Identifying research and development targets for the management of limited water resources in the Mediterranean: background and a brief outline of the WASAMED case

Bogliotti C., Todorovic M.

in

Lamaddalena N. (ed.), Bogliotti C. (ed.), Todorovic M. (ed.), Scardigno A. (ed.).
Water saving in Mediterranean agriculture and future research needs [Vol. 3]

Bari : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 56 Vol.III

2007
pages 265-284

IDENTIFYING RESEARCH AND DEVELOPMENT TARGETS FOR THE MANAGEMENT OF LIMITED WATER RESOURCES IN THE MEDITERRANEAN: BACKGROUND AND A BRIEF OUTLINE OF THE WASAMED CASE.

C. Bogliotti* and M. Todorovic*
* Mediterranean Agronomic Institute of Bari (CIHEAM-IAMB), Via Ceglie 9,
70100 Valenzano (Bari), Italy

SUMMARY - The Mediterranean basin is a very complex system due to its high rate of diversities (environmental, economic and societal) throughout the Northern and Southern regions and the Middle East countries. In the region, water is a highly considered issue at the forefront of discussions on global sustainability and food security, particularly in the arid and semi-arid areas. In the first part of this paper a special emphasis is given to the Mediterranean water problems and the logical needs to manage scarce resources through a sustainable and integrated approach to be applied to agricultural sector, being the major consumer of water resources in the region. The second part of the paper addresses the preliminary results of the regional dialogue undertaken in the EU-funded project WASAMED (WAter SAving in MEDiterranean Agriculture) on possible priorities and goals for future agricultural water development in the Mediterranean and possible indicators to be used to assess achievement of targets for improving science and technology in this sector.

Key words: water saving, sustainability, governance.

INTRODUCTION

Current patterns of water resources development in the Southern Mediterranean region are not sustainable and dramatically affect all life dimensions. The region is facing a severe water scarcity with the freshwater availability per capita among the lowest in the world. This represents a serious constraint for the socio-economic development of the Southern Mediterranean region where agriculture contributes to more than 50% of the gross income (World Water Council, 2002). In fact, water related conflicts in this area are higher than anywhere in the world, undermining efforts for global peace and stability.

One of the main lesson learned from past and current research and cooperative or development programmes in managing Mediterranean water resources could be resume as follow:

- Scientific community, institutions and relevant stakeholders must be prepared to handle complexity, thus they need to agree on a well organised frame of goals and priorities and the means to assess successful achievement.
- Positive impact of projects and programmes on society depends on human's ability to design and implement adequate national and regional integration, proper outreaching of the political, users and citizens.

The objective of this paper is to contribute to the identification of priorities and goals in science and technology for water management in the Mediterranean region. The presented results represent the elaboration of outputs coming from the Working Technical Groups carried out in the occasion of Workshops organized in the frame of WASAMED ("Water Saving in Mediterranean Agriculture") project, financed within the 6th Framework Program of EU.

BACKGROUND

In the last 10-15 years, water management policies in the Mediterranean region have been shifting from supply-oriented approaches to water demand strategies that are getting particular importance in agriculture since this sector consumes almost 80% of water withdrawal in Southern and Eastern

Mediterranean countries. This process of adoption of water saving practices and technical tools has been going on in many areas transferring the knowledge acquired at experimental sites to large scale application at farmer's level. The main activities are focussed on lining of water delivery channels and their substitution with pressurized systems, introduction of drip irrigation systems and substitution of surface methods with drippers and sprinklers, use of modelling to improve irrigation scheduling, application of supplemental irrigation and deficit irrigation practices, use of non-conventional water resources (saline water and treated wastewater), etc. The advantages of these programs has become evident in many Southern Mediterranean countries (Cyprus, Tunisia, Morocco, Turkey, Egypt, Syria, etc.) where efficiency of irrigated agriculture has been improved and farmers have started to get the benefits of a more efficient water use. Nevertheless, these actions are still at the beginning and are restricted to pilot areas that are under particular attention of local authorities. Furthermore, these programs are still sector oriented aiming to satisfied the interests of agricultural production and are not fully embedded in integrated water management strategies at local, national and regional scale. As a result, there is not equity to access to water resources, there is an increasing non-controlled use of groundwater resources (in order to produce more yield and to increase profit), there is very limited consideration of water quality issues to protect the structural and functional characteristics of the ecosystems and little attention about water related natural hazards (drought and floods). In fact, a minor attention has been addressed to integrated and sustainable management of limited water resources in the region, and to its understanding and implementation at various levels: from institutional offices and governmental agencies to research sites, pilot areas, farms and local markets.

However the Mediterranean heritage of knowledge in the domain of limited water resources can be considered rather important in a relevant part of the society living in arid and semi-arid areas. Due to the established directives on water allocation in the EU countries of the Northern Mediterranean, the public and industrial sectors did not suffer too much of water limitation, while agriculture is the sector that mostly pays for water shortage in many countries of Southern Europe. Accordingly, cultural heritage and research have shown significant outcomes in water management in Mediterranean agriculture. Contrarily, in the Southern Mediterranean, water allocation strategies and directives are not well harmonised across the different countries and they are consequently poorly regionalized. The present situation urges to fill this gap, in spite of the fact that the cultural heritage of limited water management has still an important value in Southern Mediterranean for designing adequate perspectives of water management and water technology.

Through all the Mediterranean countries, the frequent droughts forced the farmers working in rain-fed agriculture to develop excellent techniques to store water in soil. These practices are part of the set of "arid-culture techniques" common and well known in the whole Mediterranean (Laureano, 2000). Such a bulk of know-how was studied and applied mainly during the Fifties and early Sixties of the last century. Later on, after a large development in water resource infrastructures and irrigation consortia, practices in irrigated agriculture have been developed more than rain-fed practices. Minor attempts were devoted to the supplementary irrigation of those winter crops exposed to wide climate variability. In the Seventies, the majority of the research works were oriented toward the full irrigation management with special emphasis on the determination of crop coefficients for appropriate irrigation scheduling. This trend continued until late Eighties, after which, the environmental issues diverted research means away from irrigation for water productivity to irrigation for non-polluting agriculture. However, as the irrigated surfaces were expanding over time, so that the equilibrium between demand and supply of water was becoming more and more critical, the frequent droughts were perceived substantially also by the farmers working in irrigated agriculture. More efficient irrigation technology and management was implemented, but high-cash crops were of course irrigated always in order to satisfy fully crop water requirements. Modern irrigation methods and technology, crop growth modelling and irrigation scheduling, supplemental irrigation, regulated deficit irrigation, use of non-conventional waters and better on-field management practices that improve irrigation efficiency were the major issues under experimentation.

Nevertheless, the research water saving in irrigated agriculture was focused mainly at farm scale with a meagre interest to integrate the outputs at a water district level or at catchment scale as well to consider the overall impact to other water sectors, society, food markets, etc.. Only limited and modest approaches to integrated management of limited water resources were developed assuming more the shape of a case study rather than a research project or programme. Nonetheless, in the last years, most likely because of relevant and consecutive droughts (the case of Southern Italy in 2001 and 2002) and flooding (the case of catastrophic flooding in Algiers in November 2001), the scientific community and governmental or international organisations finally started to conceive the issue of limited water resources and agricultural water management based on the concept of sustainable - integrated management.

THE STATUS OF SCIENCE AND TECHNOLOGY (S&T) IN THE MANAGEMENT OF LIMITED WATER RESOURCES IN THE MEDITERRANEAN

S&T priorities for the effective and adequate implementation of Mediterranean management of limited water resources should foresee adequate means for the acquisition of a strong knowledgebase of both supply and demand as illustrated in Fig. 1 considering:

- the whole dynamic supply for water (surface water, groundwater, non-conventional and marginal waters)
- the whole dynamic demand for water (agriculture, civil, industry, energy, tourism, recreational, natural wildlife).

