in determining what share of the full costs can reasonably be included in the price. In addition the price may include a stimulus for water saving by using tiered pricing: the price increases with the amount of water used.

Keywords: Water – Price fixing – Costs – Turkey

Que couvrent les redevances, les tarifs et les coûts de l'eau? Exemples de pratiques de tarification de l'eau en Turquie

Résumé. *Ce document de réflexion porte sur la notion du tarif de l'eau en Turquie, sur les composants de ce tarif, sur les méthodes de tarification et sur les avantages et inconvénients de ces méthodes. Il décrit l'organisation du financement, de la construction, du fonctionnement et de l'entretien. La question posée est de savoir si le tarif de l'eau doit toujours couvrir tous les coûts. Les organisations internationales recommandent un recouvrement intégral des coûts, mais ce document de réflexion entend démontrer que la tarification doit prendre en compte les conditions économiques, sociales et géographiques. Le recouvrement intégral des coûts peut gravement entraver l'accès à l'eau potable, en particulier pour les plus démunis, si le prix de l'eau est trop élevé par rapport aux revenus. Dans l'agriculture irriguée, il peut entraîner l'abandon de l'irrigation si l'eau devient trop chère en comparaison avec la valeur des récoltes. L'instauration d'un indice de développement socio-économique est par conséquent proposée. Cet indice aide à déterminer la part des coûts réels pouvant être raisonnablement incluse dans le tarif. En outre, le prix peut servir d'outil d'économie de consommation d'eau au moyen d'une différenciation de la tarification : le prix monte au fur et à mesure que la consommation augmente.*

Mots-clés: *Eau – Formation de prix – Coûts – Turquie*

I – Introduction

The value given to water, which is indispensable for life, is demonstrated with the sentence 'Water is life'. In Turkey, a commonly used sentence when receiving a glass of water: 'may you be holy like water', emphasizes the value of water. It is also emphasized in many documents of the United Nations and allied organizations.

Turhan Çakar, in his study called "Access to Clean Water", has summarized the international rights accepted by the UN (Çakar, 2009). Article 3 of the Universal Declaration of Human Rights states: 'Everyone has the right to life, liberty and security of person'. In our view, this also includes the right of access to water. The 1999 United Nations General Assembly Decree (53/175) states 'access to clean water is one of the basic human rights'. Again according to the United Nations, in the Guidelines on Consumers Protection, accepted on April 9, 1985, reference 39/248: 'The governments should constitute and strengthen their national policies to improve drinking water transmission, distribution and quality according to the aims determined for International Drinking Water Transmission and Cleanness for Ten Years'. Alternatives such as proper service, quality, needs for technology and educational programs should be taken into account.'

According to the general declaration of the UN Economical, Social and Cultural Rights Committee in 2002, water right being a social and economical right, covers the right to access of each individual to water that can be demanded from the state directly. The World Health Organization (WHO) also stated that clean water is a health service that must be transmitted to individuals independent of all conditions. Also in international consumer rights access to sufficient and healthy water is referred to as one of the main rights of consumers. It is understood from these regulations that, 'access right to healthy and sufficient water' has a place in human rights concepts which are basic principles to build national legislation on. This right to water infers that the state is responsible for the provision of secure drinking water to the public. The state is obligated to develop policies and strategies to create social and political conditions to realize access to water for everyone.

The importance of water, vital part of human life and ecosystems, increases day by day. Water is one of the basic needs of humankind and is a main resource for agriculture, power production, industry, tourism and transportation. Today, 18% of the agricultural area in the world is irrigated. In these areas more than 40% of total agricultural production is produced (Johansson, 2000; FAO, 2002). Water is the indispensable input for food, fodder and fiber production.

As demonstrated by the two paragraphs above, water is an imortant input as well as a basic right. Although providing healthy drinking water is a service the state is required to supply, the state is not expected to cover all costs for exploitation, purification, transport, distribution and waste water treatment. These aspects are considered a public service and the continuity of the service is valorized by charging for maintenance and management. In this case the charge is called a fee (DSI, General Directorate of State Hydraulic Works,) 1954; Cornish *et al.*, 2004.). However, for agriculture and industry, water is used as an input and is considered a commodity to which a price can be attached. Opportunity costs of water and financing are considered (interest costs of investment and costs for forgone alternative usages of water) and water is commoditized like an automobile or a television.

In this study, conceptual approaches that balance price and costs to valorize water are investigated. The following aspects are elaborated: the concept of water price in Turkey, the components included, the methods of pricing used and the advantages and disadvantages of these methods. Some examples of irrigation water pricing in Turkey are given and some suggestions are developed specifically for Turkey.

II – Conceptual approaches to water value

Worldwide, in the last quarter of 20th century, it has been accepted that water has economical value in addition to its socio-cultural, historical, environmental and religious values. This has been confirmed in the 1992 Dublin (Dinar and Submarinian, 1997; Rogers *et al.,* 1998; Bilen, 2000; Thatte, 2002.). Evaluation of the economic value of water is important not only for determining priorities in allocation to sectors, but also to ensure continuity of water supply investments (drinking, domestic, industrial, and treatment), sustainability of present institutions, protection of water and minimizing effects on environment (Abu-Zeid, 2001). Water price should cover management, operation and maintenance (MOM) costs for the sustainability of the present institutions, investment costs for the continuity of water supply investments and treatment, drainage and environmental costs to eliminate environmental effects. It should be a payable rate and this rate should be determined according to the local social, institutional and political situation (Rogers *et al.,* 1998; Johansson, 2000 and Abu-Zeid, 2001).

Özal (1966) (Korkut Özal, former associate professor at Middle East Technical University , former minister for 'Agriculture and Rural development' and former minister for 'Internal Affairs') emphasized the fact that recovery of irrigation investments by users should be viewed as a requirement to achieve irrigation development objectives. He states that, recovery i) results in fair distribution of investment costs, ii) strongly stimulates the efficient use of the water in the project and iii) provides important finances for the continuation of investments.

Until the last quarter of the last century, water pricing was not applied in undeveloped and developing countries, especially for irrigation water where water is used as an input. The increase in water demand, reduced interest in irrigation investments, low water usage efficiency, profit opportunity by sector share and the pressure applied by credit co-operations in early '90s lead to the requirement to valorize irrigation water (FAO, 1996; Dinar 1997; Rogers *et al.,* 1998. Johansson 2000).

Environmental cost of water pollution and opportunity cost of water should be added into the water price. Costs for water thus consist of three elements: water supply cost, opportunity cost and environmental cost. The addition of these costs is expressed as the sustainability value of water usage (Rogers *et al.,* 1998). Assimacopoulos (2003) studied the implementation of the Water Framework Directive (2000/60/EC; WFD) in his country, Greece. The WFD states that the principle of 'the polluter pays' is required for sustainability and emphasizes that water is a part of the water ecosystem, is a natural source and has socio-economical relevance (Assimacopoulos, 2003) In summary, from the references we infer that many international organizations try to stimulate the use of the principle 'who uses pays- who pollutes pays' in the whole world.

III – Applicability of conceptual approaches

40 years ago opinions on valorizing water were more concerned with social and political issues. Özal (1966) stated that the state's irrigation projects can satisfy one or more of the following objectives:

i) social objectives, such as increased living standards of farmers, settlement of the nomadic population and satisfying the need for agricultural land villagers for villagers,

ii): economic objectives, such as meeting interior and exterior demand, and stabilization and development of agricultural industry,

iii) political objectives, such as stabilization of the population living near the boundaries, social stability and security. Not all costs should be covered by users in projects with social and political objectives, costs of indirect benefits should be met by the ones benefiting indirectly.

Abu-Zeid (2000) also refers to this socio-political dimension: 'cost recovery and payment of MOM costs by users is important for the continuity of the system by providing continuity of water supply investments (and constructing new water supply facilities), sustainability of present ones, protection of water and decreasing environmental effects. The poor users should be supported in a transparent way'.

Dinar and Subramanian (1997), in their study evaluated the experiences with water pricing in 22 different countries. They concluded that, generally, countries perceive the water price as a charge including MOM and renewal costs for the continuation of system and the service. Water users pay from 20% to 75% of total costs depending on the country's social and economical conditions.

Water prices can be determined in different ways: volume-based, depending on real consumed water amount or not based on volume but based on irrigated area, area-product, input or output, or market-based, depending on the income opportunities. The applicability of the methods depends on the physical, social, institutional and political conditions of each location (Johansson, 20002).

Demir, in his study that combines the conceptual approaches above and the cost/expense components of Rogers *et al.* (1998) and Assimacopoulos (2003), states that it would be beneficial to determine the contribution of water users to cost recovery according to a socio-economical development index (Demir, 2005).

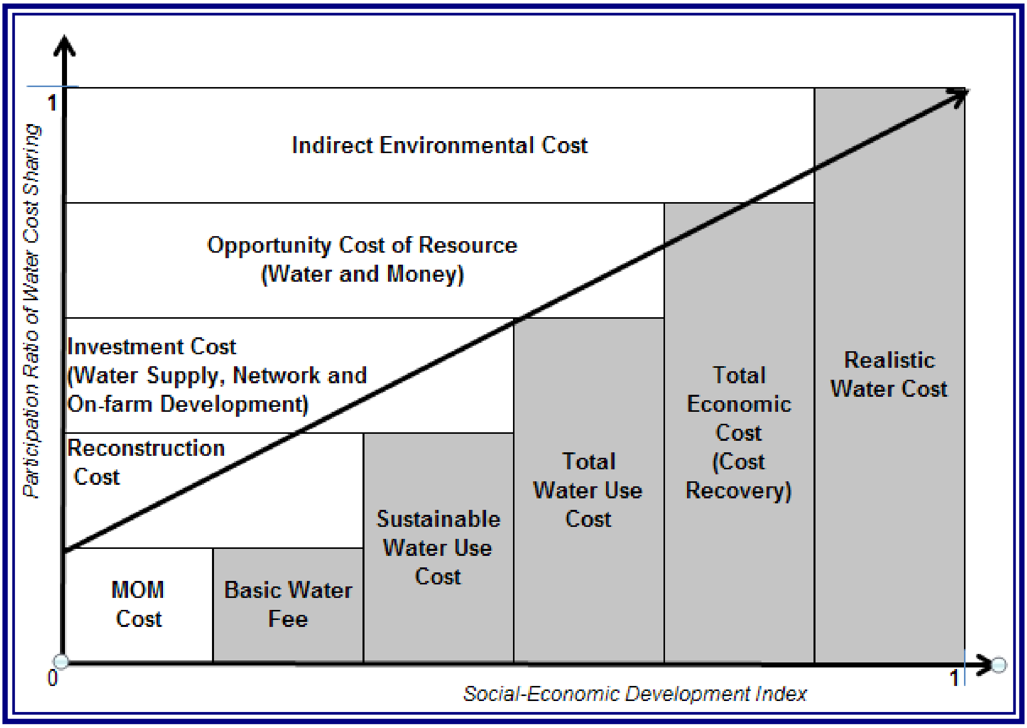

Figure 1: Social-economic development index in water cost composition and level of participation in cost sharing *(modification from Demir, 2005)*

Figure 1 illustrates the five tiers of water valorization that Demir proposes. The basic water fee corresponds with recovery only of MOM (Management, Operation and Maintenance) cost of water system, the sustainable water use fee includes both MOM and reconstruction cost of the network. When these costs are covered, the water system will serve for a long period. If investment costs are included into water fees, total water use fee is reached. A portion of financial need for the sustainability of water supply investments can be met by recovery of operational water system investments. If opportunity costs for money and water are added to the water fee, total economic water fee is reached. This is applied in California, USA. The real water fee is reached after indirect environmental costs are added total economic water cost. The participation ratio of water cost sharing indicates what portion of the real water fee is covered in the actual water price. The socio-economic development index is a measure of the standard of living. With a higher socio economic development index a higher participation ratio can be required.

Two extreme examples are discussed to explain Demir's suggestion more clearly, in the irrigated agriculture sector that is now using 75% of controlled water. The first case is the Van-Özalp-Dönerdere irrigation system on a high plateau at 2200 m. The annual total temperature is 2200 oC. An arid and cold climate is present. Dönerdere is a region at the border with Iran that was resettled because of the1967 flood in the Black Sea region (15). The second case is an irrigation system with the same irrigated area and comparable properties which is in Dönerdere. The Antalya- Kumluca irrigation system is situated at 100-200 meters and has an annual total temperature of 5000 oC.

In Dönerdere, at most three types of clovers or 1.5-2.0 ton/ha wheat or corn can be produced. The product is mostly used for domestic needs and for feeding animals. There is no product processing organization. It is far away from big markets. The level of education is low. Public services are insufficient and access to these services is inadequate. The private sector shows no interest in the area. Therefore the socio-economic development index is low. In contrast, in Antalya Kumluca flowers are grown in greenhouses for the market and two or three types of vegetables and fruits are grown on open ground. Public services are sufficient, access of people to these services are well developed. Marketing and product processing opportunities are high and big markets are near. The education level is high. The private sector has an intense interest in the area. So the socio-economic development index is high.

Even if in both irrigation systems, investment costs were the same (Dönerdere irrigation development cost is higher because of the limited construction period); the benefits of irrigation are not the same because of the ecological, social, economical and technical reasons mentioned above. Gross production values per unit of water that we calculated using State Hydraulic Works General Directorate (DSI) irrigation monitoring data, (DSI, 2005) are presented in the figure below (Figure 2).

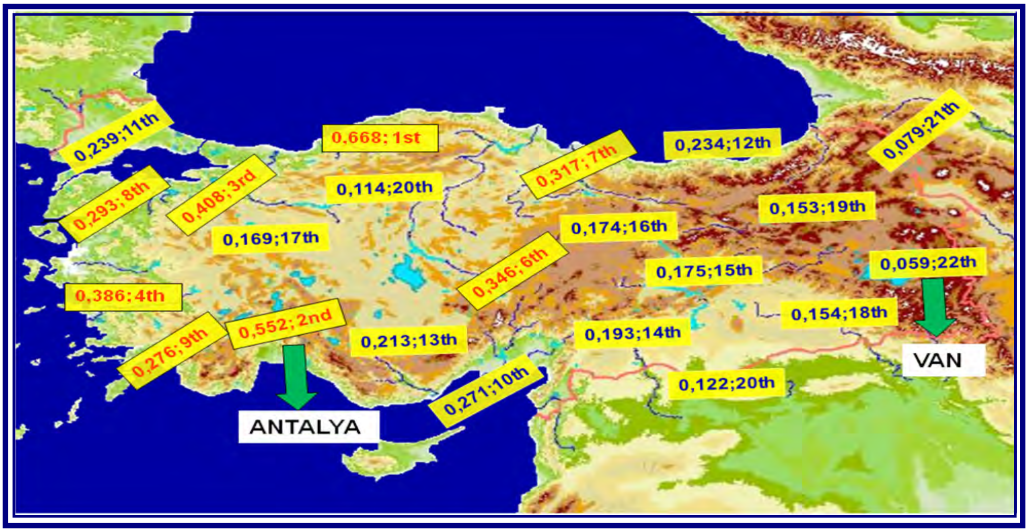

Figure 2: Gross production values in Turkey irrigation (WUE €/m3) for year 2004 and order in the country.

The gross production value of water, also referred to as water usage efficiency, is 0.06 £/m3 in Van region, whereas it reaches 0.55 £/m3, so up to 9 times as much in Antalya region. The expenses are the same in both cases, but in Dönerdere irrigated production can not even cover the basic water fee. However, in Kumluca irrigation reconstructions can be made and cost recovery of public investments is possible. Since farmers' payment power differ from one another, the willingness to pay for water also varies. The farmers in Kumluca earn a lot more than the farmers in Özalp from the same acreage.

Periodically, an 'Investigation on Socio-economical Development Rank of Districts' study of the State Planning Organization (DPT) is prepared considering income, education, health, availability of public services and transportation, etc. In 1996, Özalp district was rated 831th out of 858 districts and Kumluca was rated 272 (DPT, 1997). In seven years, while the number of districts increased from 858 to 872, the rating of Özalp decreased to 865 and Kumluca has risen to 250th place (DPT, 2004).

The two examples above expose the disadvantages of cost based water pricing. Pricing mechanisms should therefore consider social, cultural and ecological conditions. In addition, Dönerdere irrigation system serves political objectives, such as border security and social objectives such as avoiding migration from the area. Economic commitments based on social and political objectives must be paid for by the government.

IV – Water pricing in Turkey

Supplying and pricing drinking water

In Turkey, the institutions responsible for supply, operation and maintenance, and management of drinking water vary according to the size of settlement units. For villages with a population below 2,000 people, drinking water supply is the responsibility of Special City Management and investment costs are covered by the state. Drinking water management is carried out by the chief of the village. Water is priced on the basis of costs for maintenance and power supply, without profit. If water is transported through a network, the pricing is based on volume. If no network exists and villagers use water from a communal source, the costs are divided according to the number of people the source provides water for.

For districts and cities with a population of less than 100,000 inhabitants, water is supplied by İller Bankası on behalf of the municipalities in these settlements. MOM and renewal works are carried out by municipalities. Investments and other expenses are paid by water users. In this case, profit can be considered.

DSI is responsible for water supply to settlements with a population greater than 100,000 inhabitants. MOM and renewal works are carried out by the municipalities. Investments and other expenses are paid by water users. Profit can be considered too, in this case.

Settlements with a population greater than 1,000,000 inhabitants are called metropolitans. In metropolitans public organizations are established as General Directorates to carry out water and wastewater services. In these settlements water is supplied by State Hydraulic Works (DSI). All expenses are paid by the users. According to metropolitan water management law, this service should have a least a 10% profit margin. Metropolitan water managements apply this law and had on average a 29% profit. Profit ratio has reached up to 285% in Samsun Metropolitan Municipality and this service has become a source of income there (Tamer, 2006). This ratio must decrease.

If the municipality has the economical and technical capabilities, it can supply water without applying to DSI or İller Bankası. In addition to this, if the settlement has a sanitary system, additional payments are included up to 50% of water price.

In municipal regions, volume based tiered pricing is used to encourage economical usage of water. Usually, tiers in monthly water consumptions are 0-10 m^3/month, 11-20 m^3/month and more than 20 m^3/month.

In none of the municipalities pricing is done according to people's incomes. The ratio of monthly water expenses to the income of poor families is much higher than this ratio for rich families. For this reason, access to healthy water for poor people is restricted.

As most of the municipalities do not apply enough sanitation and purification is not of high quality, consumers use bottled spring water as drinking water at a considerable expense.

Supplying and pricing irrigation water

For irrigation systems that use groundwater, the constructing of wells, the installation of motor pumps and electrification works are carried out by DSI. These costs have to be paid back in 15 years, but in the first 3 years they are not charged (Türker and Kaya; 2000). Other infrastructural investments for irrigation (constructing the irrigation and drainage network, constructing field roads, leveling) are done by Provincial Private Management and are free. MOM activities in the irrigation systems are done by irrigation cooperatives, formed by water consumers. Pricing is determined according to the amount of hours of operation of the well, or product irrigation number (the number refers to how many times that crop is irrigated) and an annual payback per unit area for the investment is added to this amount.

Provincial Private Management is responsible for the construction of irrigation systems that make use of surface water, and have a discharge of less than 500 l/sec and a dam crest level lower than 15m. Investment costs are covered by the state. MOM activities are carried out by the village chiefs or Village Servicing Unions present in districts. Water consumers only pay a water fee for MOM activities and pricing is done based on product per area.

DSI is responsible for the construction of large irrigation systems that make use of surface water and have a discharge greater than 500 l/sec and have a dam crest level higher than 15m. The cost of the investment is divided equally between the water consumers and paid without interest in 20-30 years after the completion of the irrigation system, depending on the decree of Cabinet. Most of DSI irrigation systems are transferred to irrigation unions. MOM activities are carried out by these irrigation unions. Pricing of water is based on the irrigated area and the product produced. In areas with water scarcity such as in Aegean Region irrigation unions determine the water price according to irrigation water amount used. When irrigation exceeds the determined amount of water the price increases.

Irrigation systems not transferred to irrigation unions are managed by DSİ and irrigational water pricing is done according to the properties of irrigation (pumping, gravity), geographical location (coastal and interior parts and East Anatolia) and irrigation method. DSI’s pricing policy is closer to the socio-economical development index Demir suggests. Payments to DSI for irrigation are transferred to the National Treasury (Demir, 2005).

Especially for irrigation system that use pumps, individual water users and irrigation unions can be in debt because of high power costs. Because of these debts, irrigation unions may postpone operation and maintenance services.

V – Financial sources for developing water resources in Turkey

National Financing

Funds for drinking water supply to villages and smaller settlements are allocated from the national budget. Between 2005 and 2008, the Village Support Project (KÖYDES), has supplied more than 90% of the villages with healthy drinking water and has constructed village roads. As part of the same project, studies on waste water have also been started. Peasants only pay for MOM costs. Rural infrastructure investments are made by the government. The villagers can not pay these charges that are made to keep the population in rural areas.

Financing is provided by the sources of Iller Bankası (the bank founded for development of infrastructure in urban areas of Turkey) from the national budget for settlements having municipalities. Each municipality gets a share from İller Bankası according to its population. Iller Bankası gives loans for water supply projects requiring large investments, supplementing municipal funds. Municipalities collect all water fees, except for opportunity cost.

Metropolitans can use externally sourced, treasury warranted loans for large scale water supply and distribution projects. European Union Initial Participation Aid (IPA) donations can be used for improving water services. Metropolitan Municipalities collect the realistic water fees with a profit margin.

Financing by Privilege-Privatization and Built-Operate-Transfer

In the past some privileges were given or privatization to multinational companies for drinking water supply, network construction and servicing, took place. In 1880s 3 French companies were given privileges for water service management in Istanbul. These privileges were ended in 1938. In the year 1995, irrigation services in Antalya Metropolitan area were privatized and granted to a French company in compensation for a 100 million $ loan, to have 100% of the system later on. As they have raised water prices in an unacceptable way and have not fulfilled the commitment of developing infrastructure for water services, the contract was cancelled after 5 years. The international court case concerning this issue still continues. Yuvacık Dam, that would supply water to Istanbul, but could not be finished, was given to a Turkish-English partnered company, under warranty of the treasury, in order to complete the construction and subsequently for operation. However, an insufficient amount of water was stored in the reservoir, so unit-cost exceeded 1.5 $\$/m^3$. Istanbul Municipality refused to buy such expensive water. The National Treasury pays the related companies every year because of the warranty (Güler, 2006).

For power production, privileges are given to Turkish companies to construct dams and hydro-electric power plants. Yet, no Built-Operate-Transfer model exists in our country for drinking water supply and irrigation construction projects. Especially for irrigation constructions, this kind of methods is sought. For power production, a consortium formed by four companies, one of which is a Turkish partner, is commissioned to construct and operate Birecik Dam, located on the Euphrates river, for 20 years.

