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FUTURE OPTIONS AND RESEARCH NEEDS OF WATER USES FOR SUSTAINABLE AGRICULTURE

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Summary - The increased demand for other uses coupled with recurrent drought and climatic changes in countries of limited water resources, is producing unprecedented pressure for reducing the share of fresh water used in irrigation. Many countries in the Mediterranean region, give priority of water allocation to the domestic sector followed by tourism and industry, and what is left is allocated to agriculture. At the same time that agriculture is asked to give water to other uses, the increasing population demand requires increase in food production. This creates a conflict that should be resolved and should be alleviated by examining different options of water uses for sustainable agriculture. Increasing the efficient use of water is a key non-structural approach to water resources management. The agriculture water use efficiency and water productivity is very important as they are largely inefficient in so many countries due to poor distribution systems and excess irrigation. The over all global average agricultural water use efficiency in the region is in the order 40%. This paper analyzes the water situation in the region and shows how agriculture will be affected by water shortages and giving priority of water uses to other sectors. Water planners and decision makers as well as researchers are faced with different challenges including; resources, economical, environmental and institutional. There are some options that can be used to sustain agriculture in the region considering the above constraints and challenges. They include: improving water use efficiency, reducing crop consumption of water, irrigation with reclaimed water, practicing deficit irrigation and irrigation with desalinated water. Lessons learned from Jordan and other countries will be illustrated in this presentation. The research vision for the next 25 years could include the following set of actions: have more efficient use and allocation for water use in irrigation; improved water productivity by introduction of new management measures such as deficit irrigation; and the introduction of high yielding low water demanding varieties. Desalination of brackish and sea water can offer limitless fresh water that can be used for agriculture. Therefore, there is a need to find cheap methods of desalination such as the use of solar and renewable energy. As reclaimed water of urban wastewater is becoming a new source, it is necessary to maintain efficient and sustainable agriculture production while using them. Therefore, researchers should consider these needs in setting up their research priorities.

Key words: irrigation, water saving, research, education, sustainability.

INTRODUCTION

Many countries in the Mediterranean region are located in the arid to semi arid regions of the world that are classified with limited water resources and increasing water scarcity. Managing these resources for sustainability will become increasing complex and difficult in the future as climate changes increases the frequency and intensity of drought and water shortages. The decline in the available water supplies as a result of the above biophysical factors as well as other geopolitical factors, rapid expansion in population, urbanization and economic development will result in depletion of the exploitable water resources. These conditions will produce an unprecedented pressure on the share of fresh water for irrigating the agricultural sector and will force many countries to reform their water allocation policy by giving priorities to the domestic and industrial water demand. As such, irrigated agriculture will be the most effect sector claiming what is left and using the reclaimed wastewater. In many cases such as Jordan, agriculture is asked to give its share to other uses in spite of increasing demand for food production. This situation creates a conflict that should be resolved and could be alleviated by adopting different options of water uses for sustainable agriculture. Increasing the efficient use of water in agriculture would be a prime option as it is considered a key non-structural approach to water resources management.

The issues of agricultural water use efficiency and water productivity are very important as they are largely inefficient in many countries due to many factors such as poor distribution system, excess irrigation and lack of proper irrigation water management. Therefore, improving water uses efficiency and productivity on sustainable basis is an enormous challenge for the water stress and scare countries of the Mediterranean. They should set forth strategies and plan to design and carry out programs that increase water use efficiency by farmers while increasing farm incomes. This will require a combination of technology, education and extension services coupled with research programs and effective policy framework in order to reflect the real opportunity cost of water. The focus should be concentrated on crop selection for better water use efficiency and productivity with improvement of marketing performance to add value and increase the return on agricultural investment in the irrigated sector. The problem is not limited to countries of the south Mediterranean but it has reached other humid high rainfall countries like France, Spain, Italy and Greece obliging them to impose temporary restrictions. The agricultural productivity and competitiveness in the whole region is adversely affected by water scarcity and inefficient use of water. The average water use efficiency for the sector in general ranges from 40-45% (Hamdy 2005 and Osman 2006).

Efficiencies in the use of water for irrigation consists of various elements taking into account losses during storage, conveyance and application to irrigated area while optimal water productivity can take into consideration, proper water allocation and scheduling, selection of high value crop, timing of irrigation and other field practices. These practices and elements have been discussed in many articles but this paper concentrate on the options of research, education and information to improve irrigation water efficiency and its productivity.

CHALLENGING FACING RESEARCH

Water scarcity is the single most important resource management challenge in the region. Inspite of that, most countries do not treat their water as a scarce resource. Before exploring different options in research, education and information, it is necessary to discuss the issues and challenges facing them. Researchers and decision makers should be aware of the resources and management challenges as well as socio-economic and environmental issues and institutional setup.

Resources Challenges

The water shortage of the region has been traditionally addressed by increasing supply of water. The most common approach was to extend exploration and make massive investment in water resources development. Over the years, most of water resources have been almost developed, so the rate of investments is currently shrinking. Expanding the supply is unlikely to make dramatic changes in the future because their development will technically be unfeasible and economically expensive. Therefore, an essential part of any resources program must focus on managing water demand. Most of the water saving will come from agriculture by improving water use efficiency.

Economic and Social Challenges

The impact of reduced share of water to the agricultural sector will directly affect the issues of food self reliance. This may cause much economical and social reform that can create additional challenges, thus encourage decision makers, researchers and farmers for the efficient use of water and improved productivity.

Environmental Challenges

With improved water use efficiency, the extra amount of water applied for leaching can be reduced thus increasing soil salinity. Also, the agricultural sector will relay on a great percentage of its water supply on reclaimed wastewater and low quality water. These conditions will create environmental problems that should be addressed in research and management.