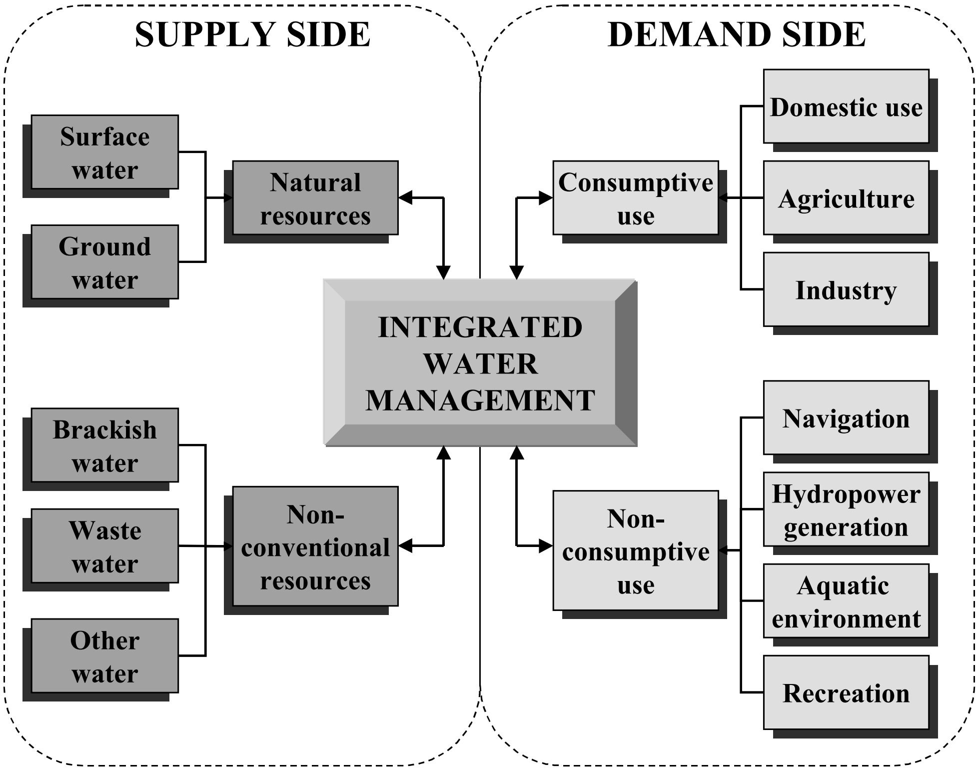

Fig. 1. Technical framework for integrated water management (Source: Todorovic and Hamdy, 2001)

The term dynamic is used here to underline the fact that water resources cannot be seen as a static total amount (supplied or required) but as a rate that varies continuously against time. It is well known that main factors influencing the local or regional variability of water yields are mainly related to the dynamics of climatic and socio-economic processes. In line with this, all aspects of agricultural water management should be considered within a holistic approach. Although the concept of water saving is extended also to the civil and industrial sectors, in the Mediterranean context the management of limited water resources is strictly related to agriculture, the latter being the major cause of pressure on natural waters (Gleik,1993; Bonnis and Steenblik,1998; Hamdy and Lacirignola, 1999). Therefore, it is important to address the assessment and development of specific “saving” aspects of agricultural water management like: Water Use Efficiency and Water Productivity; Irrigation System Performance; Non-conventional Water Use, Participatory methods of management, etc..

In relation to agricultural water management, the existing literature and on-field experiences provide information on local small- to medium-scale trials or projects (mainly at farmer scale) and assessment of water saving opportunities: a) water use efficiency and water productivity through biotechnology, crop growth modelling and eco-physiology, plant breeding, and better on-field irrigation management practices; b) irrigation system performance through monitoring and modelling of system's performance, engineering works on water delivery networks, and application of more efficient irrigation methods; c) use of non-conventional waters through experimentation on the re-use of treated wastewater, saline irrigation practices and recycling of drainage water; d) transfer of irrigation management from governmental agencies to water user associations and implementation of participatory approach. The above aspects have been addressed in dedicated literature. Notably, water use efficiency and its application for crop use are well illustrated among others in Hoffman et al. (1990), Steduto (1996), Howell (2001), Hatfield et al. (2001), etc. Research and studies on improvement of irrigation systems performance have been also carried out (Jensen, 1980; Hoffman et al., 1990; Lamaddalena and Sagardoy, 2000; Pereira et al., 2003) as well as the use of non-conventional waters is analysed for different levels of salinity or types of brackish waters (Tanji, 1990; Hamdy 1993), halophytes utilization in agriculture (Choukr-Allah et al., 1995; Lieth and Lohmann, 2000) and reuse of treated waste waters (Asano, 1998; Hamdy, 1999).

However, regardless the type of water saving pathways, the most recent literature and field experiences have revealed the need for integrated efforts in water management and water saving supported by national institutions and both regional and international organizations, focusing on the following aspects: a) establishment and application of water management policies coherent with the emerging need of ensuring sustainable development; b) developing sound and well-structured national policies and regional strategies; c) improving the efficiency of public administration at the local and national level. d) appraising water saving actions from the point of view of the public health, socio-economics, environment; e) overseeing the promotion and enforcement of national legislation and guidelines; f) setting new and more coherent water pricing mechanisms.

The literature lacks of a consistent overview of the results of water saving techniques throughout the Mediterranean countries and lacks means of assessing results and impacts which could be achieved by comparing, integrating and up-scaling the above components of water saving, accounting also the public participation and community involvement. Significant challenges still remain in the areas of technological, managerial and policy innovation and adaptation, human resources development, technology transfer and dissemination, etc.. Although technical actions of water saving should be based on the integration at farm, district and basin levels, the existing literature has proved the limits existing in up-scaling and down-scaling from/to farmer-district-basin scale constraining the understanding how much water can be really saved if adequate water regional management is in place. In agricultural water management constraints are mainly of two kinds: a) farmer level projects are scattered and fragmented and often different standards are used in different Mediterranean countries, therefore results cannot be easily compared; b) in the same time water saving actions are difficult to standardise throughout the Mediterranean, particularly at basin level, that has a particular meaning in the region since water use is strongly linked to water withdrawal from groundwater aquifers and only a limited number of important permanent water courses exists. In addition, existing literature (AWMI, 2000; Pereira et al., 2002), and statements of International Organisations (FAO, 1989, IHE-UNDP, 1991) has also proved that CWRM (Comprehensive Water Resources Management) is needed, based on decentralised management of water resources with the active participation of water users.

The analytical framework requires the examination of water resources, usually within a hydrological district as a basic spatial unit, by considering potential uses and possible effects, especially environmental ones. The participation of key stakeholders, appropriate incentives or income generating water saving options constitutes important means to ensure the sustainability of regional water management. Unfortunately, water management interventions are fragmented in the Mediterranean, due to the difficulties of networking and communication among partners from different countries and those belonging to different water sectors. The European Commission, under the RTD Programme has funded several shared cost actions in water management and there is a significant number of environmental and socio-economic data and information on water resources in the Mediterranean. These research and cooperation projects have produced results and draft guidelines, mainly within a group of researchers, but it still needs proper national and trans-boundary consensus among relevant decision makers and users before it can become effective applied.

An excellent example of these activities on water saving in the Mediterranean region represents the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM) and its Bari Institute, which since the beginning of nineties has been strengthened the networking activities with numerous research institutions from the Mediterranean region on i) Use of Non-conventional Water Resources in irrigation, ii) Eco-physiology and modelling for Water Use Efficiency, iii) Assessment and Improvement of Performances of Collective Irrigation Systems.