VI – Conclusions

Turkey has not got specific policy on water investments and pricing. In particular the lack of a policy of water pricing has led to a lot of problems. Poor people in cities and rural small farm owners have to pay the same fee as others. This causes economic hardship. These people must be supported in a transparent manner such as using the socio-economic development index. The water investments in Turkey are funded by the central budget and the recovery of cost from investments go directly to the central budget. There is not any special fund for water investments. Therefore, some administrations attribute great importance to water investments whereas others may not care about water investments at all.

VII – Recommendations

1. Water is a human right and should be seen as a public service.
2. Common properties of 'public services', such as electricity, natural gas, pipelines, railways, telecommunication, postal services, water, irrigation and wastewater, have a concentrated capital, have high sunk cost, have multiple effects on the economy by being inputs to many other areas and need to be used by the consumers for common wealth. It should never be forgotten that components of these have natural monopoly properties when their scales and conceptual costs are considered (Suiçmez, 2006).
3. As profit can not be sought in these services, the privatization and/or giving privileges to international companies can never be considered.

4. Non-governmental organizations comprising end users should share the management and responsibility in all stages starting from the development of water resources. In this way expensive investments as seen in public services may be eliminated and water can be cheaper.
5. It should be remembered that the quality of water services is measured by its sustainable and economical accessibility and by sufficient quantity and quality.
6. Water is a requirement for food security. It is compulsory to increase agricultural productivity to provide food security and sustainable development in agriculture in parallel with population increase. The very first way of increasing production and productivity is using new technologies in agriculture and increasing irrigated areas.
7. Realistic pricing should be sustained in water services to develop new water resources, to use water rationally and to protect environment. Savings should be rewarded in addition to the principle of 'who uses pays and who pollutes pays'.
8. Socio-economical development indices should be considered when pricing water and people that have difficulties paying should be subsidized using transparent principles.

References

Abu-Zeid M. (2001). Water Pricing in Irrigated Agriculture. *Water Resources Development*, Vol.17 No:4 http://ınweb18.worldbank-zeid.pdf

Assimacopoulos D. (2003). Recovery of Full Cost and Pricing of Water in the Water Framework Directive. http://www.environ.chemeng.ntua.gr/wsm/Uploads /Publications/ Recovery

Bilen Ö. (2000). *Turkey &Water Issues in the Middle East.* 2 nd Edition, GAP-RDA, 257 pp., Ankara.

Çakar T. (2009). Temiz Suya Erişim Hakkı. http://www.tuketicihaklari.org.tr .

Cornish G., Bosworth B., Perry C., Burke J. (2004). FAO Water Reports 28: Water charging in irrigated agriculture. Rome,

Demir H. (2005). Farklı İşletme Büyüklüklerinde Optimum Bitki Deseni ile Çiftçilerin Sulama Yatırımı ve Su Ücreti Ödeme Gücünün Belirlenmesi A.Ü. Fen Bilimleri Enstitüsü Doktora Tezi (basılmamış-Türkçe)

Demir H., Gündoğdu Ş., Aydoğdu F. (2000). Van-Özalp-Dorutay Köyken projesinin Değerlendirilmesi. Rapor. GAP-RDA, Şanlıurfa (basılmamış-Türkçe)

DPT (1997). İllerin Sosyo-Ekonomik Gelişmişlik Sıralaması Araştırması. 1996 http://ekutup.dpt.gov.tr/bolgesel/dincerb/il/15.pdf

DPT (2004). İlçelerin Sosyo-Ekonomik Gelişmişlik Sıralaması Araştırması. 2003 http://ekutup.dpt.gov.tr/bolgesel/gosterge/2004/ilce.pdf

DSI (2005). 2004 Yılı Mahsul Sayım Sonuçları, Ankara.

DSI (1954). Devlet Su İşlerinin 6200 sayılı Kuruluş Kanunu. http://www.dsi.gov.tr/duyuru/mevzuat/kanun/6200kanun.pdf (Law no: 6200 for establishment of State Hydraulic Works)

Dinar A., Subramanian A. (1997). 'Water Pricing Experiences: An International Perspective'. World Bank Technical Paper No: 386, 161p., Washington D.C.

FAO (1996). Guidelines for Planning Irrigation and Drainage Investment Projects. FAO, Investment Centre Technical Paper Series No:11, 24 p., http://www.fao.org/tc/tci/sectors/sec11txt.httm

FAO (2002). The salt of the Earth: Hazardous for Food Production. http://www.fao.org/worldfoodsummit/english/newsroom/focus/focus1.htm

Güler B.A. (2006). TMMOB Su Politikaları Kongresi: Çağrılı Konuşmacılar http://www.e-kutuphane.imo.org.tr/pdf/9081.pdf

Johansson R.C. (2000). Pricing Irrigation Water: A Literature Survey. World Bank, Policy Research Working Paper: 2449, 82p. Washington D.C.

Özal K. (1966). Sulama Projelerinde Geri Ödeme Problemi. ODTÜ, Teknik Yayınlar Serisi:19. Güneş Matbaacılık, 26 p., Ankara .

Rogers P., Bhatia R., Huber A. (1998). Water as a Social and Economic Good: How to Put the Principle into Practice. Global Water Partnership, 35p., Stockholm, Sweden.

Suiçmez B.R. (2006). TMMOB Su Politikaları Kongresi: Çağrılı Konuşmacılar http://www.e-kutuphane.imo.org.tr/pdf/9081.pdf

Tamer N.G. (2006). Dünyada ve Türkiye'de Su Hizmetleri Yönetim Politikalarının Değerlendirilmesi, TMMOB Su Politikaları Kongresi, http://www.e-kutuphane.imo.org.tr

Thatte C.D. (2002). Water and Food Security-How the Poor Will get Their Food. *Water Resources Management: Crosscutting Issues*, 3-34pp.

Türker M., Kaya A. (2000). Türkiye'de Yeraltısuyu Sulama Kooperatiflerinin Kuruluşu, Yatırım ve Devir İşlemleri, DSİ, Ankara.

Water pricing issues in countries with water deficit

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Abstract. In the Mediterranean countries water management is not only a matter of setting the price of water, but also of securing the availability of water. In Cyprus, water supply is based on rainfall that is becoming less and less with time. Water pricing should take into account covering the primary costs for the acquisition of water such as the cost of the distribution networks, running costs for pumps, and the intended use of the water (agriculture, industry, tourism, households and so on). Households have the right to be supplied with water of good quality at reasonably low prices. Water used for industry and other economic activities should be priced at its real cost, increased by an "availability factor" that takes into account the available water reserves of the country. A good water policy should promote issues such as: saving water in all sectors of economy and preventing irrational water use (through proper water pricing schemes, etc.); minimizing distribution network losses; safeguarding the quality of water reserves (during water production, distribution, storage, water treatment and reuse). All water resources in a country should be considered as a national resource and should be controlled by a single entity to achieve good coordination and management. This paper deals with a simplified method for water pricing, in cases of water scarcity as encountered in the Mediterranean countries.

Keywords. Water – Price policies – Water availability.

Prix de l'eau dans les pays exposés à la pénurie d'eau

Résumé. *La gestion de l'eau dans les pays méditerranéens ne se résume pas uniquement à la fixation de son prix, mais doit aussi assurer la disponibilité de l'eau. À Chypre, l'approvisionnement en eau est basé sur les précipitations qui diminuent progressivement. Le prix de l'eau doit tenir compte de la couverture des coûts primaires pour son acquisition, du coût des réseaux de distribution, des frais de fonctionnement des pompes et de l'utilisation prévue de l'eau (pour l'agriculture, l'industrie, le tourisme, la consommation des ménages, etc.). Les ménages ont tous le droit d'avoir accès à l'eau de bonne qualité, à des prix relativement bas. L'eau utilisée pour les secteurs industriels et les autres activités économiques devrait être évaluée à son coût réel, majoré d'un « facteur de disponibilité » qui prend en compte les réserves d'eau disponibles dans le pays. Une bonne politique de l'eau doit promouvoir les questions concernant les économies de l'eau dans tous les secteurs d'activités et la lutte contre le gaspillage inutile de l'eau (à travers l'application de tarifications adéquates) ; elle doit veiller à minimiser les pertes du réseau de distribution de l'eau, à protéger la qualité des réserves d'eau (tout au long de la production, de la distribution, du stockage, du traitement de l'eau et de sa réutilisation). Toutes les ressources en eau dans un pays doivent être considérées comme des ressources nationales et doivent être contrôlées par une entité unique pour assurer une bonne coordination et une bonne gestion. L'article présente une méthode simplifiée pour le prix de l'eau, en cas de pénurie d'eau, souvent constatée dans les pays méditerranéens.*

Mots-clés. *Eau – Fixation des prix – Eau disponible.*

I – Introduction

In Cyprus, water supply is based on rainfall that is becoming less and less with time. In 2008, due to a prolonged draught, there was no water available for agriculture! Climate changes negatively affect the Mediterranean basin in terms of temperature increase and rainfall decrease. Water policy is no longer only concerned with water collection, purification, distribution, quality control and safeguarding, waste treatment and reuse and so on. Since the water balance in countries like Cyprus depends on rainfall, water policies have to deal with the resulting water scarcity that leads to a water budget deficit of the national water reserves. Water policies have to provide good resource management so that the limited available water is properly distributed among the economic sectors of the country. Decisions have to take into account the priorities and the importance of each sector in the national economy.

Good water policies should incorporate issues such as:

- saving water in all sectors of economy and preventing irrational water use (through proper water pricing schemes, etc.);
- minimizing distribution network losses;
- safeguarding the quality of water reserves (during water production, distribution, storage, water treatment and reuse)
- protecting aquifers from pollution or sea water intrusion
- safeguarding uninterrupted water supply to the consumers by exploiting technological means in finding new water resources (desalination plants, etc.) and
- proper allocation of limited water resources to the different sectors (industry, agriculture, households, tourism, landscaping, etc.), in case of severe water shortage.

The “value” and importance of each sector is different from country to country according to its economical structure. The best situation, under these circumstances, would be that all water resources in a country are considered as a national resource and thus controlled by a single entity so that good coordination and management is achieved. In Cyprus, an effort is made to position water management under the authority of a “Commission for Integrated Water Management”, a part of the Water Development Department of the Ministry of Agriculture, Natural Resources and Environment of the Cyprus Republic.

For the design and implementation of a good water pricing policy, it is essential that certain statistical data are available regarding the water consuming habits of water users (Environment Canada, 2007; Organization for Economic Co-operation and Development, 1999; Tate and Lacelle, 1995). A good overview of all necessary data to be collected for water charging in irrigated agriculture, is given in the FAO Water Report 28, 2004. The existing European legislation, the Water Framework Directive (2000/60/EC), establishes a framework for sustainable water management and protection of the water resources. The prevention of further deterioration of all water resources and the achievement of a good water status in Europe by the end of 2015 is considered to be the main purpose of this Directive.

A simplified water balance model is shown in Figure 1. Rain and sea water are the primary water resources for Cyprus. Rain water is collected behind dams and contributes to the aquifer recharge, the provision of drinking water and to irrigation. Sea water is desalinated to produce drinking water. Its high cost does not allow its use in agriculture. Treated waste water is an emerging water source for irrigation purposes. In crisis situations, as was the case in Cyprus in 2008, water cut-offs have to be made, so that drinking water can be supplied to the consumers and the most important economic activities, such as tourism, are kept alive.

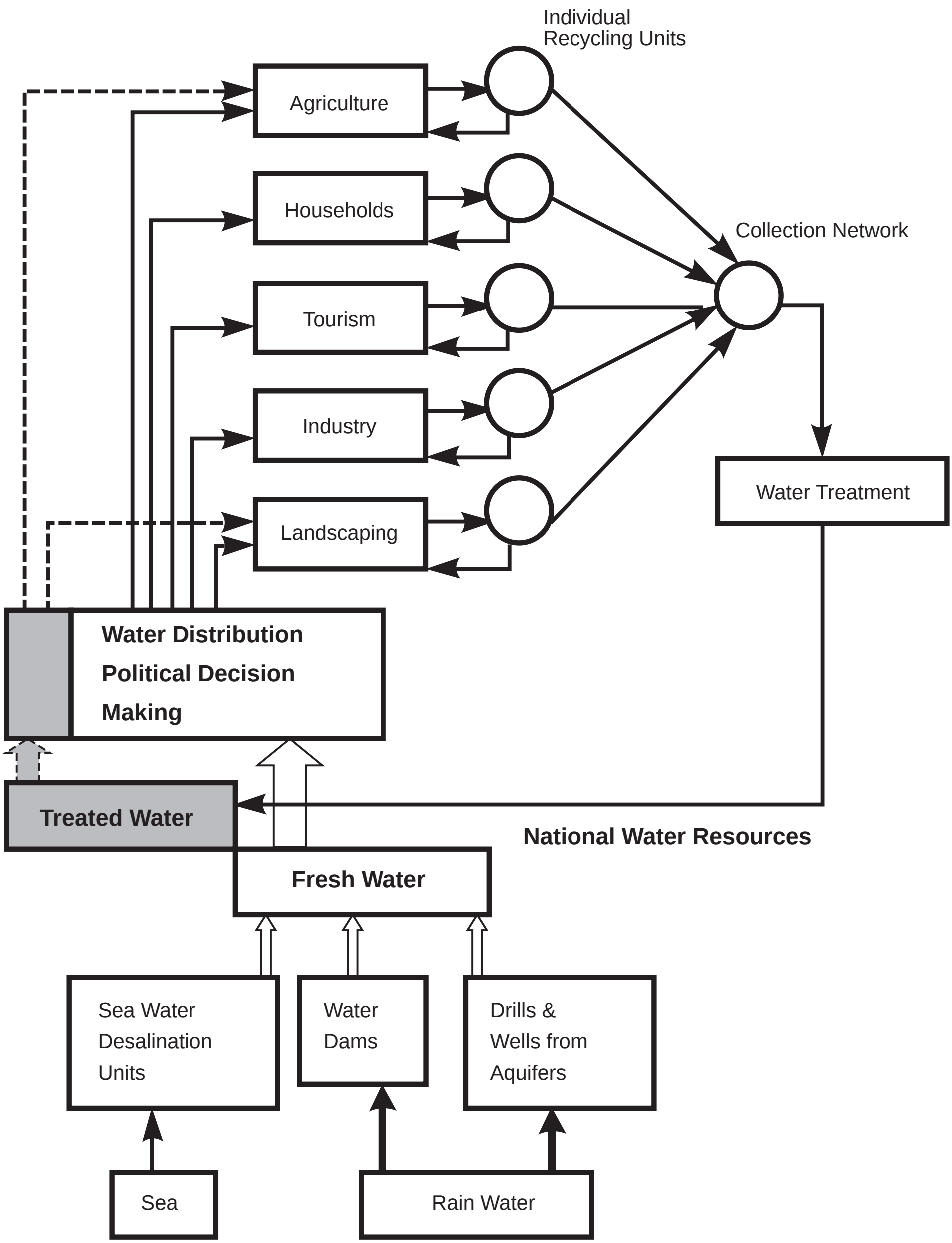

Figure 1: Simplified Analysis Model of National Water Resources for water distribution policy making.

A series of simulation models have been suggested worldwide, as useful policy making tools, trying to forecast the behavior of water consumers in relation to the water price levels and to evaluate the effect of different policies on water saving. Non-volumetric methods and a great variety of volumetric charges and pricing methods based on tradable water rights could be applied (Cornish *et al.*, 2004) even among territories within a country itself (Markantonis *et al.*, 2004).

A simple dynamic model showing the influence of changing water prices within a year, according to the available water resources allocated to households, was examined in the present work.

II – Methods

1. Software tools used

In order to describe the behavior of the influence on water consumption of decreasing water reserves during the year, in combination with water pricing policy, a model was designed and applied using SIMULINK©, a control package of MATLAB©, version 7.6.0 (R2008a).

2. Model structure and design

The model simulates the behaviour of a model household that is assumed to follow a typical consumer behaviour, within a model of national action to adjust the price of water continuously according to the available water reserves. The water reserves are limited and decrease with time as water consumption proceeds.

3. Model parameters and boundary conditions

The model uses measured or simulated data. It considers a basic water consumption of 150 liters per person per day that is provided by the water supply authorities at a base price (€ 0.90/ m^3), covering all primary water costs. Consumption exceeding this amount is charged more to motivate the reduction of irrational water use. For the simulation, a population of 800,000 people was assumed and the initial available water reserves were assumed to be 90 million cubic meters.

An estimated daily water consumption per person without any price-related measures to limit consumption, other than those usually applied by water providing authorities (i.e. simple volumetric charges), C_{wn}, was considered to be as shown in Figure 2.

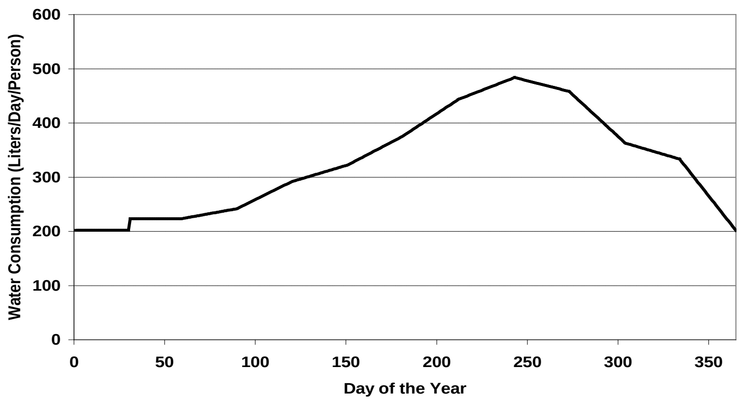

Figure 2: Estimated daily water consumption per person without any price-related measures limiting consumption, other than those usually applied by water providing authorities (i.e. simple volumetric charges).

The influence of water price, P_w, on water consumption, C_w, is shown by the Price Related Consumption Index, I_{pv}, shown in Figure 3, for the elastic case. The relation is given by the equation:

$C_w = I_{pv} \times C_{wn}$ (1)

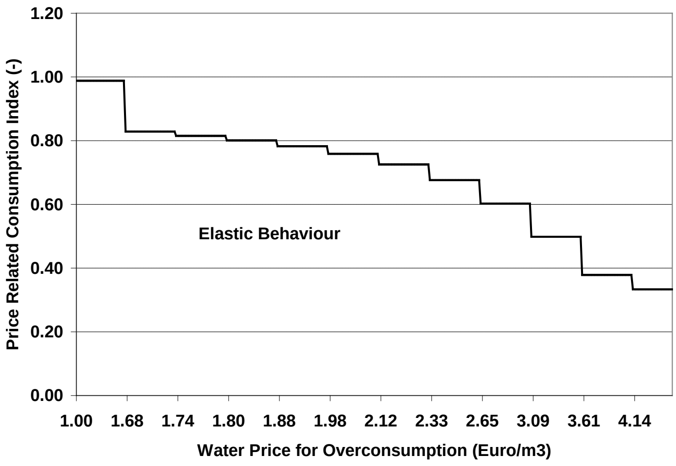

Figure 3: Estimated variation of Price Related Consumption Index according to the cost of water for the elastic case of influencing water consumption.

Water pricing should take into account the recovery of primary costs for the acquisition of water and the amortization of the whole system (e.g. desalination, filtering, purification, cost of the distribution network, running costs for pumps, etc.) and the intended use of the water (used for agricultural purposes, industry, tourism, households, etc.).

Households have a right to be supplied with water of good quality at reasonably low prices. Water used for industry and other economic activities should be priced at its real cost, increased by an "availability factor" that takes into account the available water reserves of the country. Water is in this case considered to be a primary material for the production of goods and the extra costs would be eventually transferred to the end product.

Water should be properly valued so that consumers avoid irrational use and make a conscious effort to save water. Water pricing policy may want to take into account certain social aspects, for instance the buying power of the people, the number of persons in the family, whether a household consists of pensioners. The water price should also take into account the water availability in the time period in question. The scarcer the water becomes, the more expensive it is, as an incentive to reduce consumption. The availability of water is changing with time within the year and is affected in a loop by the effectiveness of the water saving measures taken by the Water Authority.

The Water Availability Index is defined as $f_1 = A_w/(A_w - W_c)$ (2)

A_w, is the Available National Water Reserves at the beginning of the year (MCM),

W_c, is the cumulative Water Consumption during the year (MCM)

f_1, takes into account the availability of the water to be supplied to the households in the time period in question. The Available National Water Reserves at the beginning of the Year comprise of the water quantities stored behind the dams, allocated for drinking water, the water quantities pumped from wells and the desalinated water.

The effect of the number of people in the family N_p, on water price, is considered by the index

$f_2 = 1$ for household members $N_p < 5$ and $f_2 = -0.05xN_p+1$ for $N_p>5$ (3)

The social policy of most countries is to support large families so as to counter lowering birth rates. The function of f_2 for multi-person families can be adjusted by policy makers according to the family relief measures they want to apply. The measures should be such that social policies are promoted, but motivation for water saving remains.

The support of pensioners and low income families is given by the Household Status Index, f_3. The respective values given in Table 1, can be varied according to the aims of the policy makers.

Table 1: Variation of the Household status index, according to the household social situation.

Household status Index , f_3		
Pensioners	**Low Income**	**Normal**
0.5	0.2	1

In an attempt to reduce the inequality of water prices among the European countries, the purchasing power of the people is taken into account. This is done, by considering the National Per Capita Volume Index of the country, compared to the average European Index that is set to the value EU27=100 (Svennebye, 2008).

The Gross National Product Per Capita Index, f_4, is calculated as the ratio of the National Per Capita Volume Index of the country divided by the mean European value that is set to 100. The per capita volume index represents the real volume of Gross Domestic Product (GDP) in per capita terms. “Real volumes” means that the figures have been adjusted for price level differences across countries, using purchasing power parities. They are expressed in relation to the European Union average (EU27=100). When the per capita GDP index of a certain country is higher than 100, that signifies that the GDP per capita of that country is higher than that of the EU27 as a whole. Cyprus with a GDP per capita index of 91 (2007), stands about 10% below the average.

$$f_4 = \frac{\text{National Per Capita Volume Index}}{100}$$

It is evident from the above that the structure of the households, their income and social status should be known so as to adjust water pricing according to the individual conditions. This requires good cooperation among governmental departments that posses this information. These departments will, however, have to take into consideration the laws for the protection of personal data.

Regarding the consumption in households, a basic water volume should be allowed according to the number of persons in the family that is priced at a lower rate. In case that the water consumption exceeds this volume, a penalty price is to be charged for the extra consumption.