In 1998, a fruitful collaboration between CIHEAM and the European Commission (DG-RELEX) has been intensified within the frame of the “Regional co-operation in agricultural sector on training, promotion of research and communication of scientific and technical information in the context of economic transition”. The Regional Action Program on "Water Resources Management (RAP-WRM)" (1998-2003) represented one of the largest activities ever carried out by the Mediterranean Agronomic Institute of Bari. Thirty national institutions and Universities from 10 beneficiary countries, 7 Italian partners and 5 International organisations (FAO, Rome; ICARDA, Aleppo; IFAD, Rome; World Bank, Washington and INPIM, Washington) have been involved directly in the program along with about 1105 persons from 31 countries around the world. This action has enabled funding to improve and expand the networking activities more towards on-ground implementation of research findings in many pilot areas in the Southern Mediterranean countries. In fact, the activities within the RAP-WRM have produced 19 short-term courses, tens of experimental works and 68 MSc theses, 19 mobility MSc programmes, research works at seven pilot locations in the Mediterranean, two important workshops, numerous meetings and reports, 131 scientific papers, several research manuals, guidelines and databases, 24 special publications, 3 books, etc. Within the RAP-WRM, for the first time, an emphasis is given also to the socio-economic aspects of water resources management including in the program the issues of a) Participatory Irrigation Management; b) Water valuation and cost recovery mechanisms; and c) Role of gender in water management.

In general, many EU funded research projects have made good achievements in collecting information and assessing technical performance of specific water saving opportunities. On the contrary, their impact on the territory has been limited due to: i) the communication gaps still existing among top-level institutions / scientists and local communities; ii) the lack of networking among different sectors in most Mediterranean countries to enhance regional water saving; iii) lack of integration between technical-physical driven criteria and main socio-economic and environmental criteria of sustainability. The existing national governmental structures as well as the international institutions have a great role to play in the promotion of water saving for sustainable development in the region. Nevertheless, their contribution should be harmonised in order to generate long-term benefits. In addition, there is a need to strengthen the participatory approach in water management in the Mediterranean region. The joint involvement of scientists, decision makers, local communities (farmers’ association, water trading offices, irrigation consortium) and a bottom-up co-decision process is still far from being a routine of good practice (Gronfeld and Svendsen, 2000; Oblitas and Raymond, 1999).

As said above, in spite of several research activities and trials on water saving have been carried out locally in Mediterranean countries, no regional water saving research or coordinated integrated trials have been carried out Mediterranean-wide scale. This is basically due to the fact that established regional networking is in place in the Mediterranean, which would produce the necessary impulse to establish communication among countries, share experience and define objectives and tasks of a regional framework of cooperation. Few efforts have been taken in this direction and several projects and actions were carried out at a national level. However, in spite of the available information, a major need for increased efforts to co-ordinate, disseminate and share experience among Mediterranean countries still remains strong.

Many other not-solved problems exists concerning a) the extrapolation of saved water yields at large scale through farmer-district-basin up-scaling and b) the temporal scale of processes involving water fluxes at different scales. In fact, the temporal scale of processes is much longer than the time span disposed by single programme or projects aiming at reducing the impact on freshwater. Therefore, it is of utmost importance to increase concern and awareness on reversibility – irreversibility ratio of physical processes affecting water yields.

Accordingly, the Framework Program of EC gave the opportunity to continue the activities initiated in the years before and to strengthen the efforts towards a more sustainable management of water resources in the Mediterranean region.

WASAMED (Water SAving in MEDditerranean agriculture): A PLATFORM OF REGIONAL DIALOGUE

The structure and the general context

WASAMED is a Thematic Network funded by the EC in the frame of the Research-Technology-Development Framework Programme. The project started in January 2003 and lasts in March 2007. The coordination of the network has been entrusted to the Mediterranean Agronomic Institute of Bari (http://wasamed.iamb.it).

WASAMED encompasses the issues discussed in the previous sessions through a dialogue established among Mediterranean countries and it constitutes a valuable mean of regional integration.

It is based on the following elements:

- Identification and consensus on sustainability goals and indicators of management and assessment of different water saving options.
- Strengthening participatory approach.
- Build common and shared knowledge to integrate different interests and emerging conflicts in relation to saved water re-allocation.
- Strengthening communication and networking.
- Abstraction of knowledge rather than on-filed conventional research.

The ultimate objective of the platform dialogue is the construction of a common frame of priorities and goals for research and development, to be encompassed in the programmatic agendas of national agencies, European Commission and other international organisations.

The scheme of Fig.2 presents the structure of the project, which is based on a number of interlinked work packages. The structure shows the efforts of intra-discipline and intra-sector integration. In particular, it is clear how WASAMED addresses the identification of water saving strategies under a wide range of environmental, institutional, social and economic conditions prevailing in the Mediterranean Region. It evaluates the social, economical and environmental “costs” and “benefits” of such “water saving options/strategies”, to shape them out into recommendations. In addition, with such a designed structure, WASAMED is expected:

- to give strong visibility to the work done within the Region (capitalize the existing knowledge)
- to build a comprehensive frame of goals and possibly indicators to address water saving under the different dimensions of sustainable development: social, economic, environmental, governance.
- to account for the “scaling” aspects (spatial & temporal)
- to conciliate the “site-specific” and “regional” dimensions of “water saving”
- to handle “complexity”.

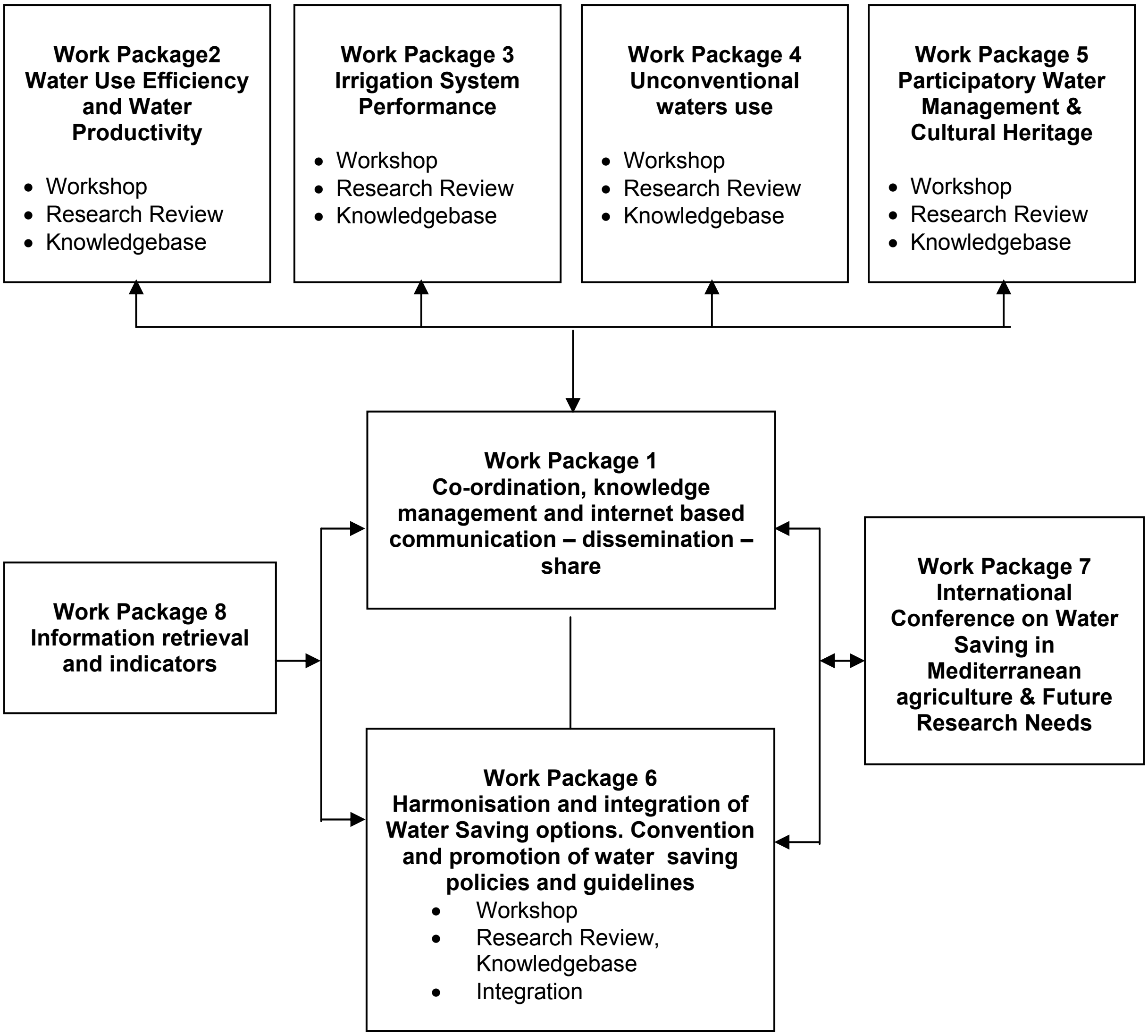

Fig. 2. The overall structure of WASAMED based in eight interlinked work-packages.