The calculated water price, P, in €/m^3 that the household consumer has to pay for the water consumption over the basic consumption, P_{wB}, of 150 liters/day/person is then calculated by the following equation:

$$P=P_{wB} \times (1 + f_1 \times f_2 \times f_3) \times f_4 \quad (5)$$

The basic water consumption is priced at 0.9 €/m^3.

III – Results and discussion

In order to take into account all the parameters involved, it is necessary to define some indices, as explained above, that quantify their influence. The process for the evaluation of the water price to household consumers, using the simple water pricing model, is explained by means of the following example:

The base water price (Euro/m^3), (production, distribution, running costs, etc.), is P_{wB}= 0.9.

The available national water reserves in the year (million cubic meters: MCM), A_w = 90 (53 MCM from desalination plants, 30 MCM from dams and 7 MCM from wells).

Yearly water requirements (in MCM), Y_w = 96 (Usual water consumption without the suggested corrective measures). This means that the available water, in the example, is less than the yearly required amount.

For this case the variation of the Water Availability Index, f_1, during the year, is shown in Figure 4. Index f_1 increases with time, as the available national water reserves are exhausted.

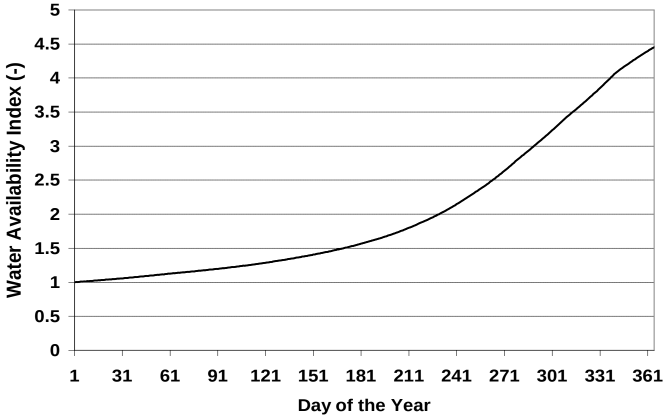

Figure 4: Variation of the Water Availability Index, f1, during the year.

The variation of the Water Price that a household with a normal income has to pay according to the number of persons in the family, for a National per Capita Volume Index of 91 units is shown for the above example in the Figure 5.

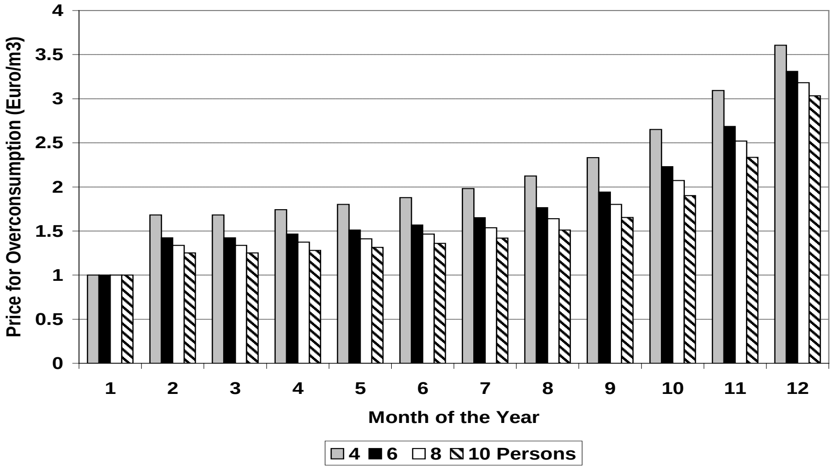

Figure 5: Variation of the water price a household with a normal income has to pay, according to the number of persons in the family, for a National per Capita Volume Index of 91 units.

The influence of the corrective measures, offered by the indices used, on water consumption in a household comprising of 4 persons and a normal income is shown in Figure 6, compared to the case that no measures are taken. Two consumer behaviour situations are compared: the elastic and inelastic relation between water consumption and water price. The consumption shown is the over consumption above the 150 litres per person per day that is considered as basic water consumption.

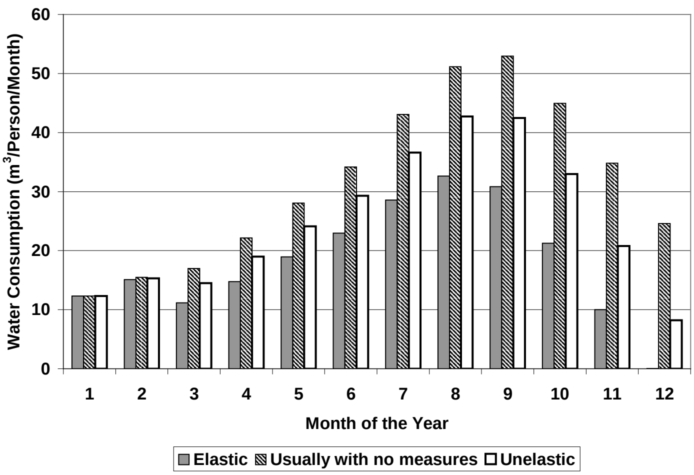

Figure 6: Variation of water consumption during the year, for a household with 4 persons and a normal income, for a National per Capita Volume Index of 91 units and an elastic and inelastic behaviour.

The variation of the price of the consumed water above base volume (over consumption), is shown in Figure 7 for the elastic and inelastic consumer behaviour. As the national water reserves are exhausted with time, the water price increases. The price charged in water bills is adjusted each month.

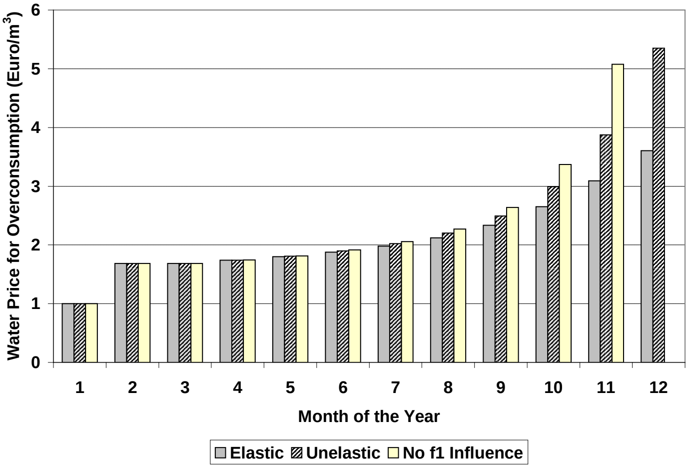

Figure 7: Variation of the price of the consumed water above base volume, for a 4 person-household with normal income, for the elastic and inelastic consumer behaviour, with time.

The cumulative estimated water consumption in households when pricing measures are applied, compared to the base consumption (150 liters/person/day) and the existing situation without the suggested measures, is shown in Figure 8. The objective of the pricing measures is to stimulate households to save water and adjust the consumption. In this way the national water resources, existing at the beginning of the year, satisfy the water demand up to the end of the year. This objective is fulfilled.

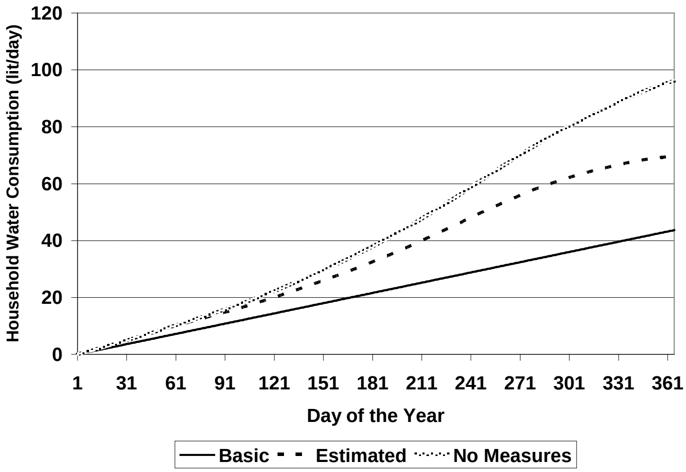

Figure 8: Different cumulative estimated water consumption patterns in households, the base consumption (based on 150 liters/person/day), the estimates based on the pricing model and the existing situation without the suggested measures, with time.

Similar considerations, with modified indices, could be followed for the pricing of the water supplied to industries or agriculture. In this case the local evapotranspiration, the crop type, the cultivated area, the farmer status (fulltime/ part-time), etc. should be taken into account.

IV – Conclusions

Water pricing is of huge importance for countries experiencing water shortage situations, since it represents a useful tool for water management policy to control consumption in crisis conditions. The modelling exercise demonstrates that water pricing can be a valuable policy instrument in stimulating households to reduce their water consumption.

Political, economic, social, environmental and other factors should be considered so as to match available water resources with demand and at the same time to keep economic activities going and minimize dissatisfaction by the public.

The water management authorities should keep records of the water demand and supply behaviour of the “market”. Statistical data are very useful for long term planning of water policy. They give a measure of the elasticity of water demand to water pricing, so that better and more accurate models can be designed as a tool for handling water crisis situations. The data have to be regularly updated, since the situation in households and other water consumer groups (e.g. agriculture), changes year by year (i.e. number of persons in a household, income situation, cultivated land in agricultural units, crop type, etc.). The way consumers react to price changes is very important in policy making on water saving, i.e. elastic or inelastic behaviour. This could be influenced by educating and informing people adequately. This is a factor to be considered by the water providing authorities.

References

Cornish G., Bosworth B., Burke J. (2004). *Water charging in irrigated agriculture*. FAO Water Report 28, Rome.

Environment Canada (2007). *Municipal Water Use: 2004 Statistics*. Ottawa.

Markantonis V., Getimis P., Zikos D. (2004). *Current status of water sector liberalization in Cyprus. Report of FP5 programme key Action “Sustainable Management and Quality of Water”* (EVKI-CT-2002_00115).

OECD (1999). *The Price of Water: Trends in OECD Countries.* Paris: OECD.

Svennebye L. (2008). *GDP per capita, consumption per capita and comparative price levels in Europe. Economy and finance.* Eurostat Statistics in focus 112/2008.

Tate D.M., Lacelle D.M. (1995). Municipal Water Rates in Canada: Current Practices and Prices, 1991. *Social Science Series* No. 30. Ottawa.

Benchmarking exercise using Data Envelopment Analysis
An application to irrigation water pricing

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Abstract. Water management is subject to conflicting economic and environmental objectives and policy makers require a clear overview of the various outcomes of different water management options. In the present paper we propose a non-parametric benchmarking technique based on Data Envelopment Analysis (DEA), specifically developed to assess the relative efficiency of alternative water pricing policies. The result of the analysis is a ranking of pricing policies, aimed at supporting decision making process. An empirical study case was carried out in Southern of Italy (Apulia region), where irrigation is an important factor of strategic relevance for policy makers. Six different pricing methods were compared. According to the findings, the alternative pricing policies perform similarly in terms of technical efficiency. However, the results show that the alternatives rank differently for the technical efficiency and the ecological efficiency indicator. The ecological efficiency shows up to 10% of inefficiency. We conclude that efficiency may be a convenient method for ranking policy hypotheses in the case of absence of information on stated preferences on some outcomes, as well as some negative environmental impacts.

Key words: Linear programming – Efficiency – Water – Price policies – Irrigation.

Etude comparative par méthode d'enveloppe des données: une application à la tarification de l'eau d'irrigation

Résumé. *La gestion de l'eau répond à des objectifs économiques et environnementaux contradictoires et les décideurs ont besoin d'une vue générale claire des résultats des différentes options de gestion de l'eau. Ce document de réflexion propose une méthodologie basée sur la méthode d'enveloppe des données (Data Envelopment Analysis, DEA), une technique d'analyse non paramétrique spécifiquement développée pour évaluer l'efficience relative de politiques alternatives de tarification de l'eau. A cet effet, une analyse des classements a été effectuée sur la base du score d'efficience relative. Une application a été réalisée dans le sud de l'Italie (Pouilles), où l'irrigation revêt une grande importance stratégique pour les décideurs. Six méthodes de tarification différentes ont été évaluées. Selon les résultats, les politiques de tarification alternatives affichent les mêmes performances en termes d'efficience technique. Par contre, les résultats de la tarification alternative montrent une différence de performance entre les indicateurs de l'efficience technique et de l'efficience écologique. L'efficience écologique affiche une inefficience maximale de 10 %. Notre conclusion est que l'efficience peut être une méthode adéquate d'évaluation des hypothèses de politiques de tarification en cas d'absence d'informations sur les préférences pour certains résultats, ainsi que de certains impacts environnementaux négatifs.*

Mots clés*: Programmation linéaire – Efficacité – Eau – Politiques de tarification – Irrigation.*

I – Introduction

Water management is very often subject to conflicting objectives. On the one hand, water management plans for the future need to comply with environmental criteria in order to ensure ecologic sustainability. On the other hand, economic viability will always be a necessary requirement for agricultural sustainability and the provision of related social services. This is particularly the case in areas where water scarcity induces a dramatic competition in the demand of the resource between agriculture and environmental needs or, in other terms, the trade-off between economic return and environmental protection. The regulation of water uses for the agricultural sector is an urgent issue especially in Mediterranean regions, where the water use share for irrigation ranges from 50 to 60% of fresh water bodies (Dworak *et al.*, 2007), rising up to more than 80% in certain areas.

Selecting the appropriate scientific tools to assess water policy measures and, thereby, support water management decisions under complex circumstances has been identified as one of the major challenges with regard to the implementation of water policy reforms (Messner, 2006). Assessing water policy embraces both economic and ecological dimensions, or attributes. As a consequence common indicators will need to be established, as well as aggregation methods for enhancing a comprehensive framework analysis.

Although a wide variety of functional forms exist that permit indicators to be aggregated, it is worth taking into account the possible incommensurability of different indicators. Although inputs, outputs, and externalities can be measured in physical or value terms, the most difficult task is the comparison of different performances. The greatest difficulty involves interpreting the combination of indicators selected to describe each policy, and therefore to be suitable as a practical administrative decision-support tool. Attempts to consider economic, social and environmental dimensions to perform some comparative analysis have been made for the issue of agricultural sustainability. Gómez-Limón and Sanchez-Fernandez (2010) provide extensive literature in this field and at the same time they propose a practical methodology for evaluating the sustainability of farms by means of composite indicators. The authors conclude that the ‘subjective’ character of the methods used to build composite indicators (weighting of indicators) is not satisfactory and could be improved.

When the relative importance of each criterion is already known, it is possible to proceed to a multi-criteria analysis (MCA), in order to obtain the ordered rank of the most preferred scenario. This type of methodology is generally considered as a sort of parametric analysis. Comparative studies on the application of different MCA in water resource management has shown that different methods are in close agreement and that there is no clear advantage in using some method above others (Gershon and Duckstein, 1983; Ozlekan and Duckstein, 1996; Eder *et al.*, 1997). The main limitations of MCA relate to the methods for preference elicitation, selection of criteria and decision options (Hajkowicz and Collins, 2007). Among these methods, it is worth mentioning the non-parametric methods, among which Data Envelopment Analysis (DEA) may also be included, which do not require any a priori assumptions about preferences.

Raju and Kumar, (2006) include DEA techniques into a MCA methodology, in which the relationship between all inputs and output are taken into account simultaneously. In fact, the DEA assigns the weights of the assessed indicators for the set of policies, in order to pursue the maximization of the ratio between the weighted (single or multiple) output and the weighted (single or multiple) input. Instead of providing the average performance among policy options, DEA can reveal the best practices in peer groups, as well as the technical efficiency score for each policy. In addition DEA evaluation overcomes the trade-off or compromise amongst the conflicting objectives, taking into account efficiency as criteria for the options ranking.

In the present paper we propose a methodology based on DEA as a benchmarking technique, specifically developed to assess the relative efficiency of alternative water pricing policies. A ranking analysis is carried out according to the relative efficiency score. The paper deals with two aspects of the efficiency. Firstly the technical efficiency, that depends on the optimal allocation of the resource to the most profitable crops. Secondly the ecological efficiency, that considers the externalities caused by the irrigated crops on the environment, in particularly pollution. In both cases, the water pricing scheme will be successful if for the same use of water it will induce an increase of output, or a reduction of the externality. Alternatively, the policy is efficient if for the same level of output or externality produced, it will induce a lower water use.

In order to estimate the efficiency of the policy, a comparison of the direct pricing scheme with indirect pricing schemes is performed. The study is based on the simulation of policy scenarios for the reservoir of the irrigation board named "Consorzio della Bonifica della Capitanata", which is located in the province of Foggia (Apulia region), South of Italy. The simulation is carried out through mathematical modeling and, the outcomes of the simulations (pay-off matrix) are analyzed by the DEA technique. In order to calculate the technical and the ecological efficiency of different water pricing policies, we use a two steps DEA analysis, as first proposed by Korhonen and Luptacik (2004). This methodology allows for the calculation of the relative efficiency and subsequently the ranking of most efficient policies, considering both the technical and the ecological aspects.

The structure of this paper is as follows. In the next section (section 2), the DEA methodology is presented and the conceptual framework proposed in this research is described. The case study is described in Section 3. Section 4 presents the main results, from which conclusions are drawn in Section 5.

II – Methodology

2.1 Overview

Data Envelopment Analysis measures the relative efficiencies of organizations with multiple inputs and multiple outputs (Charnes *et al.*, 1978). The technique is suitable to evaluate the performances of individual organizations, teams, or units, which are called "decision-making units", or DMUs. The basic feature of DEA is the identification of the so-called efficiency frontier, formed by connecting the most efficient units. All units lying on this frontier are said to be operating at 100 percent efficiency. On the contrary, an efficiency score is calculated for each of the inefficient units, measuring the euclidean distance with the closest units lying on frontier. The results of the DEA analysis are generally used to measure the performance efficiency, especially for benchmarking purposes. This methodology is useful whenever there is no information about the relative importance among outputs or inputs, as it does not require assumptions a priori (Callens and Tyteca, 1999). Another advantage of DEA is that the choice of the unit measure adopted to units' input and output will not affect the efficiency score (Coelli *et al.,* 1998).

Since the DEA technique was firstly developed by Charnes, Cooper, and Rhodes in 1978, it has been widely applied to industries as diverse as health care, finance, education, and transportation, as well as many other industries and organizations. The technique is well documented in both operations research (Banker *et al.,* 1984; Dyson and Thanassoulis, 1988; Golany and Roll, 1989; Cooper *et al.*, 1996) and economics literature (Banker and Maindiratta, 1988; Seiford and Thrall, 1990; Leibenstein and Maital, 1992). The DEA bibliography compiled by Seiford (1994) includes more than 400 articles, books, and dissertations between 1978 and 1992. A recent bibliography (Emrouznejad, 2001) reports more than 1,000 applications.

DEA is frequently used to measure the efficiency of decision units, such as firms, industrial plants, as well as governmental departments (e.g. Glass *et al.*, 2006; Bono and Matranga, 2005; Korhonen and Luptacik, 2004). Data Envelopment Analysis has also been applied as a useful methodology for ranking irrigation planning alternatives with mutually differing objectives (Raju and Kumar, 2006). In the research of Raju and Kumar, the DEA is applied to select the most suitable irrigation planning alternative in the context of the Sri Ram Sagar Project in Andhra Pradesh (India), using simulated data. The authors, however, do not include environmental objectives which, as mentioned, can be in conflict and which irrespectively need to be accounted for in the new policy frame of the European Water Framework Directive (WFD/2000/60/EU).

The first non-parametric analysis with multiple outputs (both economic and environmental) is reported in Färe *et al.* (1989), in which a data set consists of 30 US paper mills using pulp and three other inputs in order to produce paper together with four pollutants. Their results showed that the performance rankings of units turned out to be very sensitive to whether or not undesirable outputs were included. However, the general emphasis to the environmental issue has occurred later (Tyteca (1996) presents an exhaustive literature review).

In this paper, we adopt the modified two steps DEA, as first proposed by Korhonen and Luptacik (2004). Korhonen and Luptacik propose to measure the eco-efficiency of 24 power plants in Europe, in two different ways. In the first approach, they measure the eco-efficiency in two steps. The first, technical efficiency, and the second, the so-called ecological efficiency, are estimated separately. Subsequently they attempt to build up a model capable to simultaneously calculate either the 'desirable' and 'undesirable' outputs. The authors found that both approaches achieve almost the same result, in terms of finding the most efficient plants, although the ranking of the power plants resulted slightly different. The first method is adopted in this study, where an efficiency analysis is made of the performances of the local irrigated agricultural system under different water pricing schemes (see also Giannoccaro *et al.,* 2008).

2.2 Conceptual frame

In order to compare the relative efficiency of *n* water pricing scenarios, the analysis is performed on data derived from the simulation of their effects on the farmer's profitability, through a mathematical programming model. A multi-agent regional linear programming model is applied (see Giannoccaro *et al.*, 2010a for more details), consisting of a static linear programming model in which farmers are assumed to maximize their profits, subject to the following constraints: i) input endowments (land, water sources and labour), ii) technical aspects (agronomic rotations, labour and irrigation calendar), and iii) general agricultural policy issues, such as the conditionality for eligibility to the single farm payment under the CAP regime[1]. The decision variables of the model are basically referred to the optimal cropping mix, which determines the utilization of production inputs (land, labour and capital) including water and chemicals, as well as output measured in terms of gross margin, farmer's income and added value.

Two critical discrete stochastic variables representing, respectively, the price volatility of the commodities and the rainfall variability are also included in the model (Etyang *et al.*, 1998; Maatman *et al.*, 2002; Arsham, 1996). In fact, by using traditional linear programming models which consider the average right-hand-side constraint values on water availability, the results tend to overstate the farm outcome, not only in years with poor weather, but on average as well, because of the variability in rainfall. The advantage of using stochastic variables in the linear model is that it includes the stochastic nature of the rainfall distribution, which in semi-arid regions crucially affects farm income (Maatman *et al.*, 2002; Nardone *et al.*, 2007). In addition, partly because weather variations are also reflected in market prices, the technique also accounts for variation in output prices. The model is based on expected utility theory, according to which agents are neutral to risk (Neumann and Morgenstern, 1947).

The two stochastic variables representing the rainfall variability and the price volatility are discrete, and have different occurrence probabilities. The optimal solution is given by the weighted sum of the optimal solutions of each combination of the two variables, by the product of their occurrence probability. In this way, farmers are assumed to exhibit a risk neutral behavior. Therefore, water availability and the price of durum wheat (the main commodity in the area) are determined according to their stochastic probability. Under these conditions, the optimization problem is solved, by assuming the state of the two stochastic variables, are already known to the farmers at the time of decision making. So it is assumed that their decision making occurs under the condition of complete information.

The simulation model used here finds the maximum farmers' net revenue.

The simulation of the policy is performed by modifying water tariffs. From the simulation of each policy scenario, the most significant variables are selected, referred to as inputs, desirable outputs, and undesirable inputs. These variables that will be analyzed by the DEA technique can be classified into two types: economic and environmental variables. Table 1 shows the variables taken into account for running the DEA model[2].

Table 1: Variables taken into account for running DEA analysis

Conventional Resources					
	Input				Output
	Land	Labour	Capital	Water	Gross margin
Unit measure	10^3 hectares	10^3 hours	10^6 EUR	10^6 m^3	10^6 EUR

Environmental Externalities*		
	Undesirable inputs	
	Pesticides risk	Nitrogen surplus
Unit measure	10^3 Kg of rat potentially harmed	10^6 t

Source: own elaboration.
*Note: *) For environmental externality indicators see Berbel and Gutierrez (2005).*

The first step for calculating the relative technical efficiency is performed by the traditional DEA, where the technical efficiency of each of these j= 1,…, n water policy scenario is estimated. Suppose m input items and k output items are selected according to Table 1. In particular, for $m=1,2,...i$ the subscript for production inputs is assigned, and for $k=1,2,..,r$, the subscript for conventional outputs is identified. The vector of the overall technical inputs is m_{ij} and the vector of overall outputs is k_{rj}.

Therefore, for each water pricing policy, we formed the virtual input and output by (yet unknown) weights (v_i) and (u_r), with i=1,2,...k, and r=1,2,...q :

Virtual input= $v_1 m_{1j}+\ldots+v_k m_{ij}$ (1)

Virtual output= $u_1 k_{1j}+\ldots+u_q k_{rj}$ (2)

Then, the weights are determined using the DEA (CCR model, input-oriented) technique (Charnes *et al.,* 1978) to maximize the ratio Virtual output/Virtual input subject to:

$$v_1 m_{1j}+\ldots+v_k m_{ij}=1 \quad (3)$$

The second step consists of the measurement of the ecological efficiency through the calculation of the weights to be applied to the desirable outputs (k_r) and the undesirable inputs defined as $m=i+1, i+2,..., p$.

III – Empirical application

3.1 Data collection

The research is referred to the Province of Foggia, located in Southern Italy (Apulia region), where the local land reclamation and irrigation board, the 'Consorzio per la Bonifica della Capitanata' (CBC).

The area, extending over 442,000 ha, of which 80,000 ha are on average irrigated, is characterized by a Mediterranean climate with cold wet winters and hot dry summers. Rainfall varies from less than 400 mm/year to more than 700 mm/year, but there are also recurrent periods of drought, with minimum of 250 mm/year in some exceptional drought seasons.

Irrigation water comes from two main sources: CBC water is stored in large public water reservoirs and allocated directly to the fields by the CBC through high-pressure pipes. Non-CBC water comes from natural sources (wells, rivers). The public irrigation infrastructure in the area is managed by the CBC and delivers some 106,000,000 m^3 between April and November. Local (non-CBC) groundwater is largely utilized providing about 100,000,000 m^3.

The data used to calibrate the LP model is collected from official records (ISTAT, 2000). The procedure is carried out by small iterative adjustments to the gross margin of each crop, until the optimal solution approximates the current cropping pattern of the study area. According to the ISTAT (2000) data, labour is provided by the farming family (in 95% of cases). Farms were classified into three main groups according to farm size and cropping patterns.

Our technical coefficients reflect the agronomic rotations typically adopted by farmers in the area (Noviello and Nardella, 2005; Giannoccaro *et al.*, 2009). Input and output prices are based on the average (2004-2007) local market prices (Bulletin of the Chamber of Commerce). Market prices variability is included in the model only for the variability of durum wheat prices, which is the predominant crop in the area. On the basis of the time series over the last decade, three discrete values for the stochastic variable referred to the wheat price are considered: the average price (180 EUR/ton, accounting for 26.7% of probability of occurrence), a decrease of 26% (60% of probability), and an increase of 26% (13.7 % of probability).

The variability of the water availability is assumed to reflect the Gaussian distribution of the rainfall trend according to an approach proposed by Howitt and Taylor (1993). Over the last 3 decades the variation can be approximated by three water availability levels: average availability (547 mm/year, 73.5% probability of occurrence), water shortage corresponding to a volume decrease of 43.7% relative to the average (13.5% of probability) and water abundance corresponding to a volume increase of 43.7% relative to the average (13.0% of probability). Consequently, the simulation of farmers' decision making is given by the weighted sum (according to the probability of occurrence of each event) of the 3x3 possible outcome combinations generated by the LP model.

3.2 Water policy scenarios

Six water pricing schemes with three different hypothesis of saving 10%, 20%, and 30% of the current water consumption at the basin level, are compared. Two volumetric schemes, and four indirect pricing schemes are considered, of which the main features are as follows:

P0. Baseline: this is the current pricing scheme, which is based on a three-tiered rate system, applied only to pressured water distributed by the CBC, while the non-CBC water is free of charge (apart from private extraction and use costs). The three-tiered rate consist of a volume of water (2050 m^3/ha) at a lower tariff (0.09 €/m^3), sufficient to cover their running costs. An additional water volume (950 m^3/ha) is available at an intermediate tariff (0.12 €/m^3). Finally, a third tariff (0.24 €/m^3) is applied to excessive consumption exceeding the two blocks (above 3000 m^3/ha). In the case of non-CBC water, farmers carry only the private cost (estimated in as an average of 0.09 €/m^3) to lifting, accumulating, and pressuring water;

P1. Vol_tot: the current three-tiered rate system to CBC water is maintained. In addition, the introduction of a single rate volumetric method rate for the non-CBC is assumed, reflecting the environmental cost for water source depletion. In the absence of any other estimate a tariff of (0.03 €/m^3) is assumed here that would be sufficient to reduce the groundwater consumption by 10-20% of the current use;

P2. Input: the introduction of an indirect pricing method is assumed in which the water charge is applied on the basis of the input required by irrigated crops (e.g. plants or seeds, consumable irrigation equipments, ferti-irrigation[3] materials). To reflect an indirect environmental tax on irrigation practice, farmers pay a price surcharge on these inputs, regardless of the actual water consumption (from CBC and non-CBC). The surcharge is different for each crop and is calculated on the basis of average water consumption. This pricing method is intended to induce farmers to cultivate crops requiring lower inputs.

P3. Output: water consumption is charged proportionally to the gross return from irrigated crops, regardless of the water source. The charge rate for each crop is calculated as the ratio between the current value of its specific water consumption, and the corresponding gross return (vines 3%, horticultural crops 2.4-2.8%, olive orchards 1.9%);

P4. Area: a per-area pricing is assumed, based on the current irrigated area, while maintaining a fixed volume, calculated on the area suitable for irrigated agriculture. It is still a relatively easy method to be implemented and also easy to be understood by farmers. A per-area hectare charge is set equivalent to the average CBC cost per hectare of irrigated area (82 €/ha).
P5. Quota: A constant water tariff (0.09 €/m^3) is applied, but each farm is subject to a rigid constraint to water availability. This method is popular among some farmers, as they claim that the water price should remain low and constant, regardless of water availability. This does not result in a real water market, but the farmers accept the concept that the availability may change according to the rainfall regime.

IV – Results

The simulation of each pricing scheme generates different farmer's responses and agricultural system outcomes. From the 6 alternative pricing methods, combined with the three levels or prices (respectively, 10%, 20%, and 30% of water saving), a total of 18 water pricing schemes are compared with the DEA analysis.

Firstly, we analyze only the technical efficiency. This approach is the first step for assessing the water policy options. Table 2 shows the results of the DEA analysis in terms of the technical efficiency score.

Six options out of the 18 simulated options are most efficient. The average efficiency of the sample is 0.99805, and generally very slight differences are found. According to the data, the effects caused either by the pricing schemes and the pricing levels are negligible, in terms of technical efficiency. This may be explained by the fact that multi-input and multi-output farms, in the short term that is assumed in the study, are able to substitute (to a certain extent) high water demand crops with low water demand, or with non-irrigated crops. In other words farmers are able to choose their optimal crop mix within the current set of crop options. From the DEA analysis can be derived that the different crop patterns resulting from changes in water pricing policy are equally efficient.

Table 2: Technical efficiency and DEA 'peer' with Benchmarks.

Policy options	Technical efficiency	Peer with Benchmarks	
C_P1.Vol_tot	1.00000		
A_P5.Quota	1.00000		
C_P2.Input	1.00000		
A_P4.Area	1.00000		
C_P0.Baseline	1.00000		
B_P4.Area	1.00000		
A_P1.Vol_tot	0.99975	A_P4.Area	A_P5.Quota
A_P0.Baseline	0.99974	A_P4.Area	A_P5.Quota
A_P2.Input	0.99955	A_P4.Area	A_P5.Quota
B_P1.Vol_tot	0.99898	A_P4.Area	C_P1.Vol_tot
B_P0.Baseline	0.99896	A_P4.Area	C_P1.Vol_tot
A_P3.Output	0.99840	A_P4.Area	A_P5.Quota
B_P2.Input	0.99763	A_P4.Area	C_P1.Vol_tot
C_P4.Area	0.99716	C_P0.Baseline	C_P2.Input
B_P3.Output	0.99579	A_P4.Area	C_P1.Vol_tot
B_P5.Quota	0.99514	A_P4.Area	C_P1.Vol_tot
C_P5.Quota	0.99270	A_P4.Area	C_P1.Vol_tot
C_P3.Output	0.99109	C_P1.Vol_tot	C_P2.Input

Source: own elaboration.

In benchmarking, an approach originating from Torgersen *et al.* (1996), an efficient unit is ranked high if it appears frequently in the reference sets (peer) of inefficient decision units. The most frequent water pricing policy is A_P4Area. On the contrary, the same policy scheme under the water saving scenario B (B_P4Area) does not constitute an efficient 'peer reference' for any other policy. In Table 3 the ecological efficiency score and DEA 'peer' reference are shown.

Table 3: Ecological efficiency and DEA 'peer' with Benchmarks.

Policy options	Ecological efficiency	Peer with Benchmarks	
A_P0.Baseline	1.00000		
A_P1.Vol_tot	1.00000		
A_P4.Area	1.00000		
A_P3.Output	1.00000		
C_P1.Vol_tot	1.00000		
A_P5.Quota	0.99871	A_P0.Baseline	A_P4.Area
C_P0.Baseline	0.99310	A_P0.Baseline	C_P1.Vol_tot
B_P1.Vol_tot	0.98376	A_P0.Baseline	C_P1.Vol_tot
B_P0.Baseline	0.98374	A_P0.Baseline	C_P1.Vol_tot
B_P4.Area	0.98239	A_P3.Output	A_P4.Area
A_P2.Input	0.97839	A_P3.Output	A_P4.Area
B_P5.Quota	0.96003	A_P0.Baseline	C_P1.Vol_tot
B_P2.Input	0.95825	A_P3.Output	A_P4.Area
B_P3.Output	0.95557	A_P3.Output	A_P4.Area
C_P5.Quota	0.94044	A_P0.Baseline	C_P1.Vol_tot
C_P2.Input	0.93969	A_P3.Output	A_P4.Area
C_P4.Area	0.93030	A_P3.Output	A_P4.Area
C_P3.Output	0.90550	A_P3.Output	A_P4.Area

Source: own elaboration.

Findings stress that ecological efficiency reaches the best value for five over all options analyzed. The average efficiency of the sample is 0.97277 and generally major differences are found. The worst efficiency level is shown in the case of C_P3.Output, for which almost 10% inefficiency with respect to the best one is found. Taking into account the five efficient options, it should be noticed that four out five water pricing policy take place in the water saving scenario A. It seems that rise in price does not result in environmental efficiency improvement.

Finally, in Table 4 both technical and ecological efficiency scores are listed. From the findings it can be noted that only two water pricing options, namely the A_P4.Area and C_P1.Vol_tot are full efficient.

V – Concluding remarks

The reform of water pricing methods is one of the basic policy instruments necessary for the enhancement of the efficiency of using water and of its quality status, as well as the protection of depletion from natural sources depletion. Policy makers require a clear overview of the different outcomes of alternative water management policies and tools need to be improved for supporting the selection of most suitable measures to specific situations. The objective of this research is to provide information for the support of the decision making process towards the selection of water pricing measures for irrigation water.

In the present paper we propose a methodology based on Data Envelopment Analysis (DEA), a non parametric benchmarking technique, specifically developed to assess the relative efficiency of alternative water pricing policies. For this purpose a ranking analysis was carried out according to the relative efficiency score. This efficiency may be a convenient method to rank policy alternatives in the case of an absence of information on stated preferences on outcomes, as well as negative environmental impacts.

Table 4: Technical vs. Ecological DEA efficiency.

Policy options		Technical Efficiency	Ecological Efficiency
1	A_P0.Baseline	0.99974	1.00000
2	A_P1.Vol_tot	0.99975	1.00000
3	A_P2.Input	0.99955	0.97839
4	A_P3.Output	0.99840	1.00000
5	A_P4.Area	1.00000	1.00000
6	A_P5.Quota	1.00000	0.99871
7	B_P0.Baseline	0.99896	0.98374
8	B_P1.Vol_tot	0.99898	0.98376
9	B_P2.Input	0.99763	0.95825
10	B_P3.Output	0.99579	0.95557
11	B_P4.Area	1.00000	0.98239
12	B_P5.Quota	0.99514	0.96003
13	C_P0.Baseline	1.00000	0.99310
14	C_P1.Vol_tot	1.00000	1.00000
15	C_P2.Input	1.00000	0.93969
16	C_P3.Output	0.99109	0.90550
17	C_P4.Area	0.99716	0.93030
18	C_P5.Quota	0.99270	0.94044

Source: own elaboration.

According to the findings, on the one hand, alternative pricing policies perform similarly in technical efficiency term. However, since indirect methods may be easier to implement, under some circumstances they might be preferable, without losses in terms of efficiency. In our experience, for example, it was found that the pricing method based on the irrigated area performed with maximum efficiency. On the other hand, the results show a difference of rank between the technical efficiency and the ecological efficiency indicator. The ecological efficiency shows up to 10% of inefficiency. In this study it appears that a rise in price does not result in environmental efficiency improvement. The policy implication may be important given that water policy reforms are addressed to increase water price, mainly in the European Union where tariffs enforcement is expected according to the ‘full cost recovery’ (EU/60/2000/WFD).

It is worth mentioning that the study is based on a short-term horizon, with a fixed coefficient linear programming model. Further research shall aim at exploring technological change farmers may decide to introduce, in the long run.

References

Arsham H. (1996). Stochastic optimization for discrete event systems simulations. *Microelectronics and Reliability*, Vol. 36(10), pp. 1357-1368.

Banker R.D., Charnes A., Cooper W. W. (1984). Models for Estimating Technical and Scale Efficiencies. *Management Science*, 30:1078-1092

Banker R.D., Maindiratta A. (1988). Nonparametric Analysis of Technical and Allocative Efficiencies in Production. *Econometrica*, 56, (6):1315-1332.

Berbel J., Gutierrez C. (2005). *Sustainability of European Agriculture under Water Framework Directive and Agenda 2000.* European Commission, Brussels.

Bono F., Matranga D. (2005). Measures of efficiency in the environmental context. In: *S.I.S. 2005 - Statistica e Ambiente*. Messina, 21-23 September 2005.

Callens I., Tyteca D. (1999). Towards indicators of sustainable development for firms: A productive efficiency perspective. *Ecological Economics*, 28:41-53.

Charnes A., Cooper W.W., Rhodes E. (1978). Measuring the efficiency of decision making unit. *European Journal of Operational Research* 2 : 429-444.

Coelli T., Prasada Rao D.S., Batteste G.E. (1998). *An introduction to efficiency and productivity analysis.* Kluwer Academic Publishers, Boston.

Cooper W.W., Thompson R.G., Thrall R.M. (1996). Introduction : Extensions and New Developments in DEA. *Annals of Operations Research,* 66 : 3-45.

Dyson R. G., Thanassoulis E. (1988). Reducing weight flexibility in data envelopment analysis. *Journal of the Operational Research Society*, 39(6) : 563-57

Dworak T., Berglund M., Laaser C., Strosser P., Roussard J., Grandmougin B., Kossida M., Kyriazopoulou I., Berbel J., Kolberg S., Rodríguez-Díaz J. A., Montesinos P. (2007). ‘EU Water saving potential (Part 1 –Report)’ (Ecologic-Institute for International and European Environmental Policy, 2007). Available at : http// : www.ecologic.de/download/projekte/900-949/917/917_water_saving_1.pdf.

Eder G, Duckstein L., Nachtnebel H.P. (1997). Ranking water resource projects and evaluating criteria by multicriterion Q-analysis: an Austrian case study. *J Multi-Criteria Decision Analysis* 6(5):259–271.

Emrouznejad A. (2001). An Extensive Bibliography of Data Envelopment Analysis (DEA), Volume I-V. Business School, University of Warwick, Coventry CV4 7AL, England

Etyang M.N., Preckel P.V., Binkleyb J.K., Doster D.H. (1998). Field Time Constraints for Farm Planning Models. *Agricultural System*, Vol. 58(1) : 25-37

Färe R., Grosskopf S., Lovell C.A.K., Pasurka C. (1989). Multilateral productivity comparisons when some outputs are undesirable: a nonparametric approach. *Review of Economics and Statistics* 71, 90-98.

Gershon M., Duckstein L. (1983). Multiobjective approaches to river basin planning. *J Water Resource Plan Manage Div* 109(1):13–28

Giannoccaro G., Prosperi M., Zanni G. (2008). Dea Application to Evaluate the Technical and Ecological Efficiency of Water Pricing Policies, in Bartova L., M'Barek, R., Ratinger, T. (eds.). *Modeling agricultural and rural development policies. Proceedings of the 107th Seminar of the EAAE, Sevilla*, January 29 - February 1, 2008. European Communities.

Giannoccaro G., Prosperi M., Valente N., Zanni G. (2009). Valutazione degli impatti della politica di tariffazione delle acque irrigue sull'agricoltura della Capitanata (Puglia), in Gallerani V, La Via, G., Zanni, G. (eds.) *Acqua e Agricoltura in Italia. Valutazioni di scenari e strumenti di supporto alle decisioni* (Franco Angeli, Milano, Italy)

Giannoccaro G., Prosperi M., Zanni G. (2010a). Assessing the impact of alternative water pricing schemes on income distribution. *Journal of Agriculural Economics,* 61, (3) : 527–544

Giannoccaro G., Prosperi M., Zanni G. (2010b). Assessing Water Pricing Policies to enhance water efficiency in agriculture. *Ambientalia Special Issue Series (I)-The role of economics in the Water Framework Directive.* ISSN 1699-3063. Available at: http://www.ugr.es/~ambientalia/articulos/art_categorias/wfd/ECONOMIA/SPI_2_Giannoccaro_VVAA(2010)_Ambientalia_en.pdf

Glass J.C., McCallion G., McKillop D.G., Rasaratnam S., Stringer K.S. (2006). Implications of variant efficiency measures for policy evaluations in UK higher education. *Socio-Economic Planning Sciences* 40: 119–142.

Golany B., Roll Y. (1989). An application procedure for DEA. *OMEGA*, 17(3): 237-250.

Gómez-Limón J.A., Sanchez-Fernandez G. (2010). Empirical evaluation of agricultural sustainability using composite indicators. *Ecological Economics* 69(5) : 1062-1075.

Hajkowicz S., Collins K. (2007). A review of multiple criteria analysis for water resource planning and management. *Water Resources Management* 21:1553–1566

Howitt R., Taylor R. (1993). Some microeconomics of Agricultural Resource Use, in Carlson G.A., Zilberman D., Miranowski J.A. (eds.) *Agricultural and Environmental Resource Economics*, 28-68, Oxford University Press, USA.

ISTAT (2000). *5° Censimento nazionale dell'agricoltura*. Roma, Italy: ISTAT.

Korhonen P.J., Luptacik M. (2004). Eco-efficiency analysis of power plants: An extension of data envelopment analysis. *European Journal of Operational Research* 154 : 437-446.

Leibenstein H., Maital S. (1992). Empirical Estimation and Partitioning of X-Inefficiency: A Data-Envelopment Approach. *The American Economic Review,* 82:428-433.

Maatman A., Schweigman C., Ruijs A., Van der Vlerk M.H. (2002). Modeling Farmers' Response to Uncertain Rainfall in Burkina Faso: A Stochastic Programming Approach, *Operations Research*, 50(3): 399 – 414.

Messner F. (2006). Applying participatory multicriteria methods to river basin management: improving the implementation of the Water Framework Directive. *Environment and Planning C: Government and Policy* 24(2), 159 – 167

Nardone, G., Prosperi M., Viscecchia R., Zanni G. (2007). Valutazione economica della risorsa idrica nell'agricoltura della Capitanata, in: CCIAA di Foggia (ed.) *Risorse idriche in provincia di Foggia: gestione, compatibilità e fabbisogni nel nuovo quadro di sviluppo territoriale* Foggia: Camera di Commercio della Provincia di Foggia, Italy.

Neumann von J., Morgenstern O. (1947). Theory of Games and Economic Behavior.- Princeton, NJ., Princeton University Press,

Noviello N., Nardella L. (2005). I costi di produzione negli ordinamenti produttivi della Capitanata: Incidenza dell'acqua e dell'irrigazione. Bonifica 4, 17-49.

Ozelkan E.C., Duckstein L. (1996). Analyzing water resource alternatives and handling criteria by multicriterion decision techniques. *Journal of Environmental Management* 48, 69–96

Raju K.S., Kumar D.N. (2006). Ranking irrigation planning Alternatives Using data Envelopment Analysis. *Water Resources Management* 20, 553-566.

Seiford L.M. (1994). 'A DEA bibliography (1978-1992)', in Charners, A., Cooper, W.W., Lewin, A.Y. and Seiford, L.M. (eds.) : Data Envelopment Analysis : Theory, Methodology and Applications. Kluwer Acad. Publ., 437-469.

Seiford L.M., Thrall R.M. (1990). Recent Developments in DEA: the mathematical Programmig Approach to Frontier Analysis. *Journal of Econometrics*, 46 : 7-38.

Tyteca D. (1996). On the Measurement of the Environmental Performance of Firms- A Literature Review and a Productive Efficiency Perspective. *Journal of Environmental Management* 46: 281-308

Torgersen A.M., Forsund F.R., Kittelsen S.A.C. (1996). Slack-adjusted efficiency measures and ranking of efficient units. *The Journal of Productivity Analysis* 7, 379–398.

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(1) The single farm payment scheme has been introduced by the Regulation (EC) No 1782/2003 of 29 September 2003 establishing common rules for direct support schemes under the EU Common Agricultural Policy.