The Network is built on a wide and important regional partnership (Fig. 3). It has a relevant critical mass of partners in terms of “category”, “profile” and “provenience” (20 research institutions, 11 decision-policy making institutions, 11 end-users) for a total of 42 Partners coming from 15 Mediterranean Countries (Algeria, Cyprus, Egypt, Greece, Italy, Jordan, Lebanon, Malta, Morocco, Palestine, Portugal, Spain, Tunisia, Turkey, Syria). As we will see in the next session the platform discussion and communication activities were made possible through a series of Euro-Mediterranean workshops. These events are the core of WASAMED activities.

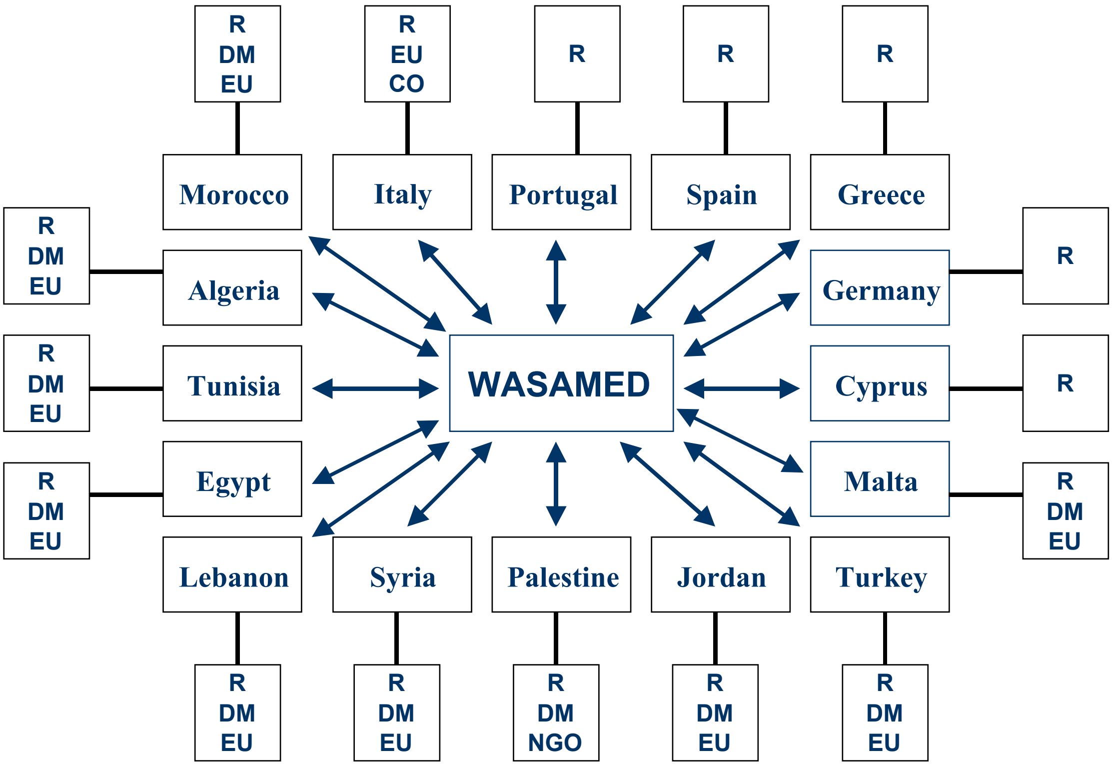

Fig. 3. The structure of WASAMED regional platform (R= research instituriion, DM = decision maker, EU = end user, NGO = non-governmental organization, CO =coordinator)

The platform has been a successful attempt of strengthening the dialogue among different actors and deliberating a frame of sustainable development goals and indicators[1] accounting the different needs and concerns of stakeholders. The effort has addressed the need of aligning the agricultural water management with the global context of sustainable development, considering the main criteria and indications given by Agenda-21, the Barcelona Convention of 1995 and the Mediterranean Commission of Sustainable Development (MCSD) and the recent literature.

Integrating concepts of sustainability in delivering goals and indicators

One of the most significant challenges of researchers, institutions and stakeholders involved today in water management is to improve the understanding of the relationships between water system related variables and the wider – but often obscure - concept of sustainable development. For example, while researchers have developed a huge number of indicators to assess the physical dimension of water resources and sustainability, the degree to which such efforts have been linked is still limited. Developing water goals and indicators has often shown to be a mono-thematic and poorly structured exercise, not well linked to the need of interpreting correctly the simultaneous coexistence of technical aspects with the social, economic, environmental and governance concerns.

[1] The identification of priorities or different levels (priority) of goals - within the platform - is accompanied at each level by the identification of nominal, ordinal or performance indicators which can be used or are functional to assessing degree of goal achievement. Goal achievement must meet the main imperatives of sustainable development as indicated in Agenda 21 and the Summits of Rio and Johannesburg.

Assessment of water management is generally constellated by a large arena of technical water indicators, which are rarely functional to the different levels of cultural, societal, institutional and policy objectives. On top of that, water indicators are often too complex, too deeply attached to the technical dimension but not explicitly functional to goals of sustainable development, difficult to be understood by policy makers, stakeholders and experts from other sectors. The degree of participation of stakeholders in building water management goals and indicators is still poor. Research on water technical indicators is rarely guided by a clear frame of sustainability goals deliberated in a multi-stakeholder dialogue. The relationships between water technical indicators (ex.: hydrological, eco-physiological, hydraulic, hydro-geological indicators) and sustainability goals are often missing or confused. This limitation has inevitably brought to the failure of most of the water technical indicators due to the increasing scepticism of decision makers and stakeholders to integrate them in the agendas and planning. It is clear that the degree of interaction between societal and institutional needs and technical dimension has held poorly focused during the last decades in all sectors (Bowen and Riley, 2003). That social, economic, institutional and environmental elements are linked to water technical targets has been long asserted. Contrarily reasoning on this has been less of a core activity in research.

However, the last years have witnessed an increasing effort to expand an understanding of the above interactions together with the structuring of a more open multi-stakeholder dialogue on building consensus on water goals and indicators.

First, this is a result of the pressure produced by institutions, stakeholders, NGOs and international organisations to assess water management by making more explicit reference to the current concepts of sustainable development. Second, the design and approval of international regulatory tools and protocols such as the European Water Framework Directive – EWFD or the Agenda 21, has provided an opportunity for more systematic and comprehensive approaches. Third, emerging initiatives like the World Water Forum or the EU Water Initiative and new models of delivering sustainability goals and indicators (Valentin and Spangenberg, 2000; Bogliotti and Spangenberg, 2005; Bogliotti and Spangenberg, 2006) can inspire the attempts of identifying water sustainability goals and indicators.

As we will see in the next sessions one of the main purposes of the dialogue within WASAMED is to reach a common frame of sustainability goals accounting the economic, social, environmental and governance dimensions of water management, and trying to seek functional relationships between technical indicators and overall goals of society.

An introduction to the working group deliberation process

The WASAMED network activities started in January 2003. Five workshops have been carried out respectively in Sanliurfa, Turkey (Participatory Water Saving Management and Water Cultural Heritage, 2003), Hammamet, Tunisia (Irrigation System Performance, 2004), Cairo, Egypt (Unconventional Water Use, 2004), Amman, Jordan (Water Use Efficiency and Water Productivity, 2005), Malta (Integration of Water Saving Options and Policies, 2006).

Each workshop has conveyed more than 60 participants with the aim of exchanging experiences, making the point of water saving today and building a shared frame of goals for sustainable water management in agriculture. Participants were scientists coming from different disciplines, stakeholders like decision makers from water and irrigation ministries, associations of farmers, NGOs representing the civil society, water boards, international organisations having a stake in the sector and the region.

Each workshop has included a dense agenda consisting of key contributions, country reviews from well reputed scientists and experts. Contributions and country reviews have inspired discussion in plenary sessions and deliberation of common goals and concerns in working groups. At each workshop members have been split in working groups respectively addressing socio-economic, environmental, institutional-governance and technical aspects. The working group deliberation has been very rich of outputs resulting, at each theme addressed by the Workshops, in goals and indicators relevant to social, economic, environmental and governance dimensions.

Conceptual models of sustainability and governance – these two fields being considered domains of criteria to pursue sustainable development (Bogliotti and Spangenberg, 2005) – have been used to inspire the groups during the identification of goals and indicators of sustainable development considering the social, economic, environmental and governance dimensions of water saving.

These criteria have been inspired by Agenda 21 and, also, from the literature (Bogliotti and Spangenber, 2005; Valentin and Spangenberg, 2000; Serageldin, 1996) as presented in Table 1. The criteria have been suggested to the participants to facilitate identification and alignment of outputs according to existing conceptual models of sustainable development. Some inter-linkages between dimensions have been also addressed during the discussions for identifying goals that better responds to the reciprocal accountability of economic and environmental interests or social and economic interests or social and environmental interests or among sub-dimensions of governance (*Table 1*).

Table 1. Sustainability – Governance dimensions referencing group deliberation (modified after Bogliotti and Spangenberg, 2005; Valentin and Spangenberg, 2000)

Dimensions-(D), Sub-dimensions (SD) and interlinkages-(ITK)	**General criteria**
Sustainability	
Economic (D)	Improve competitiveness
Social (D)	Safeguard cohesion
Environment (D)	Limit throughput[2]
Environment-Economics (ITK)	Eco-efficiency
Environment-Social (ITK)	Access
Social-Economic (ITK)	Burden sharing
Governance (D)	Improve participatory (system) management
Knowledge (SD)	Improved factual knowledge
Institutional & System capacity (SD)	Adaptation to changes and scenarios
Critical mass in network (SD)	Strengthening participation
Knowledge-Capacity (ITK)	Preventive planning
Knowledge-Critical Mass (ITK)	Comprehensive & trans-sector knowledge
Capacity-Critical Mass (ITK)	Comprehensive planning

A graphical example of sustainability and governance goals – organised after groups' identification - is provided in Figures 4 and 5. Goals have been systematised by the authors within the triangles of sustainability an governance. The working groups have provided an important number of outputs (mainly goals) at the given social, economic, environmental and governance (mainly institutional) dimensions.

An overview of non-ordered goals is given in *Table 2*, to enable a preliminary appreciation of the main vision of the platform and provide a useful ground for future discussion. Goals are given without any order of prioritisation or logical hierarchy. Technical indicators[3] have been also identified in the groups with no clear aim of contribution to specific goals of sustainability or governance.

[2] Limit throughput is the amount of raw material or resource put in a working process per unit of time (Spangenberg J.H., 2000)

[3] A "technical indicator" is meant as a measurable numerical indicator used to observe variation of physical parameters (hydrological, hydraulic, biological, eco-physiological, pedological……etc) pertinent to the quantitative assessment of water saving at different scale and levels and in the different options (irrigation system performance, water productivity, water recycling, desalination,……etc.).

Output analysis in still going on, aimed first at better clustering goals and indicators at a given dimension of sustainability (economic, social or environmental) and at given options of water saving (irrigation system performance or water use efficiency or water productivity). Then after, the ongoing analysis is aimed at ordering goals in a three-level hierarchical order accounting for a logic of intervention based on the different importance and character of goals as shown in the scheme of Fig. 6. This simplified approach is derived by the SWOT method used to identify intervention logic in a given theme or sector.

Finally, the ongoing analysis is aimed at linking the ordered goals with possible technical and non-technical indicators. The ordering process is framed at the given dimension of concern (social, economic, environmental). The first level is fed by main goals or – better – long-term goals ensuring linking and alignment of the all sequence of objectives with the criterion of sustainability or governance (Fig. 6).

The second level goal restricts sector boundaries of achievement (addressing specificity of goal) and is generally linked to a medium-term time scale of achievement. It contributes to the achievement of the first level goal (Fig. 6). The third level goal has an even more specific character and short to immediate time-space of achievement, and it contributes to reaching the second level goal (Fig. 6).

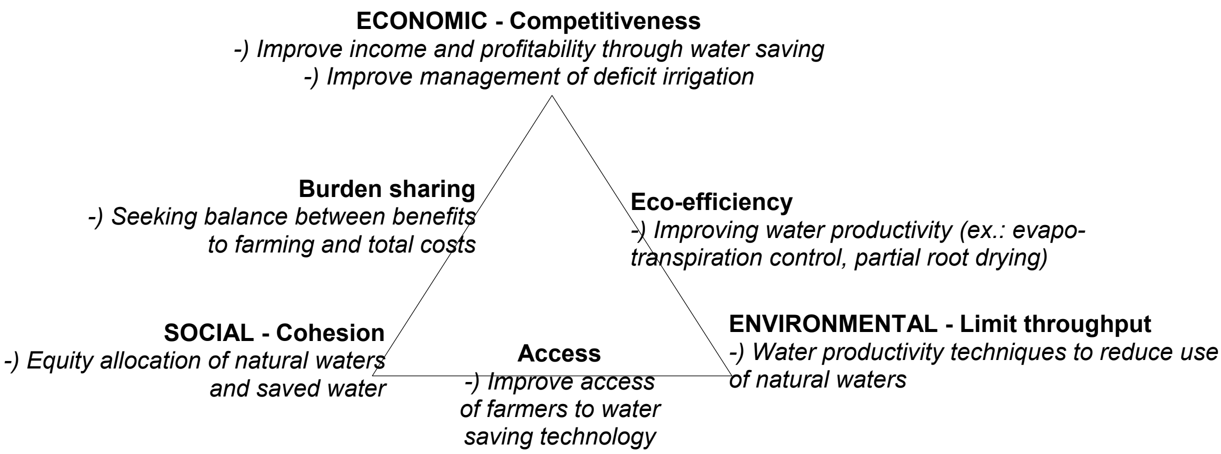

Fig. 4. The triangle of sustainability (source: Bogliotti and Spangenberg, 2006): some sustainability goals (italic) selected from the whole of goal deliberation. Dimensions, dimensions' inter-linkages and criteria of sustainability in bold.