(2) In this research an application exercise is shown. More comprehensive analysis is carried out in Giannoccaro *et al*. (2010b).

(3) Ferti-irrigation is a system in which fertilizers are dissolved in the irrigation water before applying the water to the crops.

Third part

Implementation of water framework directive: principals and concepts

The implementation of the Water Framework Directive in Italy

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Abstract. This paper presents the main issues and trends in water resources management in Italy. After a description of water resources availability and use, as well as patterns of water management organization, the paper sketches the legislative history on national environmental issues and the administrative steps taken to transpone the European directive in Italian law. Furthermore, the actual implementation of WFD is discussed. In Italian legislation, water and environmental protection consisted of laws that gave incentives to water use to increase productivity. The aim of recent Italian legislation has been the development of land-use planning policies in correspondence with the physical and environmental characteristics of the land. The reference to these two aspects is one of the most innovative features of the new legislation, adopting a systemic approach to the problem of hydro-geological balance, at the same time protecting both land and water resources. Finally, we report on the case of the Po River District, which complies with the administrative and normative requirements of the European directives on environment and water. For this reason it represents a useful guidance for the rest of Italy, demonstrating how to implement the WFD and to develop effective, efficient and integrated water policy.

Keywords. Environment – Efficiency – Productivity – Water use – Water balance – Policies

La mise en œuvre de la directive-cadre sur l'eau en Italie

***Résumé**. Cet article a pour objet de présenter, d'une manière générale, les principales dispositions au regard de la gestion de l'eau et des ressources en eau en Italie. L'article traite d'abord de la disponibilité des ressources en eau et de l'usage de l'eau à l'intérieure des organisations de gestion des eaux, puis il aborde l'histoire de la législation dans ce domaine et toutes les actions entreprises pour transposer la directive européenne en Italie. Dans la loi italienne, le rôle de la protection de l'eau et de l'environnement est d'améliorer l'usage de l'eau et d'augmenter la productivité. L'objet des récentes lois italiennes est de développer les politiques de planification des sols qui s'alignent sur les caractéristiques de l'environnement et du territoire. La référence à ces deux aspects est une des plus importantes améliorations des récentes lois, qui adoptent une approche systématique au bilan hydrogéologique et, dans le même temps, protègent à la fois le territoire et les ressources en eau. Dans cette étude est présenté l'exemple du district du fleuve Pô, qui satisfait les requêtes administratives et normatives de la directive européenne au regard de l'eau et de l'environnement. Il constitue pour cette raison un bon exemple à suivre pour savoir comment mettre en œuvre ces directives en Italie pour développer une politique de l'eau qui soit efficiente et intégrée.*

***Mots clés.** Environnement – Efficience – Productivité – Usage de l'eau – Bilan d'eau – Politique*

I – Introduction

Water policy has changed in all industrialized countries. In the past respecting both quality and quantity of water resources was promoted, imposing socio-economic procedures and methods to adapt the overall system to it. Today, the protection, conservation and rational use of water resources are essential to guarantee a balanced hydrological cycle and the rights of future generations to use this precious natural good. Due to the expected climate change, water is destined to become a crucial issue in the twenty-first century as social stability partly depends on the availability of water resources.

The Water Framework Directive 2000/60/EC (WFD) establishes a European frame for the protection and management of water resources. The main aims are the prevention of water resources deterioration, both in terms of quality and quantity, compared to the present condition and the improvement of the quality of all water bodies in order to reach a ‘good status’ before 2015. These objectives should be considered part of a more general framework for the protection and the improvement of the environmental quality. This framework calls for the rational and restrained use of natural resources, through the application of the ‘precautionary’ principle, i.e. the reduction of the pollution at its source. The directive also introduces the ‘the polluter pays’ principle, including the concept of ‘responsibility’ of polluters for the damage caused, connected to the attribution of the costs of repairing the damages to those that caused them.

The WFD in Italy was transposed in 2006, with the legislative decree no. 152. Delay in the identification of water districts and in the attribution of the related competences forced the Italian Government to introduce a specific administrative procedure for the active participation of all the involved stakeholders, in order to respect the European Directive procedures and deadlines.

The Italian legislation already foresaw the needs for planning activities at hydrographical basin scale. Several plans at both the hydrographical basin and sub-district level were the basis for the preparation of the RBMPs.

In the Italian national context a particular case is the Po River Basin, the largest in Italy and an economic strategic area for the country. This basin district has actively participated in the programme developed by the Ministry for the Environment of Land and Sea (in the following called Ministry for the Environment) to implement the WFD in Italy. Moreover, in many respects the basin authority has anticipated the implementation of the WFD, by putting into effect procedures that are included in the water directive, prior to the transposition of WFD.

A final relevant aspect of the River Basin Management Plans is the economic analysis; according to the directive, this aspect has to be taken into account in all phases of the decision making process, integrated with other components. In Italy, as in other Member States, economic analysis has been carried out at a preliminary level only, due to the difficulty of procuring the needed information. This gap will be filled when data are collected by the monitoring system that has been set up. When the economic analysis is integrated, the Italian RBMPs will be really effective to evaluate the efficiency of the costs linked to the different scenarios. These economic analyses will be integrated in the RBMPs during the revision phase foreseen by the directive.

The main aim of this paper is to illustrate the national water policy and the status of WFD implementation in Italy. We discuss the principal legislative aspects of water matters, before and after the WFD came into force, because it is fundamental to share knowledge and plans for accurate integrated water management. The laws and legislative decrees, preceding the WFD, on the one hand, have strongly facilitated the preparation of all the needed actions, to achieve the ‘good ecological status’ before 2015, as WFD requires, but, on the other hand, it showed that the national normative frame is very complex and fragmented, making it often difficult to apply. For this reason it is necessary to rapidly adapt the laws to the new situation, in order to reach the environmental objectives. Furthermore, the present status, both quantity and quality, of the water bodies in Italy is described, distinguishing four regions: north, central, south and islands. Finally, the case study of the largest river basin in Italy (Po basin) is described, because the Po River Basin Authority and the regions of the basin have actively participated to implement the WFD in Italy and in many aspects the basin authority has anticipated the legislation implementing the WFD. In fact, the River Po Basin Authority since 2003, in advance of the transposition of the WFD at the national level, developed a plan for studying and monitoring activities, with the aim of increasing knowledge on the water resource at basin scale in accordance with the classification system provided by the WFD.

II – The Italian normative framework before the WFD

The first law anticipating the WFD was called 'Norms for the organizational and functional rearrangement of soil protection' (Law no. 183 of 1989). The purpose of this law was to enhance the 'protection of lands, water rehabilitation, use and management of resources for a rational, economic and social development, and for the protection of the related environment' (art. 1). Therefore, the law stated the need of planning at the hydrographical basin scale and created new ad hoc public agencies: the River Basin Authorities (6 national River Basins and 18 inter-regional River Basin Authorities). The main objective of these authorities was to develop and apply the River Basin Management Plan. This plan includes four transitional plans: i) the transitional plan for the restoration of hydraulic structures; ii) the transitional plan for the hydro-geological Settlement (PAI), also containing the transitional plan for fluvial areas; iii) the special plan for areas with high hydro-geological risks; iv) the transitional plan for the control of eutrophication. The same law introduced the innovative concepts of the minimum stream flow (also called environmental flow), aimed at the protection and safeguarding of river ecosystems and several issues of water quality remediation. Furthermore, its following modification and upgrading resulted in the concept of 'water balance' in standard classical sense (inputs – outputs), as the central element for water resources management. So, the law 183/89 enabled the change from the culture of mere protection to the culture of environmental improvement.

In 1994 on the basis of the law no. 36 'Provisions concerning water resources' (also known as Galli Law) water supply, urban drainage and wastewater treatment systems were reorganised in Optimal Territorial Areas (ATO) on the basis of efficiency, effectiveness and economic criteria, leading to integrated and comprehensive management of water resources under the ATO authority. The law assigns pollution control and environmental monitoring to the Regional Environmental Agencies. It also states that water quality has to be seen in the context of 'final use requirements'. In fact, the 'the polluter pays' principle was introduced. Moreover, the law also affirmed the concept of the public nature of all surface and groundwater and gave priority to water for human consumption.

A milestone, regarding the integration of the protection of water ecosystems into Italian legislation was the legislative decree no. 152 of 1999 'Arrangements for the protection of waters against pollution and implementing directive 91/271/EC concerning urban wastewater treatment and directive 91/676/EC concerning the protection of waters against pollution caused by nitrates from agricultural sources'. This was integrated with and amended by legislative decree no. 258/2000 on 'the protection of waters against pollution' that re-examined environmental protection from a new pro-active perspective and anticipated some aspects of the WFD. The decree defines the general procedures to safeguard water, pursuing the objectives of (i) preventing and reducing pollution, (ii) reclaiming and improving the water status, (iii) protecting the water allocated to special uses, (iv) ensuring the sustainable use of the resources and (v) supporting well diversified animal and plant communities. These objectives can be achieved through the application of proper water quality and quantity planning, represented in the Water Protection Plan within each hydro-graphical basin. By the introduced measures the water bodies are expected to reach a good environmental status for surface and groundwater by December 31, 2016. The River Basin Authorities charged to set up a preliminary definition of objectives and priorities at basin scale for the protection plans.

III – Analysis of the Water Resources Status

3.1 Availability

Water in Italy is abundant, since the renewable water resources are theoretically around 185 km^3 per year and the availability per capita is about 3,000 m^3 per year (Shiklomanov and Rodda, 2003).

As a result of the seasonal and regional patterns of rainfall distribution, but also due to low efficiency of water supply systems, water losses and technical and socio-economic constrains, the effective availability is much lower: about 45 km^3/year, which is about 750 m^3 per capita per year (IRSA, 1999). This availability corresponds to more than 2,000 litres per capita per day, which is higher than the European average (1,677 litres per capita per day). The average water availability is shared unevenly throughout the country: 65% in northern Italy, 15% in central Italy, 12% in southern Italy and 8% in the islands. While the runoff of Alpine rivers is well distributed during the year (9%, 24%, 41% and 26% respectively for winter, spring, summer and autumn), in the rest of the country between 60 and 90% of total run-off water is concentrated in winter and spring (Rusconi, 1996). Since this distribution has a strong impact on water resources availability, flood management often causes dramatic problems.

3.2 Water use

Water use can be divided into four main categories: civil, energy production, industry, agriculture. According to the study by IRSA-CNR (Water Research Institute, 1999), in Italy, on average, 19% of all water uses are for civil purposes, 11% for energy production, 21% for industry, 49% for irrigation.

In the last decade water use per capita increased, even though water consumption for residential use (70 m^3 per inhabitant in 2007) shows a decreasing trend in the last six years (ISTAT, 2008).

In metropolitan areas, the percentage of the population served by wastewater treatment plants in the last six years shows a sharp increasing trend going from 72.2% in 2002 to 82.4% in 2007 (Ministry of environment, 2009).

Civil uses are basically related to groundwater, being around 23%, while the European average is 13%. In the north, groundwater and springs account for roughly 90% of household supply. In southern Italy, especially in the islands, 15-25% of water supplies are based on surface water resources. Whole provinces rely on reservoirs in the upstream area for the entire supply (Massarutto, 2001). In Italy the most water demanding industrial activities are the petrochemical and metallurgic industries, together with textile and food production. In the last years, the water demand for industrial purposes has decreased, due to the reduction of manufacturing activities and the introduction of new, more efficient, technologies that consume little water. Hydro-electric energy production does not consume water resources, from a quantitative point of view, because after its use the water is released back to the water body, but the displacement in time of water volumes operated by reservoirs can often endanger other downstream uses. Groundwater resources represent the main source of supply for industrial uses, especially in the north, in general by direct private extractions. Industrial use of surface waters occurs generally for cooling purposes.

Surface water in the north is essentially used for irrigation, in general after an intensive upstream use for hydro-power generation. At the present, in Italy more than 503,000 farms use water for irrigation purposes; this represents more than 29% of utilized agricultural surface (UAS). The irrigated surface (adding to more than 2,600,000 hectares) represents 20.4% of the cultivated surface, with water requirements of over 20 km^3 per year. Concerning southern Italy, a study by INEA[1] (Lamoglie, 2004) estimated that the water use for irrigation purposes is over 3,300 millions of m^3 per year, while the water requirements are about 3,700 millions of m^3 per year. This deficit can be attributed to both distribution deficiencies and to insufficient availability of suitable resources (Lamoglie, 2004).

Nonetheless, a further 10-25% of water for irrigation is derived from groundwater, small streams, small private rain water harvesting systems and springs. In the north and centre this occurs basically in mountains and hilly areas, where irrigation is often practiced during the winter in order to prevent damage from hard-frost; in the south and in the islands, on the contrary, groundwater is used intensively during the summer, either in the centre or along the coastal plains. Local resources – basically groundwater and 'non conventional' sources like desalinated and brackish water – are used as complimentary resources, in particular in southern Italy.

The analysis of water availability and irrigation use in the Country presents specific characteristics that are consequences of traditional agricultural practices and morphological shape of territory. This fact explains the different and not homogeneous conditions existing among north and south areas of Italy in terms of forms of agricultural practices, irrigation systems and of water body management for supply and distribution. The Italian water system can be characterized by positive as well as negative aspects. The positive issues are (i) the high level of technical competence and system technologies, (ii) the accurate spatial covering of water supply and urban drainage systems. On the other hand, the weaknesses are (i) backwardness of facilities, (ii) uneven water distribution, (iii) high water losses from the distribution network (at National level it is estimated at an average of around 40%[2]), (iv) high administrative fragmentation, (v) inadequate pricing, (vi) scarcity of financial resources (Gilardoni e Marangoni, 2004; Rossi, 2001).

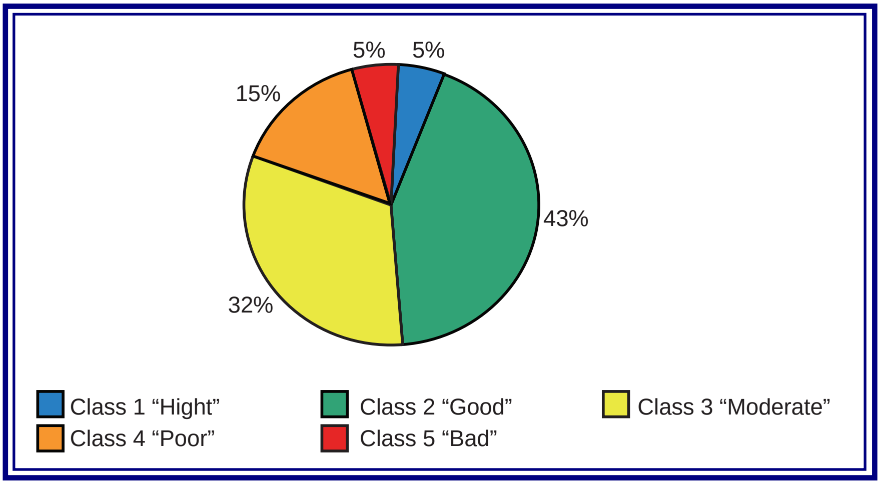


Figure 1: Percentage distribution of the classes of the Ecological Status Watercourses quality index. *(ISPRA, 2009).*

3.3 Water quality

Decree no. 152/1999 introduced the 'integrated system for monitoring and control' of water resources for quality and quantity. The monitoring system is based upon the DPSIR model (Determinant-Pressure-Status-Impact-Response, i.e. the analysis of driving forces that can assert pressure on the state of water bodies). It is very important in order to plan actions as part of the Water Protection Plan. The decree defined standard parameters for expressing the overall environmental quality of surface water resources by integrating the chemical (LIM- Level of Pollution from Macro-descriptors) and biological approaches (IBE– Extended Biotic Index).

In Italy, in 2007, 48% (1,014) of monitored sites fall into quality class 1 (very good) and 2 (good), 32% fall into class 3 (sufficient) and the remaining 20% of sites are of poor quality (fig. 1). In general, the biological parameters are the most sensitive to different kinds of pollution, contributing to the poor quality of a watercourse.

From the data shown in figure 2 it appears that in northern Italy the watercourses have a good status, with 55% in classes 1 and 2, compared to 41% and 48% in respectively the centre and south (including the islands). However, these results come from a different number of stations in the three macro-regions and no data of Basilicata, Campania, Calabria and Sardinia regions for the south and island group are included.

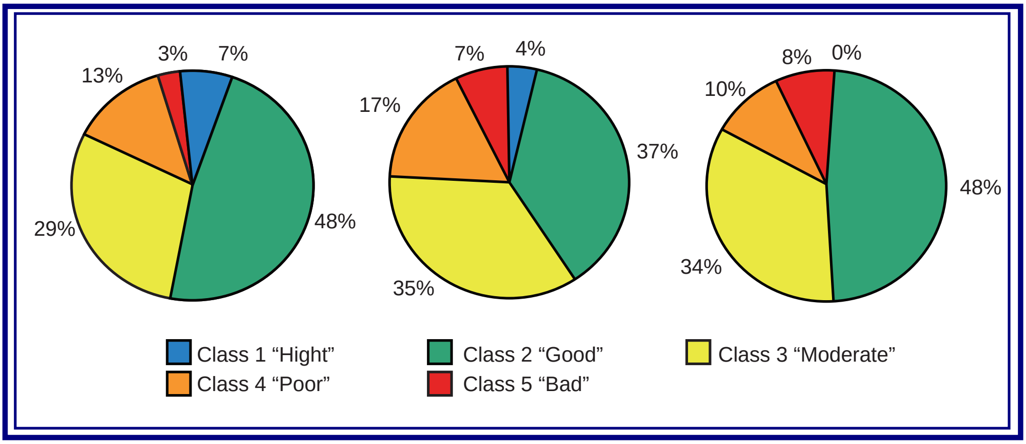


Figure 2: Percentage distribution of Ecological Status Watercourses index quality classes by macro-regions. *(ISPRA, 2009).*

The available data for the assessment of the water quality of lakes (expressed as Ecological Status of Lakes – ESL) are not homogeneously spread over the national scale. In 2007, 73% of the stations representative of the 134 lakes (most of which are in North Italy, where 85% of Italian lakes are located) fall into the classes ‘sufficient’ to ‘optimal’ (fig. 3).

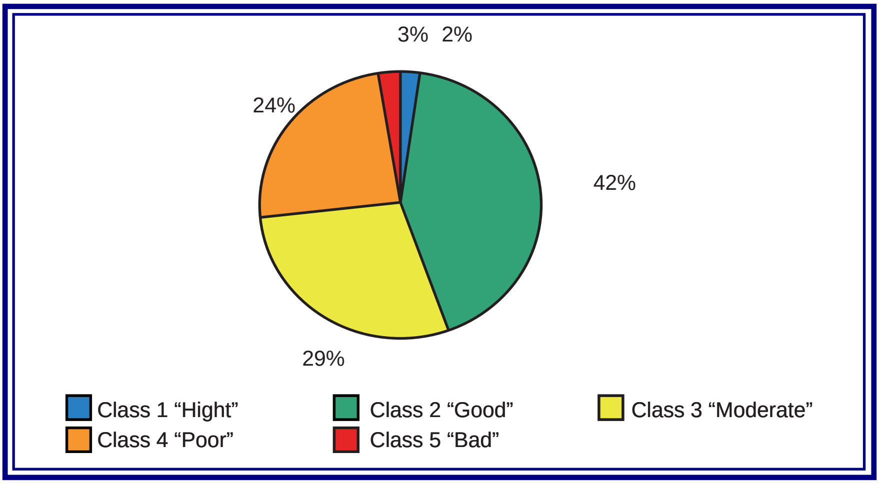
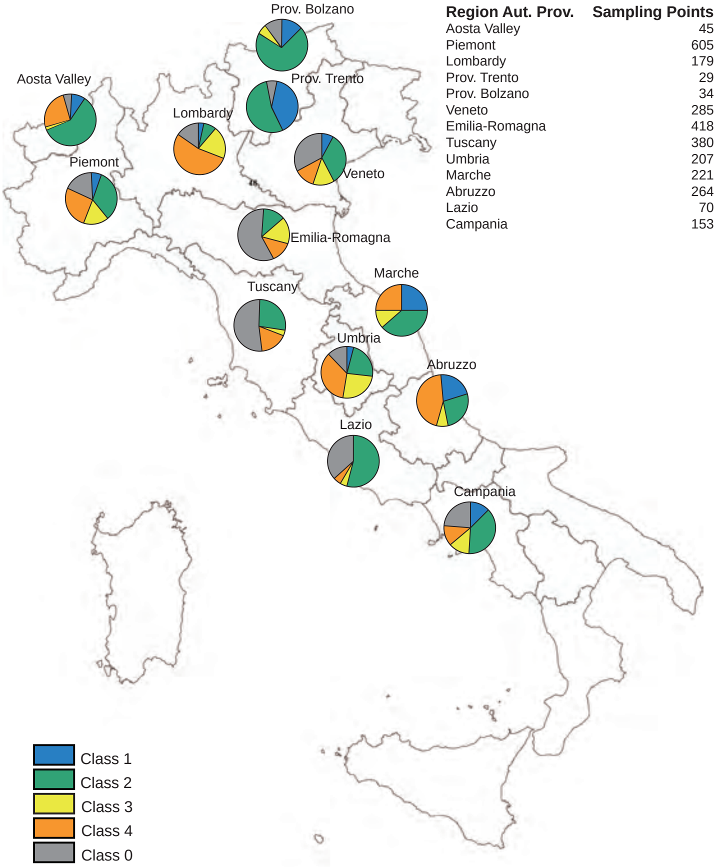


Figure 3: Percentage distribution of the Ecological Status of Lakes index quality classes, 2007.

Another indicator of the quality of a water body is the presence and abundance of fish. The data of 2007 (based on 14 regions) indicated that more than 90% of the watercourses comply with the values of both physical and chemical parameters reported in Table 1/B - Annex 2 – Part III of decree 152/06. Actually, only 3.8% of the flows are under the threshold values. Instead, the lakes show a full conformity at 100%.

The monitoring (based on 7 out of 15 coastal regions) of both marine and salty areas, suitable to molluscs, is performed in 66 sample sites, 45 marine and 21 salty areas. According to the values of Table 1/C – Annex 2 – Part III decree 152/2006, 47 waters are classified as standard quality of which 36 sea and 11 salty waters. The environmental quality of groundwater is determined by both the 'quantitative' and the 'chemical' states. While data on quantity are not available, the 'chemical' state can be described by the Chemical State of Groundwater index (CSGW). Analytical testing carried out in 2007 in 11 regions and 2 autonomous provinces involving 2,890 sampling stations shows the qualitative state of water bodies ranging from 49% in classes 1 and 3 (quality from good to sufficient), 24% in class 4 (poor quality due anthropogenic causes), and 27% in class zero with no or negligible anthropogenic impact (ISPRA, 2009).

Nitrates are among the pollutants of anthropogenic origin. A limit for nitrates is set at 50 mg/l (limit of drinkable water). As this limit is often transgressed, they are responsible for many analyzed regions to fall into class 4 (fig. 4).



Region Aut. Prov.	Sampling Points
Aosta Valley	45
Piemont	605
Lombardy	179
Prov. Trento	29
Prov. Bolzano	34
Veneto	285
Emilia-Romagna	418
Tuscany	380
Umbria	207
Marche	221
Abruzzo	264
Lazio	70
Campania	153

Figure 4: The quality status of underground water bodies on the regional level (11 regions and 2 autonomous provinces). *(ISPRA, 2009).*

The European directive 2006/118/EC on groundwater protection has been transposed within the national legislation through legislative decree no. 30/2009. It requires to set threshold values for pollutants, pollutant groups and pollution indicators, which have been identified as factors contributing to placing groundwater bodies at risk of not reaching the 'healthy state' level. The directive indicates a minimum list of 10 parameters and requires that the member States, on the basis of existing monitoring data, set further limits for pollutants present in the country.

Tests performed on 7,372 km of seacoast in 2007 show that more than 67% of coastal waters are suitable for bathing, 15% are not tested due to inaccessibility, 12% are permanently off-limits for bathing due to pollution, 3% are off-limits for bathing for reasons other than pollution and the remaining 3% are temporarily unsuitable for bathing due to pollution.

In 2006, through the regional Monitoring Programs for recovering the sites unsuitable for bathing, an increase of the number of bathing sites has been registered. Furthermore, in the same year, Programs and data presented by regions decreased, mainly due to the long time needed for the implementation of the measures. With respect to 2006, the total percentage of bathing coast is increased, due to the realization of improvement programs (Ministry of environment, 2009).

IV – The adoption and the implementation of the WFD in Italy (decree 152/2006)

As previously stated, the transposition of the WFD in Italy has been carried out on 2006, with the legislative decree no. 152 with three years of delay with respect to the directive. This decree enabled the establishment of River basin districts and assigned to the District Authority the competence of the development of the River Basin Management Plan. As showed in the figure 5, eight territorial districts were formed by aggregating territories previously belonging to existing authorities (the former River Basin Authorities).

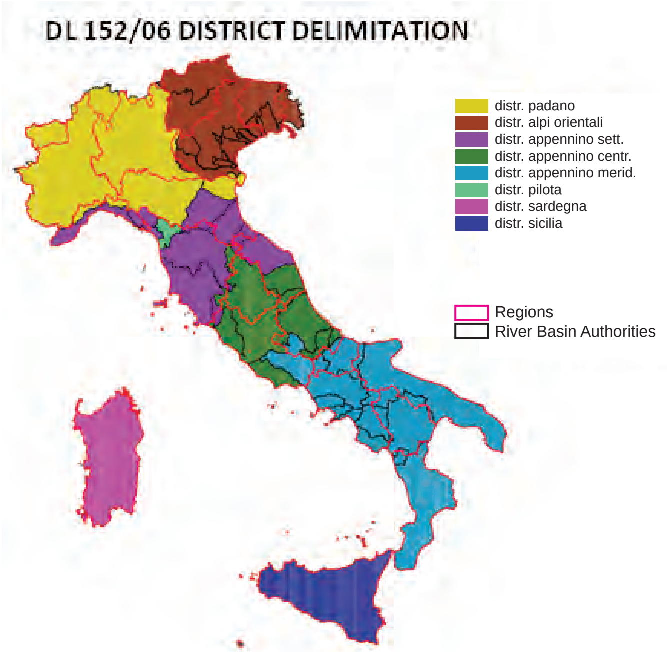


Figure 5: Regions (red borders), River Basin Authorities territory (black borders) and River Basin District territory (coloured). *(Ministry of Environment, 2009).*

After they were founded, the Italian River Basin District Authorities were not in force immediately due to the lack of both legislative arrangements and specific funds. So, in 2009 the law 13/2009 'Special measures on water resources and environment protection' was issued, to attribute the task to develop the RBMPs, to the River Basin Authorities at National level working together with the regional representatives.

The delay in the identification of the Districts and in the attribution of competences reduced the available time for developing the RBMPs with respect to the EC deadline: 22nd December 2009. This forced the Italian administration to introduce a specific administrative procedure, with strict time schedule, in order to respect the deadline: before the 30nd of June 2009. The Authorities, or the competent Regions, should be in charge of the contents and the objectives of the RBMPS, while the Ministry for the Environment should be in charge of the publication of specific guidelines for the editing of the plans.

After being published, the first version of the eight RBMPs was adopted by the end of July 2009 and at the same time they were submitted to the Strategic Environmental Evaluation (SEE) for a three months period, as required by the national legislation, and to public consultation for a six months period, as foreseen by the WFD.

Since the public participation period that should end by January 2010 contradicted the respect of the deadline (22 December 2009) for the adoption of most of the RBMPs, the Italian administration obtained from the European Commission the permission to shift the adoption date. This shift should also guarantee the proper and correct participation of the population and institutions to the RBMP development process.

The adoption of the Italian RBMPs occurred in different periods, the first RBMP (20 November 2009) was the one by the 'special statute' Sicily Region, six further plans were approved on 24 February 2010 while the last one was the plan for the 'special statute' Sardinia Region. While the initial approval of the final RBMP was the responsibility of the River Basin Authorities, the formal approval will be by a specific on-coming decree by the Presidency of the Council of Ministers. This decree will also contain the main outcomes from the SEE and the public participation, together with some prescriptions on the integration of the less thoroughly investigated aspects. In particular, it will contain some important observations from the Ministry for the Environment required for a rapid integration of the plans, in order to avoid in European Commission infraction procedures. For this reason, the above mentioned decree foresees an intermediate deadline for the revision and integration of the plans in one year starting from the approval date of the decree.

A special remark is necessary about the content and the needed measurement for the preparation of the Italian RBMPs. As mentioned in section 2, the Italian legislation already foresaw a planning at hydrographical basin scale with the establishment of the River Basin Authorities (law no. 183/1989), actually anticipating the WFD. Therefore, the background for the elaboration of the Plans exists and is part of already existing plans that are in force at the hydrographical basin level together with the integration and harmonization of the planning tools at the sub-district scale. The basin-wide 'Hydro-geological Risk Exposure Plan' constituted the knowledge base for the management of alluvial risk and the protection of river basins, for hydro-morphological characterization of the hydrographical net, for impacts on the lateral and longitudinal continuity of the rivers, for bed load transport and for channel dynamics. The Water Quality Protection Plans of the regional areas designed and developed the monitoring systems for both the surface and groundwater bodies, it also identified the interventions and the measures necessary to reach and maintain both the quality and the quantity objectives for the water system. These evaluations are based on the concepts of 'water balance' and 'compatible water uses' with respect to the use priority and both the quality and the quantity characteristics of the different uses.

The last, relevant and most critical aspect of the development of the RBMP is represented by the economic analysis. This aspect, following the directive's indications, should support the decision process in all phases, integrating with all other components. Actually Italy, as other Member States, is having difficulties to carry out a complete extensive economic analysis and to define the mechanism of water cost recovery. Now Italy has carried out only a preliminary economic analysis based upon the characterization of the productive-economical structure of the different basins, where available, and on the evaluation of the cost of the different water uses. However, a serious gap exists in the needed information. This gap will be filled by using data coming from the monitoring systems that have now been activated. When the economic analysis is integrated, the Italian RBMPs will be really effective to evaluate the efficiency of the costs linked to the different scenarios. This integration will be performed in the revision phase foreseen by the directive. The integration of prescriptions and observations issued by the Ministry for the Environment will, however, facilitate the integration of some important issues, such as these economics, within one year.

V – The case of the River Po District

The Po River is the largest basin of Italy with a hydrographical basin area of 74,700 km2 which represents 23% of the Country. The Po basin is extended from the Alps to the Adriatic Sea and it includes the following regions: Valle d'Aosta, Piemonte, Lombardia, Liguria, Emilia Romagna, Veneto, Toscana and the Autonomous Province of Trento.

The size of this basin makes the territory very complex with respect to physical-environmental and social-economic aspects. The Po River basin is populated by around 17 millions inhabitants (in 2007), it represents the largest agricultural area with a production equal to around 35% of the National total, 37% of industries are concentrated in this area, with a profit equal to 40% of national GDP.

The Institutional Committee of the Po River Basin Authority has adopted the Po District Management Plan on February 24, 2010. The adopted plan must still be approved with the specific decree mentioned earlier (even so, it is now covered by decree no. 152/2006, art. 66). Directly after the deliberation about the adoption, both general and urgent measures came into force for a temporary transition period.

The Po River Basin Authority had already put a series of plans and programs into force related to soil preservation, biodiversity, land use and water management, in order to assure a sustainable use of water resources. All plans and programs have been reconsidered and this has assisted the preparation of management plans. These strategic plans are based on territory and sector, prescribing specific actions for the protection of the environment and water. For each plan the competent administrative organisation, the area of interest, the normative references and the principal objectives consistent with the RBMP were indentified. The Po River Basin Authority and the regions of the basin have actively participated in the programme developed by the Ministry for the Environment to implement the WFD in Italy. In many respects the basin authority has anticipated the legislation implementing the WFD, putting into effect a set of procedures complying with the Water Framework Directive. In fact, the Po River Basin Authority since 2003, before the transposition of the WFD at national level, has developed a plan for studying and monitoring activities with the aim of increasing knowledge on the water resources at basin scale according to the classification system provided by the WFD.

According to the classification system 'B' of the WFD (Annex II) the hydro-eco-regions have been defined, through the use of the obligatory and optional descriptors appropriately combined to ensure the reliable determination of reference conditions specific for each type of water body,. These regions (Inner Alps East, Inner Alps South, Inner Alps Central, Southern Pre-Alps and Dolomites, Monferrato, Po Plain, Langhe Piemonte Apennines, Ligurian Alps, Apennines North) are areas characterized by limited variability for chemical, physical and biological variables, following the approach developed by the Centre National du Machinisme Agricole, du Genie Rural, des Eaux et des Forêts (CEMAGREF) of France. In addition, the type of surface water bodies inside the hydro-eco-regions and criteria for the definition of reference conditions for each type were identified and defined.

The knowledge development phase, based upon data collected by the Basin Authority since 1992, have allowed to identify the most critical environmental issues (according to the model DPSIR), within sectors and to develop the process of planning and intervention on the area in order of priority, with efficient and effective results.

The main problems related to water management in the Po River district concern the following aspects: (i) water quality, (ii) water use, (iii) land degradation, (iv) flood defence, (v) environmental preservation and restoration, (v) climate change, (vi) common water resources management. Many critical issues have already been addressed in the regional protection plans and various measures have been implemented. Now they being realized, both through the RBMP themselves, as well as in the context of the planning at lower level (Plan for the Hydro-geological Settlement, PAI).

Furthermore, a study (IEFE, 2004) was conducted to investigate the feasibility of integrated economic analysis at basin scale to support the measures of strategic planning for the implementation of a correct water policy. The analysis, for example, shows that simply implementing the protection plan would lead to very different rate values at different locations within the basin. Additional measures, aimed at restoring the good status, will have impacts on specific areas. In analogy with the tools adopted in other countries, it may be advisable to develop systems to share the cost at regional or basin level. These findings highlight some critical elements for the implementation of measures envisaged by the water management system. In particular, in the Po River Basin, as all over Italy, planning is performed at two levels: 1) basin plan and 2) regional protection plan (which the law considers as a ‘brief excerpt’ of the first one), while the management is shared among different services (civil services: reclamation-irrigation, soil conservation, etc). Another critical aspect is related to the very limited level of integration of the water policies. Some protection plans, for instance, provide mostly measures related to facilities, other measures have a compensatory nature (based upon public financing). Then, also redistributive mechanisms at the territorial level are needed, in order to recover areas with a poor status, caused, by excessive human impact on very restricted areas.

The Po River district still has many shortcomings: (i) the lack of assessment of the impact on the quality of water bodies, (ii) the risks of overlap between the activities of the different plans, (iii) the lack of consistency between design and planning, (iv) the inadequate economic analysis to explain the economic status of investments and the determination of the rates. Despite these weaknesses, the Po River district satisfies the administrative and normative requirements for implementing the European directives on environment and water. All the preliminary phases in environmental planning, following the principles of the recent national and European environmental policies, were completed. For this reason it represents a useful guidance for Italy on how to implement the WFD and to develop effective, efficient and integrated water policy.

VI – Conclusions

This paper presents a legislative national frame on water and environment. Italy has a long history of water legislation, but after the WFD 2000/60/EC came into force it was necessary to rapidly adapt its laws to the new disposition in order to reach the environmental objectives. In the last 20 years, important reforms have taken place, in particular: (i) the structure of water resources planning, (ii) the environmental regulation and water quality, (iii) the organization of public utilities in the water sector, this last stimulated by a trend towards privatization. Overall, the national regulative frame is complex and fragmented making it often difficult to apply. In Italian legislation, the water and environmental protection consisted of laws that gave incentives to water use to increase productivity. The aim of recent Italian legislation has been the development of land-use planning policies corresponding to the physical and environmental characteristics of the land. The reference to these two aspects is one of the most innovative features of the new legislation, which adopts a systemic approach to the problem of hydro-geological balance, at the same time protecting both land and water resources.

The decree 152/06 has been defined as “unified code for environment”, abrogating all previous legislation regarding water policy. Despite the effort of getting together all environmental topics in one single law the fragmentations of interventions, competencies and processes is still not overcome. The implementation gap still represents a problem for Italy. The water sector is really an ensemble of sectors that are little integrated (on the hand, ATO for civil water use and supply, on the other hand, the Reclamation and Irrigation Board for water irrigation and agriculture). From a legal point of view, however, the decree is a new the law on water and environment, instead of adapting the existing regulations.

As far as the quality of water bodies is concerned, the actions foreseen by the European Directive and decree 152/06 have faced difficulties in being put into practice. The available information on water quality of the country, at the moment of the emanation of the decree, is insufficiently useful to define the reference conditions and quality classes of water bodies as foreseen by the Directive. This aspect was needed for the development of the Management Plan in each District, causing the coming into force to be delayed until 2009.

The last, relevant and most critical aspect on the development of the RBMP is represented by the economic analysis. This aspect, following the directive’s indications, should support the decision process in all phases and should be integrated with all other components. Actually Italy, as is demonstrated by River Po Basin case, is having difficulties to carry out a profound complete economic analysis and to define the mechanism of water cost recovery.

Now, Italy has carried out only a preliminary economic analysis based upon the characterization of the productive-economical structure of the different basins, where available, and on the evaluation of the cost of the different water uses. However, a serious gap exists in the needed information. Such a gap will be filled when data will be available from the monitoring system that has been set up. When the economic analysis is integrated, the Italian Plans will be really effective to evaluate the efficiency of the costs linked to the different scenarios. This integration will be realised in the revision phase foreseen by the Directive.

References

Gilardoni A., Marangoni A. (2004). *Il settore idrico italiano*. Franco Angeli, Milano

IEFE (2006). *Studio di fattibilità concernente lo sviluppo dell’analisi economica dell’utilizzo idrico a scala di bacino del fiume Po così come prevista dalla Direttiva 2000/60/CE.* Institute of Economy and Policy of Energy and Environmental for River Po Basin Authority (IEFE)

IRSA-CNR (1999). *Un futuro per l’acqua in Italia*

ISPRA (2009). *Italian environmental data yearbook 2008.* Available online: www.apat.gov.it e http://annuario.apat.it

ISTAT (2008). *Agricoltura, struttura e produzioni delle aziende agricole anno 2007*. Online on:

www.istat.it/salastampa/comunicati/non_calendario/20081203_00/testointegrale20081203.pdf

Lamoglie C. (2004). *La domanda del settore irriguo nel Mezzogiorno,* Conferenza Permanente dei presidenti delle Regioni e delle Province Autonome, Matera.

Law 18 maggio 1989, no. 183 - Norms for the organizational and functional rearrangement of the soil protection.

Law 5 gennaio 1994, no. 36 – Provisions concerning water resources**.**

Legislative decree 11 maggio 1999, no.152 - Arrangements on the protection of waters against pollution and implementing directive 91/271/EC concerning urban wastewater treatment and directive 91/676/EC concerning the protection of waters against pollution caused by nitrates from agricultural sources.

Massarutto A. (2001). *Water Institutions and Management in Italy*, Working paper n. 01-01-eco, Working paper series in Economics, Università degli studi di Udine – Dipartimento di Scienze Economiche. Online on: http://diec.uniud.it/Series-in-Economics.265.0.html. Last access: April 2010.

MATTM (2009). *Enviromental Challenges*- Summary of the State of the Environmental in Italy, ISBN 88-87728-07 0, downloaded by website: www.minambiente.it, (last access: 2010-01-15).

Rossi G. (2001). Utilizzazione delle risorse idriche superficiali e rischio di siccità, in: *Hydrogeo, Rilevamento e tutela del territorio*, Maggioli, Rimini, pp. 183-201

Rusconi A. (1996). *Acqua, Editoriale Verde Ambiente*, Roma.

Shiklomanov I.A., Rodda J.C. (2003). *World Water Resources at the Beginning of the Twenty-First Century*, Cambridge University Press, Cambridge, p. 450

Internet sources

Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA): www.isprambiente.it

Ministero dell'Ambiente e della Tutela del Territorio e del Mare (Ministry for the Environment, Land and Sea: www.minambiente.it

Implementation Water Framework Directive: www.direttivaacque.minambiente.it

River Basin Management Plans, available at the following sites:

www.alpiorientali.it/documenti/list_doc/PdP_doc.php

www.adbpo.it/on-multi/ADBPO/Home/PianodiGestioneepartecipazionepubblica.html

www.appenninosettentrionale.it/distretto/testo.php?id=32

www.abtevere.it/distretto/pdg/pdg_30_06_2009.htm

www.ildistrettoidrograficodellappenninomeridionale.it/relazione_progetto_di_piano%20.pdf

www.regione.sardegna.it/documenti/1_41_20090717130227.pdf

www.artasicilia.it/web/pdi/progetto%20di%20piano.pdf

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(1) The data utilized take into account the potential supply and the connected source. For determining the actual requirement,, data from both remote sensing and field surveys was used.

(2) APAT, Annual yearbook, 2007.

Comparative analysis of Egyptian Water Policy and Water Framework Directive

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Abstract. Water is a finite resource and it is imperative that all nations have sound policies and plans for its exploration, development and use, to meet the requirements of all users. There are two categories of water policies in Egypt; water development policies and water allocation policies. The objectives of this paper are to highlight the main issues considered in the Egyptian Water Policy (EWP), and the water notes addressed by the Water Framework Directive (WFD). Moreover, the paper presents a comparative analysis of the similarities and differences between the EWP and the WFD adopted by the European Union. The analysis shows that protection of water bodies from pollution, as well as water quality monitoring programs are the main similarities between the EWP and the WFD. Specific similarities and differences are listed in the paper. In general the Egyptian Water Policy addresses the same issues as the WFD although some, for instance cost recovery, are dealt with in a different way. A recommendation is that more attention should be devoted to climate change issues in any new water policy.

Keywords: Water management – Water availability – Water use – Policies

Analyse comparative de la politique égyptienne de l'eau et de la directive-cadre sur l'eau

Résumé. *L'eau est une ressource limitée et il est impératif que tous les pays appliquent des politiques et des planifications rigoureuses en matière d'exploration, de développement et d'utilisation de l'eau, afin de pouvoir répondre aux demandes de tous les utilisateurs. L'Egypte connaît deux catégories de politiques de l'eau : les politiques de développement de l'eau et les politiques de répartition des ressources en eau. L'objectif de ce document de réflexion est de mettre en avant les principales problématiques qui ressortent de la politique égyptienne de l'eau (PEE) et des notes abordées par la directive-cadre sur l'eau (DCE). Ce document de réflexion présente également une analyse comparative des similitudes et des différences entre la PEE et la DCE adoptée par l'Union européenne. L'analyse montre que la protection des plans d'eau contre la pollution ainsi que les programmes de surveillance de la qualité de l'eau constituent les principaux points communs entre la PEE et la DCE. Des similitudes et différences spécifiques figurent dans le document de réflexion. De façon générale, la politique égyptienne de l'eau aborde les mêmes problématiques que la DCE, bien que certains aspects, tels que le recouvrement des coûts, se caractérisent par une approche différente. Une recommandation est que les problématiques du changement climatique devraient faire l'objet d'une attention plus soutenue dans toute nouvelle politique en matière de ressources en eau.*

Mots clés: *Gestion des eaux – Eau disponible – Utilisation de l'eau – Politique*

I – Introduction

Water resources in Egypt are becoming scarce. Surface-water resources originating from the Nile are already fully exploited and groundwater sources are being brought into full production. Egypt is facing increasing water needs, caused by a rapidly growing population, an increased urbanization, higher standards of living, and by an agricultural policy which focuses on increasing production in order to feed the growing population. Improved planning and management procedures to develop, allocate and use water are key measures generally prescribed to make the optimum use of available water. Dr. Abu-Zeid, chairman of Egypt's Water Research Centre points out that 'satisfying future demands in Egypt depends on better utilization and efficient use of present water resources. Optimal water management is an essential prerequisite for sustainable development of Egypt' (Hvidt 1995).

Life in Egypt is based on Nile water. Availability of water, in both quantitative and qualitative terms, is a basic human right and sound planning is necessary to ensure it. Without any water policy, all our activities would be conducted on the basis of our experience and expediency. However, we have come to realize that water is not an infinite bounty of nature. Rather it is a finite resource and it is imperative that we have sound policies and plans for its exploration, development and use to meet the requirements of all users (MWR-Bangladesh 1999). The objectives of this paper are to highlight the main issues considered in the Egyptian Water Policy (EWP), and the water notes addressed by the Water Framework Directive (2000/60/EC; WFD) that has been adopted by the European Union. Moreover, the paper presents a comparative analysis of the EWP and the WFD.

II – Review of the Egyptian water policy

There are two categories of water policies in Egypt, Water Development Policy which is an action affecting the increase of quantities of water available for distribution and use; and Water Allocation Policy that is defined as action affecting the distribution of given quantities of water among different uses and users (Abdin and Gafaar, 2008).

Historically several policies have been formulated in Egypt to manage the water resources. Following is a list of these polices from 1975 till 2002.