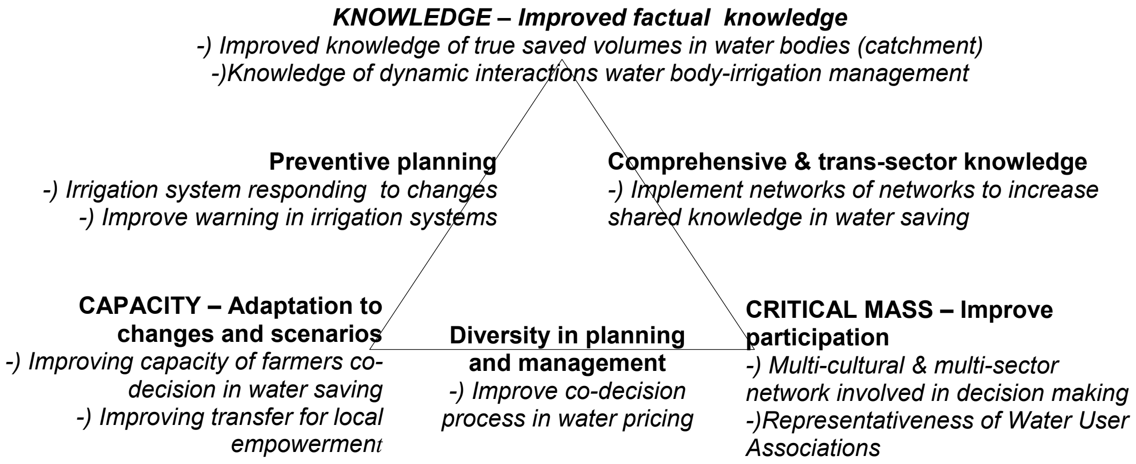

Fig. 5. The triangle of governance (source: Bogliotti and Spangeberg, 2006): some governance goals (italic) selected from the whole of goal deliberation. Dimensions, dimensions' inter-linkages and criteria of governance in bold.

An application of three levels logics of goal ordering is given for the WASAMED case in *Table 3*. The application is centred on the tentative ordering of sustainability goals of water saving at the given environmental, economic and social dimensions. Some of the technical and non-technical indicators, which were deliberated during the platform discussion without explicit link to sustainability goals, have been selected as possible mean of achievement of water saving related sustainability goal. Indicators have been attached to levels 1 and 2 (*Table 4*).

DISCUSSION

In Table 2 are presented generic and non-ordered goals at the given governance, economic, social and environmental dimensions as deliberated by the WASAMED Working Groups. Governance goals underline a basic concern regarding the need to improve transfer of rights, power, capacity (including capacity to take part in the co-decision mechanisms) and knowledge (innovation and technology) to farmers through recognized water user associations. Another common concern is related to the improvement of laws and regulatory framework that could better respond to the need of irrigation system modernization and explicit integration of water saving into policies. On the economic side, there is a certain level of concern to the need of improving competitiveness and redditivity beyond the farmer, addressing system level competitiveness rather than individual benefits only.

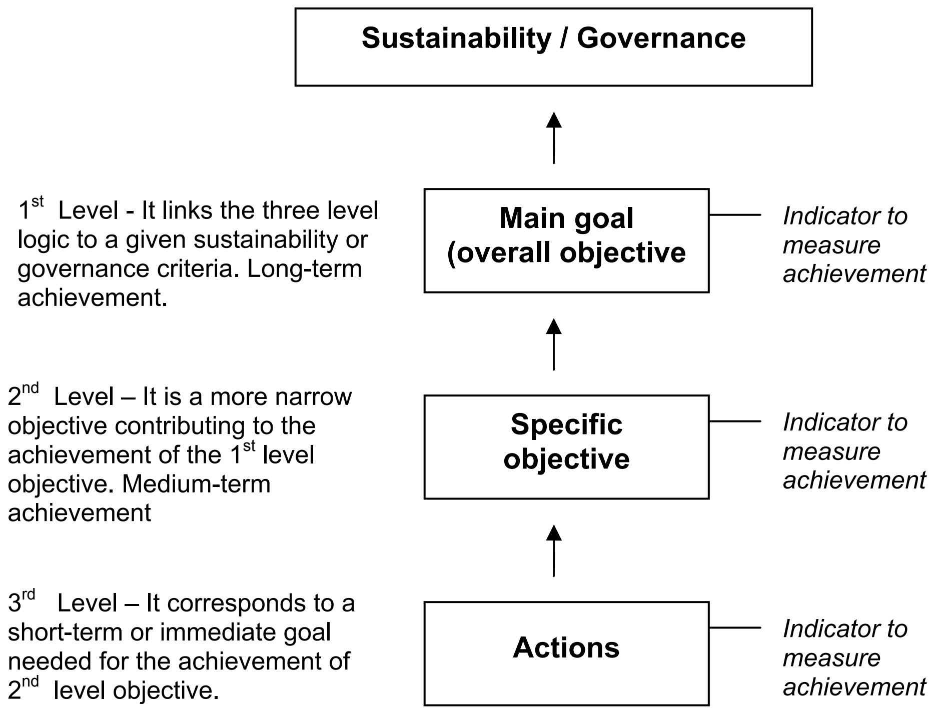

Fig. 6. The three levels logic of goal ordering

As we will see later in the paper, multi-dimensional indicators encompassing explicit social and economic parameters against traditional technical parameters of water saving need to be developed for measuring achievement of system competitiveness. Table 2 shows an ample spectrum of goals concerning the social dimensions. They range from the need of equal access to resources and water saving technology to the need of improving the awareness and understanding of farmers in relation to the safe use of non-conventional waters, resistance to the use of alternative water saving options and improving communication with other farmers and users. Equity in allocation of water saving benefits accounting for total societal cost is a further concern. On the environmental side, many goals have been put forward underlining the need of safeguarding the ecosystem while strengthening the implementation of water saving practices. Improving public and private (users) awareness of environmental and technical aspects is still a target to meet.

From the environmental point of view there is a clear indication to pursue different water saving options with the aim of meeting the main criteria of eco-efficiency giving equal importance to social, economic and environmental concerns. Improving and increasing resource investment in technologies, education and knowledge transfer must aim at reducing the volumes of natural water withdrawal on one side while ensuring competitiveness (economic), increasing rate of employment, productivity and stability of farmers on the other side. A deeper knowledge of real volumes of saved water at different scales (from farm to district and basin scale) is also an important target to meet, in order to quantitatively assess the positive impact of water saving on water bodies. From the policy point of view, the need of explicit integration of water saving inputs into environmental policy is fundamental to improve re-use of saved water for groundwater replenishment, forestation or other environmental purposes (*Table 2*). However, outputs deliberated from the platform are disordered and do not show clear and separate paths of logical intervention and prioritization at the given environmental, social, economic an institutional dimensions. It is not clear how and when goals contribute to sustainability criteria and what are the possible sets of sustainability indicators (supported by technical indicators) used to measure them throughout the process of implementation of water saving activities. Developing a logic of intervention and identifying means to measure achievement of goals has been a difficult exercise. As mentioned in the previous sessions an example is given in Table 3 by ordering 1st – 2nd - 3rd level goals derived from the platform discussion.

Most of the goals of Table 2 have been used and ordered. They have been complemented, to round up the logics, with goals sought by the authors.

Table 2. Non-ordered goals at given governance (institutional), economic, social, environmental dimension (Source: WASAMED Working Groups)

GOVERNANCE - INSTITUTIONAL CAPACITY	
• Improve transfer of irrigation management and improve empowerment to end users • Improving laws regulating the constitution of Water User Associations (WUA) • Improve capacity of government or WUA for system O&M • Improve laws systematically enhancing water saving • Improve rules of warning and risk management • Improve role of WUAs in irrigation management • Improve role of users in WUAs • Pursue integration with other uses • Improve farmers involvement in water pricing • Attitude of central government to transfer rights • Increase political willingness • Capability of institutions to transfer rights	• Increase awareness of users to associate in WUAs • Improve availability of funds for water saving • Improve suitability of resource allocation • Improve quality of irrigation system diagnostic • Develop suitable technology • Modernisation of irrigation system • Increase impact of policy on water saving • Integration of water saving in environmental policy • Increase capacity of irrigation systems to respond quickly to external changes • Increase impact of water saving on political agenda to attract funds • Improve capacity of farmers in co-decision • Improve suitability of water tariff
ECONOMIC DIMENSION	
• Improve agricultural and non-agricultural system competitiveness through water saving practices • Increase farmer income • Assure long term economic stability of farmer	• Improve trend of redditivity of farm • Optimise use of financial capital in water saving • Efficient trans-sector water allocation • Private sector investments in water saving technologies
SOCIAL DIMEMSION	
• Mitigation of water conflicts • Improve equity of access to water resources • Improve balance between farm benefit and total cost • Increase level of acceptance of water saving options • Improve perception of safe use of non-conventional waters • Improve collective knowledge and bridging different positions • Equity in re-allocation of saved water • Equity in access to water saving technology	• Guarantee minimum water supply to farmers • Increase mutual trust / transparency between farmers and institutions • Equity in allocation of water saving benefits • Improve society involvement in water saving investment and benefits • Reduce resistance of farmers to alternative water saving options
ENVIRONMENTAL DIMENSION	
• Reducing pressure on water bodies through water saving • Increase knowledge of quantification of saved water volumes Improve on-farm irrigation system aiming at water saving • Improve management of deficit irrigation • Improving impact on environmental quality • Increasing ecological efficiency • Improve environmental care through water saving • Reduce water withdrawal from water bodies • Improve practices of conjunctive use of saline and freshwater in irrigation • Optimisation of Water Tariff • Knowledge of interlinkage water body-irrigation system from farm to catchment scale	• Improving land management • Improve use of saline water in irrigation • Improve information management • Improve quality of irrigation system design • Improve rainfed agriculture • Integration of water harvesting and water saving practices • Improve use of treated wastewater in agriculture • Improve use of fertilisers • Improve environmentally sound innovation in water saving • Joint irrigation system and natural water monitoring • Improve co-decision (participatory) process in monitoring