1. Water Policy for the year 1975
2. Water Policy for the year 1980
3. The Egyptian Water Master Plan, year, 1982
4. Water Policy for the year 1986
5. Water Policy for the year 1990
6. Water Security Project, 1993
7. Water Policy for the year 1999
8. The National Water Resources Policy (NWRP 2005)

Those polices have lead to many important projects such as:

1. The construction of new barrages at Isna, Nag-Hammadi and Assiut along the course of the Nile with the purpose of expanding its cultivated area and to increase the cropping intensity.
2. the Aswan Dam and its rehabilitation, and the construction of Gabal Awlia Dam in Sudan which increases water storage capacity to enable the country to convert more than half a million feddan (a feddan is 0.42 hectare) in the Upper Egypt from basin to perennial irrigation.
3. Financing the rehabilitation of the Owen Falls Dam in Uganda to make use of the additional quantities of water to increase the cultivated area.

Recent water resources policies include different structural measures such as rehabilitation of irrigation structures, improvement of the irrigation system, installation of water level monitoring devices linked to telemetry systems, improvement of the drainage system, etc. Several non-structural measures have also been implemented, including the establishment of the irrigation advisory service and the expansion of the water users association (WUAs) for ditches and mesqas[1], the establishment of water boards on branch canals, the promotion of public awareness programs as well as the involvement of stakeholders. Laws and legislation are also considered to be non-structural measures.

III – The National Water Resources Plan (NWRP)

This section describes in some detail the latest water policy (1997-2017) emerged from the NWRP project. The planning horizon covers a period of 20 years until the year 2017. A more integrated management approach is adopted herein, which requires a much closer coordination among the concerned government institutions and the active participation of water users in planning, management and operation of the water distribution system. It also necessitates the establishment/enhancement of the legal basis for water allocation, conservation and protection as well as user participation in water management (ICID, 2005). The main objectives of this policy are to improve the utilization efficiency, water productivity, and protection of water resources in Egypt. The new water policy considers both water quality and water availability to achieve a match between water supply and demand, both spatial and temporal, (NWRP, 2005).

The NWRP describes how Egypt will use its water resources in a sustainable and responsible way from a socio-economic and environmental point of view. With the rapid growth of population and new land development for agriculture, there is a threat of more pollution. There is a need therefore to (i) reduce water use (demand management), (ii) optimize the supply (supply management), and (iii) abate water pollution (pollution control). The drafted plan also comprises of an investment plan, completed in March 2004. The plan addresses all water related activities and considers both the technical, managerial and institutional interventions. Important decisions on allocation of resources and priority setting of interventions are indicated.

1. Water Pollution

The Egyptian Water Policy (EWP) strives towards enhancing water quality that is threatened by the steady increase in population and the continuing expansion of urbanized and industrialized areas. Also, significant quantities of municipal and industrial wastes are presently discharged into the Nile River, canals and drains without proper treatment and cause chemical and biological pollution. In addition, agricultural activities, especially excessive fertilizer and pesticide use and associated run-off, are a source of pollution (Fahmy *et al.,* 2002). The EWP suggests a number of protection measures for water quality that will mainly focus on keeping poor quality waters separated from good quality waters, which will maximize the localized drainage water reuse. Tremendous efforts are required to prevent untreated domestic water and industrial water from discharging into drainage networks, as it is recommended to apply intermediate drainage reuse (Elwan, 2006).

Over-pumping of groundwater, particularly from coastal aquifers or from groundwater reservoirs close to geological formations carrying saline water, is increasing groundwater salinity with negative impacts on land use. The shallow groundwater reservoir of the Delta region is exposed to pollution, especially in its northern part which also faces seawater intrusion. The newly reclaimed areas north and west of the Delta region face similar problems. The aquifer in these areas receives seepage from agricultural drains, which are in some cases polluted with industrial and municipal wastes. Untreated rural wastewater also percolates into the groundwater aquifer.

As a result, the Egyptian government has been increasingly concerned about the protection of the Nile and other water bodies. Laws and legislation have been passed to ensure the sustainability of water resources development and use, including the definition of suitability of water quality for each specific use, and the control of water pollution. The most important of these laws are Law 48/1982, relating to the protection of the Nile and other waterways from various sources of pollution, and Law 4/1994 on protection of the environment. Pollution control is also being achieved by establishing the water quality-monitoring network (NAWQAM, 1998) along the irrigation and drainage systems, as well as in groundwater wells.

2. Water Allocation

A number of policy measures and considerations that affect overall water use efficiency, water allocation, and its effect on quality can be stated as follows (NWRP, 2005):

- Improvement of irrigation efficiencies and drainage conditions in prioritized areas (i.e. areas overlying or adjacent to salt sinks, and where reuse of drainage water is not recommended).
- Gradually introduce modern irrigation techniques to replace traditional irrigation methods.
- Prioritization of drainage water reuse in areas where;
- drainage water would otherwise flow to sink,
- the least harm is done to other downstream users, and
- Groundwater is least vulnerable to pollution.
- Local reuse of drainage water in the upstream stretches will result in less accumulation of salt and pollutant concentration at the downstream ends.
- Reuse of drainage water policy should be reviewed, considering the application of intermediate reuse at appropriate locations.
- Water allocation should be de-centralized based on equal opportunities for farmers within the same region, and be based on a set annual amount per feddan.
- Improvement of the infrastructures for proper water distribution, and installation of upstream discharge regulators and control structures at key points of the irrigation system.
- Promoting the use of non-conventional salt tolerant crops and fish farming.
- Separating return flows of low quality water from fresh water, and forcing municipal and industrial users to treat effluent before discharging into the drainage system.

Within the 1997-2017 policy the water savings were assumed to come from the following interventions:

- Change of cropping pattern (mainly reduction of rice area).
- Increased reuse of drainage water.
- Increase of the area covered by irrigation improvement projects.
- Reduced amount of drainage water flowing to the Mediterranean Sea.
- Increased exploitation of deep groundwater.
- Increased reuse of treated sanitary sewage and treated industrial effluent.
- Increased production of desalinated water.

IV – Review of the Water Framework Directive

This section gives an introduction and overview of key aspects of the implementation of the Water Framework Directive (WFD). It is a European Union directive which commits European Union member states to achieve good qualitative and quantitative status of all water bodies (including marine waters up to a kilometer from shore) by 2015. It is a framework in the sense that it prescribes steps to reach the common goal rather than adopting the more traditional limit value approach. To achieve good water status both the ecological status and the chemical status of a water body need to be at least good (WFD).

The European Commission, division Environment, published twelve "Water Notes" (http://ec.europa.eu/environment/water/participation/notes_en.htm) to inform about the key aspects of WFD implementation. We use these notes as the basis of our discussion of WFD and the comparison with water policy in Egypt.

Water note 1: Joining forces for Europe's shared waters - Coordination in International River Basin Districts (IRBD)

After setting up administrative structures, the next step in implementing the directive was the environmental and economic analysis of river basins, to be completed in 2005. In many IRBD, this meant bridging different national traditions in water management. For example, while some countries already used a river basin approach, others did not.

Water note 2: Cleaning up Europe's waters - Identifying and assessing surface water bodies at risk

By designating separate water bodies along the course of a river, Member States can focus their monitoring activities on problems affecting specific water bodies. They can then tailor measures to improve conditions in the water bodies at risk. Governments, stakeholders and the public will be able to track the progress of these measures to improve the status of the bodies at risk. This strategy assures rational applications of effort on urgent water qualities.

Water note 3: Groundwater at Risk - Managing the water under us

Groundwater provides the steady, base flow of rivers. Maintaining this flow and keeping it free from pollution is vital for surface water ecosystems. Groundwater is also a crucial source of drinking water, supplying the water systems used by three out of four EU citizens. In order to delineate individual groundwater bodies, Member States share monitoring data and scientific knowledge to analyze underground geology.

Water note 4: Reservoirs, Canals and Ports - Managing artificial and heavily modified water bodies

The directive allows Member States to designate some of their surface waters as heavily modified water bodies or artificial water bodies whereby they will not need to meet the same quality criteria required of other surface waters. An artificial water body is defined as a body of water created by human activity, while a heavily modified body is a water body that has undergone man-made alterations that have substantially changed its character.

Water note 5: Economics in Water Policy - The value of Europe's waters

Two key economic principles have been introduced, first, WFD requires water users – such as industries, farmers and households – to pay for the full costs of the water services they receive; second, the directive calls on Member States to use economic analysis in the management of their water resources and to assess both the cost-effectiveness and the overall costs of alternatives when making key decisions. Other benefits of clean water are more difficult to measure.

Water note 6: Monitoring programs - taking the pulse on Europe's waters

Monitoring is the main tool used by Member States to classify the status of each water body (a water body is a section of a river or other surface water or a distinct volume of groundwater). The directive sets a five-class scale - high, good, moderate, poor and bad status - and it requires Member States to achieve good status in all waters by 2015. The directive sets a common approach for monitoring water quality across all Member States, but does not specify the methods to be used. It is up to Member States to decide on the best method based on local conditions and existing national approaches.

Water note 7: Inter-calibration - a common scale for Europe's waters

To ensure that national assessment methods to measure good ecological status deliver comparable results and are consistent with the directive, an inter-calibration exercise is required between Member States with the assistance of European Commission. The directive also specifies a five-point scale for surface water quality, from high to bad (see the following figure). The work focuses on defining the upper and lower boundaries of good status. The line between "good" and "moderate" status is particularly important, as it defines whether or not a water body will meet the directive's 2015 goal of good status.

Water note 8: Pollution - Reducing dangerous chemicals in Europe's waters

Chemicals find their ways into European waters from point sources, such as waste waters from industrial installations, and from diffuse sources, such as pesticide runoff into water from agricultural lands. Chemicals from consumer products and other products can leach into water from unprotected landfills, another diffuse source. In designing measures to control the chemical pollution from these many sources, the Water Framework Directive takes a combined approach. It considers pollution in terms of what is released into the environment and the resilience of the receiving waters.

Water note 9: Integrating water policy - linking all EU Water legislation within a single framework

This note invests in infrastructure for collecting and treating sewage in urban areas, while the Nitrates Directive requires farmers to control the amounts of nitrogen fertilizers applied to fields. The Directive on Integrated Pollution Prevention and Control (IPPC), adopted a few years later, aims to minimize pollutants discharged from large industrial installations.

Water note 10: Climate change - Addressing floods, droughts and changing aquatic ecosystems

Preparing for climate change is a major challenge for water management in the European Union. Climate impacts will in turn affect aquatic ecosystems. Hotter temperatures and reduced water flows will increase the risks of eutrophication in many rivers, lakes, and coastal waters. This will particularly be the case in southern Europe where wetlands and other protected areas may disappear. Likewise, climate change will also harm water quality in northern Europe with warmer temperatures potentially increasing eutrophication in the Baltic Sea. Climate change is also expected to bring sea-level rise, which will erode coastlines and, together with strong storm surges, will put low-lying coastal cities and towns at greater risk from flooding. Sea-level rise will also harm coastal wetlands.

Water note 11: From rivers to the sea - Linking with the new Marine Strategy Framework Directive

The new Marine Strategy Framework Directive extends EU water legislation to the marine environment and constitutes the environmental component of Europe's new cross-sector Integrated Maritime Policy. The new directive calls on EU Member States to ensure the "good environmental status" of all of Europe's marine regions and sub-regions. The new directive states that fishing and other activities should not push the populations of commercially exploited fish and shellfish beyond their safe limits and that non-indigenous species should not affect ecosystems. Good environmental status also requires physical, chemical and acoustic conditions that support healthy ecosystems.

Water note 12: A common task - Public participation in River Basin Management Planning

The directive calls for the public to be informed and involved in the preparation of river basin management plans, which identify measures to improve water quality. Participation occurs via consultation mechanisms that government bodies use to consult people and interested organizations (stakeholders) to gain from their knowledge and experience and to jointly develop solutions to problems. To ensure public participation, the directive recognizes that it is necessary to provide proper information to the public of planned measures before final decisions on the measures are adopted. Public participation extends to all water users and non-governmental organizations, such as local and national environmental groups.

V – Comparison between the WFD and EWP

Protection and preservation of the natural environment is essential for sustainable development. As most of the countries' environmental resources are linked to water resources, continuous protection of water bodies from pollution, as well as water quality monitoring programs are the main similarities between the EWP and the WFD. In the following paragraphs comparisons are made between the water notes of the WFD and main policy items of the EWP. Some of the water notes will not be discussed because they are not relevant, such as note 7, a common scale, which is specific for EU countries and does not apply to Egypt because we do not manage our system, or develop a common scale, together with other countries.

The following similarities between EWP and WFD are discerned:

1. ***Cleaning up polluted waters,*** water note 2, was tackled by the NWRP. Treated agricultural drainage water was considered a non-conventional water resource. The NWRP includes considerable attention towards the increased use of treated wastewater. Additional attention is required to protect sensitive areas, such as groundwater wells and intakes of public water supply. Hence, major programs are already being implemented to treat domestic and industrial sewage water and desalination of sea water (until now 55 million m3 was desalinated). Still, those programs are not sufficient yet and water quality in many areas is below the standard, and thus public awareness programs are strongly encouraged, see figure (1), (NWRP, 2005).
2. ***Groundwater,*** water note 3, is given a lot of attention in the EWP in order to achieve an optimum utilization of the different aquifers. To achieve this objective, many studies were done to estimate available water quantities within each aquifer, and to estimate suitable abstraction rates of it. Also, unlicensed wells (37,500 wells) were identified (Fahmy *et al.,* 2002).
3. ***Reuse of treated water.*** Treated sewage and industrial effluent reuse are increased with the increase of the construction of wastewater treatment plants. However in Egypt, the rate of construction of new treatment facilities (e.g. figure 2) lags behind the planned rates due to budget constraints. Sea and brackish water desalination is taking place at a modest rate, as the rocketing prices of oil cause the desalination cost to be a major constraint. In order to bridge the gap between supply and demand, drainage water is heavily used unofficially by individual farmers whenever they experience shortage in fresh irrigation water. This situation is causing severe uncontrolled water pollution especially in the most northern part of the country.

Figure 1: Water pollution and need of public awareness.

Figure 2: Water treatment plant.

Stakeholders participation is taken care of by enhancing the participation of the public and private sectors with other civil society groups and organizations. The EWP is elaborating on the institutional reform policy in water management that aims at an improvement of the performance of the irrigation and drainage system by transferring public responsibilities to the private sector. The present vision is that the government should remain fully responsible for the main infrastructures of the irrigation and drainage system. Meanwhile, the private sector should be more involved in the operation and maintenance of the lower infrastructures of the system, such as the branch canals and the district canals. This new policy advocates some further steps towards such an involvement. Examples of the Egyptian experience with these steps are the establishment of water users associations at mesqas' level, (see figure 3), and water boards at branch canals or district's level.

Figure 3: Farmers' participation in an improved irrigation system.

4. ***Finally, the integration of water management with related socio-economic policies*** requires co-operation between representatives of different groups, i.e. stakeholder involvement. These stakeholders are not to be restricted to organizations of public administration, such as other ministries and governorates. The private sector and civil societies have their own responsibilities as water users. This sector should also have a task and role in an efficient use of water resources, the development of new water resources and the protection of water quality. The new strategy contains proposals to enhance the involvement of representatives from all stakeholders.

The following differences between EWP and WFD can be discerned:

1. ***Water pricing and economics*** in the water policies, as in water note 5 where the WFD calls on water users - such as industries, farmers and households - to pay for the full costs of the water services they receive. However, in EWP adopts different cost recovery concepts for different water users. Not all users pay the full costs: farmers may pay only for the operation and maintenance costs for the water delivery system. Other users such as industries and domestic users may pay differently and may share the full costs. This difference results from a different cultural perspective (water is essentially free, only services related to it are charged) and different socio-economic circumstances (some people are so poor that if they would have to pay the full costs they could not buy water).
2. ***Linking with marine and coastal water,*** the new WFD calls on EU Member States to ensure the "good environmental status" of all of Europe's marine regions to achieve ambitious environmental objectives for aquatic ecosystems. In contrast, the EWP calls on adopting the concepts of Integrated Coastal Zone Management (ICZM) within the context of Integrated Water Resources Management (IWRM) policy. Such linking of ICZM and IWRM would allow achieving ambitious goals of protecting both coastal and transitional water such as the Northern Lakes of Egypt. Demonstration of such a comparison is presented in figures 4 and 5. So this a broader objective than the WFD has.

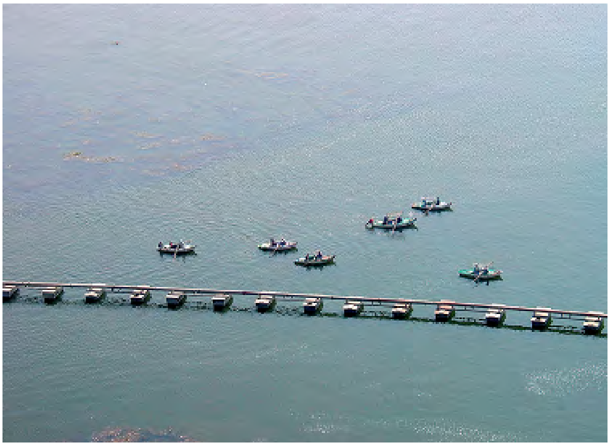

Figure 4: Pollution risk of coastal water and marine environment, Red Sea, Egypt.

Figure 5: Wind power turbines at Denmark's coasts.

3. ***Shared waters and coordination in international river basins.*** The Nile basin is a unique case, in which Egypt has taken the lead and signed a number of agreements with the Nile Basin countries. The most important ones are the 1929 and 1959 agreements. Initiated by the importance of cooperation among the Nile river basin countries, Egypt has participated in certain projects in the upper Nile counties. Examples of such projects are: (a) The Hydromet project to study the Equatorial lakes basin (mid 1960s), (b) The Nile basin cooperation framework (1992), and (c) the Nile basin initiative program (1999). So Egypt is well aware of the responsibilities connected to belonging to an international basin. Cooperation between Egypt and the other Nile Basin countries is going on and will continue to ensure the supply of sufficient water to all basin countries needed for development.

4. ***Regarding Public participation in River Basin Management Planning,*** WFD calls for the public to be informed and involved in all steps required for the preparation of River Basin Management Plans (RBMP). EWP has adopted the concepts of stakeholder's participation and users' involvement in water management at different scales of the river basin by, for example, the establishment of the irrigation advisory service, the expansion of the water users association (WUAs) for ditches and mesqas and the establishment of the water boards on branch canals. So whereas WFD requires public participation to be part of the planning process, EWP adopts participation in the domain of operational management and planning.

VI – Conclusions and recommendations

The latest water policy in Egypt has taken into account all the relevant issues addressed in the water notes, based on the European Commission's water framework directive, as well as all the international experiences that could help in improving water sector in Egypt. In general the Egyptian Water Policy addresses the same issues as the WFD although some, such as cost recovery, are dealt with in a different way. The new water policy measures will address various kinds of governmental objectives. It is impossible to achieve all objectives at the same time, either due to financial limitations or because different objectives may require contradictory measures. This implies that choices have to be made with respect to the strategy orientation and the related measures. The new policy will address the trade-offs involved and put them forward in the discussions with the stakeholders. In additions, the climate change issues (such as seal level rise, floods, and droughts), which are strongly related to coastal zone management and water resources have to be taken care of seriously in drafting any new water policy for Egypt.

References

Abdin A.E., Gafaar I. (2008). *Egyptian Water Policies towards Increasing its Value*, paper presented at MELIA workshop, Istanbul 21-23 March 2009.

Fahmy S., Ezzat M. N., Shalaby A.R., El-Atfy H., Kandil H., El Sharkawy M., Allam M., El Assiouty I., Tczap A. (2002). *Water policy review and integration study*, working paper. Report no. 65, United States Agency for International Development/Egypt.

ICID (2005). *Water Policy Issues of Egypt.* Country Policy Support Programme

Elwan H.S. (2006) *Impacts Of Integrated Water Resources Management Policy on Water Quality And Availability.*

EC (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

EC (n.d.). http://ec.europa.eu/environment/water/participation/notes_en.htm

Hvidt M. (1995). Water resource planning in Egypt. In: Watkins, E. ed. T*he Middle Eastern Environment.* Selected Papers of the 1995 Conference of the British Society for Middle Eastern Studies, St Malo

NWRP (2005). *National Water Resources Plan for Egypt - 2017*, Ministry of Water Resources and Irrigation, Planning Sector. Cairo, Egypt, January 2005.

MWR-Bangladesh (1999). *National Water Policy.* http://www.mowr.gov.bd/Documents/National%20 Water%20Policy%20%28English%29.pdf.

NAWQAM (1998). *National Water Quality and Availability Monitoring Project, 1998.* Inception Report, National Water Research Center, Cairo, Egypt.

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(1) Mesqas are very small channels within the end user farm

Comparative study between Moroccan water strategies and WFD

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Abstract. Water resources in Morocco are limited, and irregular in time and space. Furthermore, the water resources undergo a deterioration of their quality by the various pollutant emissions, such as domestic and industrial wastewater. On the other hand, these resources are increasingly scarce due to a continued growth in demand. A new water law has come into force in 1995 that provides a comprehensive framework for integrated water management. This new law constitutes an efficient juridical tool to develop considerable efforts for water use and mobilization in order to make them compatible with aspirations of socio-economic development of Morocco in the 21 century. The Water Law has a number of similarities to the Water Framework Directive. For example it specifies the establishment of Basin Agencies which evaluate, plan and manage the water resources in their respective river basin, in order to strengthen the institutional arrangements of water management. Other principles stated in the Law are; 1) water as a public domain, 2) regulation of development, distribution, and sale of potable water, 3) improvement of agricultural water development and use, and 4) security against illegal water resources development, or conduct which causes water pollution. The paper concludes that including water demand management in Moroccan water policy has required major changes in the institutional arrangements.

Keywords: Water management – Policies – Institutional reform – Water availability – Water use

Étude comparative de la politique de l'eau au Maroc et de la Directive-cadre sur l'eau

Résumé. *Au Maroc, les ressources en eau sont limitées et irrégulières dans le temps et l'espace. Elles subissent en outre une dégradation de leur qualité en raison des diverses émissions polluantes comme les effluents domestiques et industriels. D'autre part, ces ressources en eau se font de plus en plus rares en raison de la croissance continue de la demande en eau. Une nouvelle loi sur l'eau est entrée en vigueur en 1995 et fournit un cadre complet pour la gestion intégrée de l'eau. Cette loi constitue un instrument juridique efficace, qui permet par ailleurs de valoriser encore plus les efforts considérables consentis pour la mobilisation et l'utilisation de l'eau, et de les rendre compatibles avec les aspirations au développement économique et social du Maroc au 21e siècle. La nouvelle Loi sur l'eau présente des similarités avec la Directive-cadre sur l'eau. La Loi spécifie par exemple la création d'agences de bassins hydrauliques qui ont pour mission d'évaluer, de planifier, de développer et de gérer les ressources en eau au niveau du bassin respectif, afin de renforcer les arrangements institutionnels concernant la gestion de l'eau. Les autres principes mentionnés dans la Loi sur l'eau sont : 1) l'eau est un domaine public, 2) la régulation du développement, de la distribution et de la vente de l'eau potable, 3) l'amélioration du développement et de l'utilisation de l'eau pour l'agriculture, et 4) la lutte contre le captage illégal des ressources en eau et contre tout comportement pouvant entraîner la pollution des ressources en eau. L'article conclut en déclarant que le fait d'inclure la prise en compte de la gestion et de la maîtrise de la demande en eau dans la politique de l'eau marocaine a exigé l'apport de changements majeurs dans les arrangements institutionnels.*

Mots clés: *Gestion des eaux – Politique – Reformes institutionnelles – Eau disponible – Utilisation de l'eau*

I – Introduction

Morocco is a dry country with unevenly distributed water resources and erratic rainfall patterns. Therefore, the country has increased the number of dams from 12 in 1960 to 114 by 2006, which has led to a nine-fold increase in water storage capacity. Water problems remain serious, however, and reservoir water levels have decreased as a consequence of successive years of drought. This has resulted in the need to use groundwater either as a supplementary or as the main source of water. Unfortunately, groundwater is being rapidly depleted as the drilling of a massive number of wells has overtaxed subterranean supplies (World Bank 2009).

Morocco is located in the northwest of Africa, and its climate is marked by sharp contrast in temperatures between the Mediterranean climate and desert. In addition the annual rainfall varies from less than 100 mm in the south and south east of the country to 1000 mm in the middle Atlas and greatly exceed 1700 mm on the Rif Mountains (Choukr-Allah, 2005).

The average annual precipitation in Morocco is 150 billion m3, varying year by year between 50 billion m3 and 400 billion m3. Annual evaporation is, on average, 121 billion m3. Of the remaining 29 billion m3, about 22 billion m3 of water are technically and economically exploitable. These exploitable resources are comprised of 18 billion m3 of surface water and 4 billion m3 of groundwater (Benbiba, 2010).

In Morocco, the volume of water available per inhabitant per year, an indicator of a country's wealth in terms of water, is about 1000 m3/capita/year. Scarcity is often defined as starting from this point. At present, the available water varies between 180 m3 per capita per year for the areas known to be poor in terms of water resources (Souss-Massa, Atlas South, Sahara) and 1850m3 per capita per year for areas of the basin of Loukkos, Tangiers and Mediterranean Coast, known to be relatively rich. It is probable that the water resources per inhabitant will reach around 720m3 per capita per year towards 2020. At this time, about 14 million inhabitants, i.e. almost 35% of the total population of the Kingdom will have less than 500 m3 per capita per year at their disposal (Choukr-Allah, 2005). Water scarcity is thus becoming a permanent situation that can no longer be ignored when drawing up strategies and policies concerning water resources management in Morocco.

Table 1: Water Resources Availability.

Basin	**Population (Millions of inhabitants)**	**Water resources availability (m3/ capita /year)**
Loukkos, Tangiers and coasts	3.645	1353
Moulouya	2.448	1065
Sebou	7.918	0996
Bou Regreg	9.076	0109
Oum Er-Rbia	6.171	1232
Tensift	3.131	0546
Souss-Massa	3.250	0362
Atlas South	2.606	0735
Sahara	0.625	0168

Source: AGR/DDGI (1999).

The hydraulic assessments prepared within the framework of planning studies, carried out at the level of all the hydrologic basins, (table 1) show the available water per person per year for all Moroccan basins. Moreover, during the last decades the water quality has degraded as a consequence of pollution originating from various sources of (domestic, industrial, agricultural wastewaters etc.).

The paper outlines the Moroccan legal and institutional framework compared with the European commission's Water Framework Directive ((2000/60/EC; WFD), followed by a description of the Moroccan water plan. Subsequently, both environmental and economic aspects of the policies are discussed.

II – Legal and institutional framework

Morocco has instituted, within law 10/95 (OB 1995), river basin agencies (RBA). Their mission includes contributing to water resources protection. The role of RBA's will be discussed in some detail later in the paragraph. Other principles stated in the Law are; 1) water as a public domain, 2) regulation of development, distribution, and sale of potable water, 3) improvement of agricultural water development and use, and 4) security against illegal water resources development or conduct which causes water pollution.

The water-related strategy rests on a fundamental principle which considers water as a limited resource requiring optimal management and protection against all forms of pollution. The institutional organization in Morocco is based on 3 levels, including the major stakeholders involved in the water domain (see Fig 1).

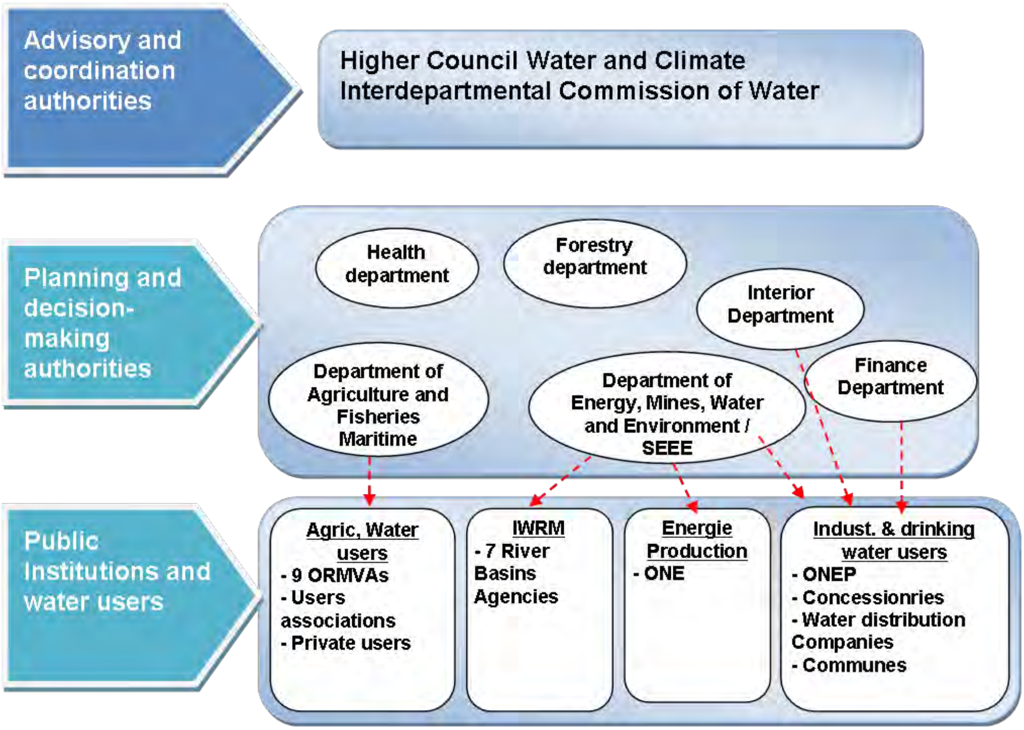

Figure 1: Major stakeholders involved in the water domain. (Ouassou *et al.,* 2005).

The Water Framework Directive outlines an overall strategy for water management and mentions a number of important aspects, namely: river basin management, whereby water resources are managed in an integrated manner at a catchment level. The implementation of the first step of the WFD — basin characterization (pressure and status, identification of main water management issues, definitions of environmental objectives) has been implemented through the water strategy of Morocco. However, it is very complex implementing these principles (dealing with the catchment area in its entirety, integrating a high number of water usages and users, implementing multidisciplinary strategies).

The declaration of a 'water' law in 1995 was a major breakthrough in Moroccan water policy. The aim was to rationalize water use, providing access for all to this resource and reducing disparities between cities and villages, intending to ensure water security all over the country. This law provided Morocco with some effective technical, financial, and institutional tools in order to face the most crucial challenges in the water sector. In addition, the Government created River Basin Agencies to implement a decentralized water policy in line with national guidelines; encourage the participation of all regional and local players and specifically water users in the implementation of this policy; and finally implement this policy in a framework of partnership and participation, in line with the guidelines expressed in local development plans (Saleth and Dinar, 2004).

In this way the Moroccan water strategy complies with one of the major objectives of the WFD which is the objective to reach a good water status based on participatory river basin management planning. It includes a five-yearly plan which specifies programmes of measures requiring the consultation and active involvement of all stakeholders.

The River Basin Agencies have the responsibility of managing and regulating water resources besides their role in developing and supplying water. They have to monitor and regulate water use and water quality as well as plan and organize flood control and water-related emergencies within their respective basins' (Doukkali, 2005). Morocco is divided into 9 major river basins, with long-term water resources development policies planned and specified in Integrated Master Plans. Establishing these plans mainly aims to estimate water demand from different sectors such as potable and industrial water, irrigation and hydropower generation, and to determine optimal integrated scheme of the water resources development. The first RBA pilot (Oum Er Rbia) was created in 1997, six others River Basin Agencies in 2002, and two more River Basin Agencies were defined by the year 2009. The RBAs in Morocco are special as they are based more on projects than on the river systems and therefore, their boundaries are defined both by hydrology and demand areas. Moreover, as agricultural agencies actually manage them, they integrate water delivery with the provision of farm inputs (Saleth and Dinar, 2000).

An important responsibility of the RBAs is to prepare their river basin management plans based on the principles of IWRM. The RBA Water Master Plan, as specified in Article 16 of the water law, is a constituent part of the National Water Master Plan. It must be formally approved by decree. The twenty-year Master Plan summarizes available water supplies in a river basin and proposes allocations to municipal, industrial and agricultural users. The water plan also prescribes measures for groundwater exploitation and indicates the conditions for granting of permits to water users. Moreover, the Master Plan can be reviewed and amended every five years if changing conditions warrant amendments (Doukkali, 2005).

III – The Moroccan national water

Morocco will not only focus on increasing water supply but also on further demand management in the future, in view of the decrease in potential water resources, depletion of underground water due to over-development, sedimentation in dams, and deterioration of water quality.

Although Morocco has a centralized political structure, water administration is comparatively decentralized and demonstrates functional specialization. The Directorate General of Hydrology under the Secretary of State of Water and Environment (SSEE) plans and develops water resources. Furthermore, the nine Regional Authorities for Agricultural Development (RAADs) under the Ministry of Agriculture and Fishery (MOAF) develop and maintain water distribution networks, acquire and distribute water, collect water charges, and provide farm inputs and extension services. Local governments and farmers play a stronger role in water distribution and system maintenance in smaller systems, including areas depending on groundwater. 'The National Office of Potable Water, again under the SSEE, acquires and distributes water not only on a retail basis to households and industries in major urban centers but also on a bulk basis to municipal/provincial governments' (Saleth and Dinar, 2000).

Water policy and water administration were significantly affected by the water law of 1995. It states that the Supreme Water Council (involving all major water sector stakeholders) the key organ for national level water policy and the RBOs - each covering one or more RAADs - as the regional nodes of water administration. The national and basin water plans are to provide technical framework for formulating both national and regional water management strategies. By advocating users pay principle and full cost recovery, the law allows the imposition of water abstraction and pollution taxes. Although the new law views water as a public resource, it does permit authorized use rights and recognizes also the water rights obtained under the 1914 law' (Saleth and Dinar, 2000).

The latest ministerial reorganization brought together mines, water, and environment under the Ministry of Mines, Water, and Environment. This can strengthen the administrative cohesion between water and environment sector agencies and can support the development of integrated water resource management policies. The ongoing programs for canal lining, pressurized supply of canal water, and the application of sprinkler and drip systems are vigorously pursued to enhance water use efficiency (Kerfati, 2001). Although more institutional changes are required, the basic institutional conditions for water management improvement have been established (Saleth and Dinar, 2000).

In order to recover the cost of water supply Moroccan government has granted autonomy to public urban water supply agencies and the privatization of urban water supply in cities such as Casablanca, Rabat, and Tanger. The privatized water supply in Casablanca provides an example of how the urban water sector may be organized differently. Similarly, the use of a revolving fund to provide loans to urban users both for water meter installation and for retrofitting water appliances is also an innovative way of having users self-finance urban water conservation (Saleth and Dinar, 2000).

The major objectives of the water resources sector plan in Morocco are to continue the regulation and institutional reform implementing and applying all the decrees of the water law 10-95. Also, the preservation and protection of the water resources and the fragile zones, the protection of water quality and development of measures to prevent their pollution, the protection of ground waters (groundwater contract), and sensitive zones by developing water shed basins, oases, humid zones, natural lakes and coastal region (Kingdom of Morocco 2001). In the mean time the water plan encourages the management and development of the supply by increasing the use of non-conventional water resource, including desalinization of 400 Million m3 per year, the reuse of treated wastewater at a rate of 300 Million m3/year and efficient uses of rainfall water harvesting. The plan includes also a programme of capacity building of the water department.

IV – Environmental aspects

A national monitoring programme of the water surface, ground and coastal water quality has been set up by the Secretary of state in charge of water and environment. Since 1999 several national reports on water quality for the years (1999, 2000, 2003 and 2009) were published and over 700,000 analysis per year are processed to measure several indicators of water pollution including physical, chemical and microbiological parameters.

Potable water supply will be doubled before 2010 to cope with the 4% per annum demand increase. The rate of the urban population connected to potable water networks in their homes will be raised to 94% in 2010, from 85% in 1999. The access rate to public water supply system in rural areas will also be increased as in 1999 it was only 38% in. In addition, privatization of water resources development sector will be promoted (NODW - FAO 2001).

The actual total volume of sewage discharged in Morocco is estimated at about 600 million m3; 48% of these waters are discharged into the rivers or applied to land, the rest is discharged into the sea. The pollutant load from wastewater is estimated at around 131,715 tons of organic load, 42,131 tons of nitrogen and 6,230 tons of phosphorus. Therefore, to comply with the WFD, to protect water resources and reduce the pollution a national sanitation and sewage programme is developed to improve sewerage collection, the treatment of both industrial and domestic wastewater, and increase the reuse.

The preparation of the national water quality protection plan included a diagnosis of the quality of water resources, an analysis of sources of pollution and their impact on water quality, and the preparation of a water quality protection plan for the country in general. Morocco has budgeted about 4 billion Euros for sewerage projects between now and 2015 within the framework of the national plan for reducing urban pollution.

Moroccan government, furthermore, put a plan in place to reduce the damage of flooding. The preparation of the national flood protection plan included the formulation of a typology of floods, a study of the vulnerable sites, establishing maps of zones vulnerable to droughts and flooding as well as prevention measures to be adopted for each site. Furthermore a study on the institutional context and the preparation of a detailed action plan was performed. All those steps have been completed and the resulting action plan combines physical realization with institutional measures such as the formulation of a number of decrees dealing with the organizational and legal aspects of flood protection.

V – Economic aspects

Incentives for efficient water use

The considerable fall in the domestic and industrial demand for water can be explained essentially by the several steps taken, aimed at rationalizing the use of drinking water in Morocco. These include (i) progressive pricing (water fee base on 4 categories); which, while favoring access to drinking water among low income social groups, acts as an incentive against wastage (Doukkali *et al.,* 2002); (ii) Campaigns to raise awareness of the need to save water; (iii) The installation of a system of payment by vouchers for public bodies. This category of subscribers used to pay for water consumption by internal administrative accounting procedures which were typically cumbersome and took no account of water saving (iv) Providing staff accommodation with meters and withdrawing shared meters; and (v) The introduction of the private sector in the distribution of the water.

In the agriculture sectors, Morocco still has a low value of the mobilized water, particularly due to low efficiency in irrigation (80% is now surface irrigation). Therefore, Morocco launches major operations, including a program for conversion of gravity irrigation system into drip irrigation systems (560,000 ha), improved efficiency of drinking water, protecting water resources and the fight against pollution by national sanitation and sewage treatment in 2006, solid waste, industrial pollution (4 billion Euros will be invested in the national programme of sanitations), improving the collection and reuse.

The strengthening of capacities of the agencies for irrigated areas (ORMVA) and their carrying out of the trials/demonstrations of improved technical packages for irrigation, as well as the training of staff and farmers, will result in the adoption of those improved techniques by a number of farmers. The benefits of those techniques will be additional crop production at lower costs and less water use.

Cost recovery: ‘the polluter and user pays’ principle

For drinking water two instruments were adopted through the law 10-95, including a pollution permit system that stipulates that every outflow is subject to an approval, and that every outflow is subject to payment of a charge. As mentioned before the concessions for water distribution in four large cities (Casablanca, Rabat, Tangers and Tetouan) were granted to private water companies. The privatization efforts in the urban water and sanitation sector indicate the growing commitment of the government to quality of services, managerial efficiency and financial sustainability (Doukkali, 2004).

This positive experience of private management of the urban water sector, encouraged the Morocco government to experiment with public–private partnership (PPP) in the irrigated agriculture sector with the initiation of the first-ever public-private–partnership project (Lamrani & Marin, 2002). Under this PPP initiative, two projects were planned for the construction of a transmission pipeline (Guerdane project) and a distribution network (Gharb project).

VI – Conclusion

In order to achieve good water resource management, Morocco is divided into 9 major river basins (RBA), with long-term water resources development policies written down in Integrated Master Plans. On the whole, the achievements of Morocco to realize specific objectives in integrated water resources management are considered satisfactory. The achievements include the establishment of an institutional framework for the creation of a River Basin Agency at the national level; improving the government’s capacity for water resources planning; improving water use efficiency; increasing effectiveness of existing hydraulic infrastructure; introducing water pollution control measures. The key elements of an institutional framework for integrated water resources management are in place, namely: a national water master plan, a national water quality protection plan, a national flood protection plan and the recommendation of a study on water pricing.

‘The paradigmatic shift from water development to water allocation requires a radical reorientation of water institutions. The challenge lays not so much in having allocation-oriented water laws and policies as in building an allocation-oriented organizational structure out of an existing water administration with insufficient skills and resources’ (Saleth and Dinar, 2000).

The Moroccan government is convinced that for the irrigated agriculture sector transferring the managerial responsibilities, including cost recovery and system maintenance, to WUAs is the main path towards further decentralization. Decentralization in the urban water sector is performed by creating autonomous and financially self-dependent utility-type organizations for the provision of urban water services. To acquire financial viability and physical sustainability of the Morocco water sector, and to improve cost recovery, water quality grading, quality standards, and pollution control regulations are implemented (Saleth and Dinar, 2000).

Strong integration of water demand management in water policies was very effective in strengthening the country´s water security. The involvement of the private sector in water resources management was an effective solution to water resource management problems. Moreover Morocco is developing a New Water Plan in synergy with WFD for implementing sound water policies and achieving a Common Vision for water management.

References

AGR/DDGI (1999) *Study of the national scheme to protect the quality of water resources.* Ministry of Agriculture, Rabat, Morocco.

Benbiba M. (2010). Une nouvelle Stratégie Nationale de l'Eau Pour une meilleure adaptation aux changements climatiques. *International conference on water scarcity and drought*, Madrid, Spain, 18-19 February 2010.

Choukr-Allah R. (2005). Wastewater Treatment and Reuse in Morocco: Situation and Perspectives. In: Hamdy, A., El Gamal, F., Lamaddalena, N., Bogliotti, C., Guelloubi, R., eds. *Non-conventional Water Use - WASAMED Project,* CIHEAM

Doukkali R., Benabderrazik H. (2002). Pricing irrigation water based on efficiency and implementation costs. *International Conference on Irrigation Water Policies: Micro and Macro Considerations*, Agadir, Morocco, June 15-17.

Doukkali R. (2005). Water institutional reforms in Morocco. In : *Water Policy*, 7 (2005) page 71–88.

Kerfati A. (2001). *Improving the management and usage procedures of hydrous resources in agriculture in the Kingdom of Morocco.* AGR, Rabat, Morocco.

Kingdom of Morocco (2001). Water Saving: An Opportunity and a Challenge for the Irrigation Sector. *Conseil Superieur de l'Eau et du Climat, 9th Session*, Agadir, Morocco, June 21–22.

Lamrani H., Marin P. (2002). PSP in irrigation pilot projects in Morocco. *Water Week Presentation,* May 7, World Bank, Washington, DC.

NODW – FAO (2001). *Development of drinking water supply and cleansing in rural zones. Improving knowledge about treated waste water development processes*. Project Utf/mor/023.

Ouassou A., Ameziane T., Belghiti M., Ziyad A., Belhamd A. (2005). Morocco. In : Options Méditerranéennes, Series B, No. 51 page 105-120.

Royaume du Maroc (1995). La Loi No. 10-95 sur l'Eau. Rabat, 16 Out 1995. Official bulletin No.4325

Saleth R. M., Dinar A. (2000). Institutional changes in global water sector: trends, patterns, and implications. *Water Policy*, volume 2, Issue 3, 14 July 2000, Pages 175-199

Saleth R. M., Dinar, A. (2004). *The Institutional Economics of Water: A Cross-Country Analysis of Institutions and Performance*, Edward Elgar, Cheltenham, UK.

World Bank (2009). *Project performance assessment report. Morocco water resources management project*. Report No.:48732

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MEditerranean DiaLogue on Integrated Water ManAgement
MELIA

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Water issues need to be viewed in their entirety: not just water demand, but also water availability; not just irrigation water, but also drinking water; not just water quantity but also water quality. This notion has lead to the development of the concept of Integrated Water Resource Management. Due to the complexity of integrated water resources management, a need has arisen to develop adequate indicators to assess the extent of the problem and explore policy alternatives. The concept of Rational Use of Water, as discussed by Kolberg and Berbel and Mandi and Moujabber, and the review of indicator sets by Lutter are the focal point of the first part of this volume. The following two papers give examples of rational water use: Omrani and Ouessar for the oasis in Tunisia, and Elkassar and El-Fotouh for Egypt. Groundwater pollution as a threat to RUW, by Ghreib et al., and water use in ancient times by Buxó complete this part.

The second part deals specifically with the issue of the value of water and the price that is asked to users of this water. Water pricing is a disputed issue. Some believe that water cannot be priced by all, but perhaps the service of providing water can be priced. Shatanawi and Naber demonstrate that water value is different from the water costs. Demir et al provide a method that indicates what costs can be recovered from users, based on an index of the living standard of the users. Polycarpou describes a mathematical approach to establish a water price taking into account the social and economical situation of users as well as the availability of water. Finally Giannoccaro et al., report their findings on optimization methods to compare the efficiency of various price policy options.

The third and final part concerns the Water Framework Directive. This directive is a vital piece of law for member countries of the European Union, but its concepts are a source of inspiration for many other countries, close to Europe but also far away in China and the USA. The implementation of the WFD in Italy is the subject of the paper by Rana et al., Abdin compares the requirements of WFD with Egyptian water policy as does Choukr-Allah with the Moroccan.

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