First level ordering includes main goals responding in a more direct way to the main criteria of sustainability. They are: A) the effective water bodies enrichment (environmental dimension), B) improved quality of the environment (environmental dimension), C) system economic growth and competitiveness (economic dimension); improved long term stability of farmers (economic dimension); D) improved cohesion (social dimension), E) strengthening institutional participation and system governance (institutional dimension). Achievement of these goals is possible in the long-term, made sure that secondary level goals are achieved.

A second level of goals have been clustered in the middle column of Table 3. For example, a main goal like "water bodies enrichment" could be achieved at the condition that specific goals are priory pursued like: a) improved integration of run-off control and use of non conventional waters in agriculture, b) improved agronomic practices of irrigated agriculture, c) improved engineering devices and systems operation and maintenance, d) improved rain-fed agriculture practices, e) improved quantitative assessment of different water saving practices; f) improved use of saved water for environmental purposes (ex.: groundwater recharge, reforestation, surface water discharge...), g) improved regional and local knowledge and education on water saving practice having positive impact on environment

A lower (3rd) level of goals (actions) has been found necessary to contribute to the achievements of the 2nd level goals. Some of them are proposed in the right column of Table 3 and include: i) improved runoff control practices and environmental planning of water saving practices, improved/increased use of saline water, treated wastewater and recycled drainage water in agriculture; ii) implementation of better land management practices, improved knowledge on biotechnologies, development and application of criteria for improving cropping pattern, use of modern technologies (crop growth models, GIS, remote sensing), improvement of irrigation scheduling, improvement and implementation of (regulated) deficit irrigation practices, optimization of supplemental irrigation, better use of nutrients and pesticides, use of greenhouses, plastic tunnels and mulching; iii) shift from traditional open channels delivery networks to closed pressurized systems, use of more efficient irrigation methods, improved design of irrigation systems and water distribution uniformity, use of land leveling and furrow diking, use of new technologies and devices (simulation models, ACQUACARD, etc.), improved system operation and maintenance; iv) improved land management and water harvesting and conservation practices, improved knowledge on rainfed crops biotechnologies and development and application of criteria for improving crop selection in rainfed agriculture; v) implementing plot experimentation at farm and basin level, improve monitoring of dynamics of water bodies at farm, district and basin level; vi) increased awareness of policy makers, carrying environmental awareness campaign, improved integration of water saving in environmental policies; vii) increased and improved exchange of information and study results on water saving best practices (training, seminars, workshops, etc.) and establishment and use of water quality monitoring network.

The economic growth and system competitiveness calls for 2nd level goals ranging from improving trade position of farmers to adaptation and coping to the continuous evolving economic scenarios, optimisation of water price and long-term trend redditivity at both farm and system level. The social dimension of the problem aims to pursue improvement of social cohesion (*Table 3*) which would be achieved through an increase of employment rate (sector and trans-sector scale) due to successful water saving, together with a good balance between water saving benefit and total social costs. From the institutional point of view, the 1st level goal of strengthening institutional participation and system governance is in line with the modern models of sustainable development. Table 3 indicates 2nd and 3rd level goals – as necessary means of main goal achievement – mainly centred on the farmer empowerment (through the enforcement of water associations) and on the capacity of the whole system to adapt and cope with changes and perturbation through the enforcement of preventive design and planning (including drought preparedness). Farmers' water rights and regulatory framework are also considered.

Table 4 indicates that measuring 1st and 2nd level goals needs indicators able to balance technical and non-technical notions. This is particularly relevant for social and economic related goals, where cohesion or system competitiveness should be measured against the physical component of water saving. For example, 1st level social and economic goals like improved cohesion, or system economic growth and competitiveness, need to be assessed with multidimensional indicators, where rate of employment (determining the degree of cohesion) or degree of societal satisfaction could be measured against quantitative parameters of water saving. As water saving consists of the combination and integration of different options (ranging from water use efficiency – WUE – the ratio between the water effectively used in crop ET and total water input, and water productivity – WP – the ratio between biomass/yield and crop ET, to irrigation system performance – ISP – hydraulic/engineering performance, and use of non-conventional waters – NWU), successful stories in meeting social cohesion and systems demand and growth could be better measured with multi-dimensional indexes. Multi-dimensional indexes based on the rate of employment (sector and extra-sector) against overall water saving index could be more adequate when addressing socio-economic goals. We consider the overall water saving as function of WUE, WP, ISP, NWU activities that can be integrated in the ratio between the volume of water used in irrigation and irrigated land. More specifically, at farm scale, water saving can be measured either by using the ratio between the biomass (or yield) and crop evapotranspiration (scientific, research point of view) or by applying the ratio between the economic value of biomass (or yield) and irrigation water use (farmer's point of view). Another way of appreciation of agronomic practices in irrigated agriculture could be to measure the volume of water necessary to produce 1 kg of biomass. However, all those indicators are influenced by factors like overall land productivity and management, application of fertilizers and pesticides, weeds control, etc.. A further refinement of the agronomic (water) use efficiency is possible through the consideration of a whole set of indices that simultaneously considers "consumption efficiency, transpiration efficiency, assimilation efficiency, biomass efficiency, harvest efficiency as indicated by Hsiao et al. (2007). All these indicators are useful to measure quantitative aspects at farm scale level but they might be inadequate to respond comprehensively and simultaneously to the assessment of efficiency of the whole water path from the source to the root zone of crop under consideration. For this purpose, can be suggested a comprehensive approach quantifying overall engineering water delivery efficiency through an explicitly defined chain of water delivery structures and indices considering the output and input water volumes.

More in general, we can conclude that traditional indicators of water saving might show some limits in assessing multi-dimensional (social, economic, environmental) sustainability. They tend to focus on the economic or productivity aspects against the volumes of water used, leaving unsolved the need of measuring water saving accounting the socio-ecological aspects. More research is needed in this area to develop new indexes that can simultaneously assess economic and social rewarding against a real enrichment of natural water bodies through good practices of water saving. In conclusion the attempt of goal ordering allows the outline of more explicit paths of intervention which can possibly be more useful to develop modular future water saving strategies more explicitly aligned with the major environmental, social, economic or institutional concerns of today evolving society. Moreover, it gives a future perspective for identifying technical and non-technical indicators functional to a logical sequence of sustainability oriented goals. The dialogue within the WASAMED platform gives the opportunity to identify perspectives of sustainable agricultural water saving based on goals and indicators. A complete work to this regard will be available in the form of project deliverable in the project-WEB http://wasamed.iamb.it and a synthesis of results will be published.

Table 3. An example of sustainability goal ordering for water saving

1st LEVEL GOAL	2nd LEVEL GOAL	3rd LEVEL GOAL
ENVIRONMENTAL DIMENSION		
Effective water bodies enrichment	• Improve integration of run-off control and non conventional waters use	• Improve runoff control and environmental planning • Improve/increase use of saline water, treated wastewater and recycled drainage waters
	• Improve irrigated agriculture	• Improve land management practices • Improve and implement knowledge on biotechnologies • Effective use of models, GIS, remote sensing techniques • Cropping pattern optimization and improved irrigation scheduling • Improve and implement (regulated) deficit irrigation • Optimize supplemental irrigation • Use of greenhouses, plastic tunnels and mulching
	• Improve engineering devices and systems operation and maintenance	• Shift open channel to pressurized delivery networks • Implement more efficient irrigation methods • Improve design and distribution uniformity • Use of land leveling and furrow diking • Use of new technologies and devices • Improve system operation and maintenance
	• Improve rain-fed agriculture	• Improve land management practices • Improve water harvesting and conservation • Improve knowledge on biotechnologies • Develop and apply criteria for improving crop selection
	• Improve quantitative assessment of different water saving practices	• Implementing plot experimentation at farm and catchment level • Improve monitoring of dynamics of water bodies at farm and catchment level
Improve quality of environment	• Improve use of saved water for environmental purposes (ex.: groundwater recharge, reforestation, river base flow….)	• Increase awareness of policy makers • Carrying environmental awareness campaign • Improve integration of water saving in environmental policies
	• Improve regional and local knowledge and education on water saving practice having positive impact on environment	• Increase and improve exchange of information and study results on water saving best practices • Water quality monitoring
ECONOMIC DIMENSION		
System economic growth and competitiveness	• improved trade position of farmers and neighboring land system	• Develop adequate models to simulate socio-economic and market scenarios
	• Coping water saving with evolving economic system	• Create system of participation in decision making able to tackle external irrigation system perturbations • Improve education to understand changing • Develop reflexive economic models for adaptation to changes
	• Improve water pricing	• Development of adequate models water pricing • Improve co-decision mechanisms of setting water pricing • Develop and apply policies for incentives to reduce water use • Application of penalties for inefficient use • Private sector involvement in water management
Improved long term stability of farmers	• Increased trend of redditivity through water saving	• Integrate water saving in economic policies • Adequate shift or rotation of crop patterns • Develop adequate models for economic simulation
SOCIAL DIMENSION		
Improved cohesion	• Use of innovative technology	• Training and education on use and adoption of water saving technologies • Farmers participation in innovative system O&M
	• Optimise balance between water saving benefits and total social costs	• Adequate expenditure programme based on convenient use of capita • Develop water saving according to system needs
	• Increase rate of employment through water saving	• Improve education in water management and operation • Create incentives and policies to increase sector investment
INSTITUTIONAL DIMENSION		
Strengthening institutional participation and system governance	• Improve participation in decision making and building shared knowledge	• Increased empowerment of water user associations • Increase number of farmers in water associations • Increased gender involvement in water management
	• Improved farmer water rights and land tenure	• Develop modern regulatory framework and increase institutional awareness
	• Improve collective preventive planning and caring	• Implement and improve monitoring of water supply/demand and water bodies dynamics • Improve scenarios of climate change, variability, drought events • Improve models of integrated drought management • Improve system of water governance able to cope with drought and climate variability and change (drought preparedness)

Table 4. Ordering of possible indicators at given 1st ad 2nd level goals derived from Table 3.

1st Level goal	Indicators
• Effective water bodies enrichment	• Groundwater table • Surface water discharge
• Improve quality of environment	• Environmental indexes
• System economic growth and competitiveness	• Average GDP / unit of area where water saving is applied
• Improved long-term stability of farmers	• Degree of satisfaction of farmers
• Improved social cohesion	• Water used in agriculture/total water use • Rate of system employment; gender ratio
• Strengthening institutional capacity and participations	• Volume of water saved/ total resources invested in water saving • Effective application of new water policies • Irrigated land / irrigable land • N. of farmers in WUAs / total N. of farmers • Surface area managed by WUAs / total irrigated area
2nd Level goal	**Indicators**
• Improve integration of run-off control and non conventional waters use	• Volume non-conventional water used + volume of run-off water / total volume of water used
• Improve irrigated agronomic practices	• Biomass (yield) / crop evapotranspiration • Yield / Irrigation Water Used (IWU)
• Improve engineering practices	• Water Use Efficiency chain (output volume / input volume)
• Improve rain-fed agriculture	• Biomass (yield) / crop evapotranspiration
• Improve quantitative assessment of different water saving practices	• Water used in irrigation / irrigated land • Overall water saving index (WUE, WP, NWU, IWU)
• Improve use of saved water for environmental purposes (ex.: groundwater recharge, reforestation, river base flow….) • Improve regional and local knowledge and education on water saving practice having positive impact on environment	• Volume of water used for environmental purposes • Volume of water saved / N. of water saving practices • Density of water quality monitoring stations
• improved trade position of farmers and neighboring land system • Coping water saving with evolving economic system • Improve water pricing	• Quantity and diversity of production / demand • Degree of adequacy of available economic scenarios • Economic value / Crop evapotranspiration (IWU) • Farmer satisfaction
• Increased trend of redditivity through water saving	• GDP / capite * N. of years * Volume of saved water at farm
• Use of innovative technology • Optimise balance between water saving benefits and total social cost Increase rate of employment through water saving	• N. of technology patents in water saving • Cost of 1 m3 saved water / total material cost • Rate of employment / overall water saving (WUE, WP, UWA, ISP)
• Improve participation in decision making and building shared knowledge • Improved farmer's water rights and land tenure • Improved farmer's water rights and land tenures • Improve collective preventive planning and caring	• Rate and diversity public and private participation in decision making • N. of farmers involved in managing water saving • N. of new water concessions and rate of land ownership • Money spent in planning and monitoring • Number of new monitoring and forecast devices • Density of monitoring stations

CONCLUSIONS

An important aspect to be encompassed in S&T agenda is certainly related to communication and networking (national and regional level) to promote integrated management of limited water resources, increase public awareness and achieve the necessary critical mass of researchers, end-users and decision makers to enable the implementation of long-term sustainable programmes. Research projects addressed to relevant regional and national issues should be implemented through the integration of technical, social, economic, environmental and institutional aspects. Accordingly, the conceptual model of "integrated management of limited water resources" should be formulated through the integration of: 1) water related technical outputs; 2) socio-economic factors; 3) environmental factors; 4) governance/institutional dimension. New models of limited water resources management should include dynamic assessment of water resources, based on explicit socio-economic, policy, environmental-climatic and institutional goal and indicators that account for a short to long-term multi-dimensional assessment perspective. To this regard, new knowledge and tools for building adequate reference scenarios are needed.

Following the partial outcomes of WASAMED and the indications of several convention workshops stimulated by the European Commission during the last five years, it is plausible to suggest some main issues for future science and development agendas in water management:

- strengthening multi-stakeholder regional and local networks;
- promotion and adoption of a comprehensive and dynamic methodological framework that develops horizontal and vertical integration in water management;
- develop methods of sustainability assessment of water related policy;
- better identification of targets and multi-dimensional indicators that adequately respond to the socio-economic-environmental-institutional assessment of water saving;
- develop innovative technology based on real needs, to support modernisation of irrigation systems;
- identification of sustainable indicators to build-up dynamic socio-economic-environmental scenarios;
- strengthening the participatory approach at the various levels;
- building-up a comprehensive and dynamic knowledgebase;
- strengthening networking and communication actions;
- giving added value to networking through the processing and elaboration of existing results rather than conducting on-field conventional research and experimentation;
- producing tools that give to networking and communication the open boundaries and dynamic structure, so they may grow in critical mass and evolve gradually toward a real integration of "resources" and "expertises";
- developing integration of water saving actions and sustainable development in water policy in the Mediterranean.

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