Management Challenges

Supply and demand management, through the more economically efficient supply and use of water and through changes in production practices as well as reduction of loses, is a vital issue in resource management strategies and planning. Legislation an economic approach to water demand management is properly the most important instrument that water resources managers has to develop and use. They should work together with researcher in order to come up with an optimum approach to water saving.

Institutional Challenges

For any water management program to be successful and effective, there should be a close link between researchers and decision makers, between extension workers and researchers and between farmers or farmer's associations and extension workers. For these reasons, an institutional set up must be created where the four groups are integrated; researchers focus on on-farm research and extension agents focuses on adoption process. In developing countries, irrigation extension services dose not exist thus establishing extension agencies for irrigation and water management imposes a great challenge.

RESEARCH OPTIONS

Universities and research institution are asked to participate in the improved management of irrigation water and they should demonstrate that they are capable of developing sustainable and integrated research programs. On the other hand, public sectors (represented by ministries of agriculture and water and irrigation) and the private sector should give the universities the leading role in research to gain experience in improving agricultural water use efficiency and productivity. Research results in many developing countries demonstrates that agricultural demand for water can be reduced without decreasing the total irrigated areas or the value and the quality of the agriculture production. Proper water usages along with crop selection might actually increase agriculture's contribution to the economy and at the same time decrease its water usage. However all research efforts and results are considered worthless unless they can reach and be adopted by the end users and farmers. Therefore, universities and research institutions should have extension units linked to the public sector extension services that are capable of disseminating the results to the farmers. The later are in need of information which are site specific and time dependant because many of them have realized that optimal agricultural production requires good water management.

The research on supply management are limited to improving the quantity of supply by using various management tools through modeling and enhancing water supply such as water harvesting and recharge of groundwater. However, other minor options such as cloud seeding, fog harvesting and water desalination should not be ignored. On the demand side, the research challenges and options are attractive because water saving and increasing the value per cubic meter of water are highly achievable. Any improvement in the irrigation efficiency means expanding irrigated area by the same percentage. Below are some options that might be adopted by researchers in order to orient their research program in water demand management aiming at increasing water use efficiency and improving its productivity.

Crop Water Requirements

Previous calculations of crop evapotranspiration using different formulae and procedures have always overestimated the actual consumptive use of different crops. Due to lack of data and research results, these methods were applied to be the basis for the design of many existing projects. In these projects, the system capacity and the delivery schedule allow for over irrigation most of the time. The FAO paper 56 has suggested a new procedure in calculating ET based on the revision of previous methods. Although, FAO procedure is general but the results of field trials have shown that about 20% of ET have been overestimated by previous methods. For example, the average peak ET for citrus in the northern part of the Jordan Valley was calculated as 5.4 mm/day using FAO methods compared to previous calculation of 6.5 mm/day according to Blaney-Criddle method. The results of

recent research (Shatanawi et al 2006) and the farmer's practices in the same area have shown that the average ET has drop to about 4.8 mm/day without any impact on the produce quality and quantity.

On the other hand, crop requirement for near maximum yield is determined by plant physiology, there are associated management factors manipulating the microclimate environment that can provide some advantages. For example, the irrigation requirement for open field vegetables may be twice or triple that for crops grown in plastic houses. A complementary approach is to select planting times and growing seasons that minimize the atmospheric demand for water consumption. Another possible action aimed at reducing ET is to change cropping patterns in favor of high value crops indented to the export that have relatively smaller water requirement.

With the availability of new technologies like real time automatic weather stations and modern devices like the Eddy correlation, it would be possible to determine the exact amount of daily ET. The use of remote sensing data using satellite images coupled with ground truthing, ET and crop coefficient can be determined at district and regional level.

The EU has supported a research project (STRP) entitled "Improved Management Tools for Water-Limited Irrigation: Combining ground and satellite information through models, (IRRIMED)" with the participation of 6 Mediterranean countries under FP6. The aim of this project is the establishment of tools to support efficient management for water used for irrigation as well as to test scenarios for long term sustainable policies. Accurate knowledge of water demand and use by irrigated agriculture is the key to an effective water management strategy. The general scientific objective is the assessment of temporal and spatial variability of water consumption of irrigated agriculture under limited water resources condition. Intensive measurement campaigns with eddy correlation equipment will allow combining ground and satellite measurements into models, to ultimately produce simple methods to assess evapotranspiration (ET) over large areas.

The accurate assessment of actual ET over selected crop during the growing season, will allow validating models and to update the crop calendar and crop water requirements. Also, remote sensing of crop extension and evolution during the growing season will help to measure the actual acreages of the different crops. Refining existing methods for simple ET estimation will be used to deriving ET maps from satellite data. This line of research will continuously update information that can be revised annually based on agro-climatic conditions.

Precision Irrigation

The issue of irrigation scheduling (in when to irrigate and how much water to apply) is a matter of delivery schedule and farmer's decision. With the availability of soil moisture sensors and stem water potential devices, it is possible to irrigate at the exact time when water is needed by the plant. These devices can be installed in the soil at two depths or can measure the tension in the leaves or fresh stems may be connected to electronic control panel that can tell the farmers the need to irrigate. Research on who to integrate these modern sensors to the irrigation systems is an option that should be exploited in the future.

Precision irrigation is not limited to irrigation scheduling but can be extended to incorporating them into the design of various irrigation systems. In surface irrigation, laser land leveling can insure good uniformity distribution and improved irrigation efficiency. In pressurized irrigation system, the systems can be operated through automatic control panel. Also, leaks and uneven distribution of irrigation water along the lateral and subunits can be detected easily. The introduction of such technology will certainly improve irrigation efficiency and water productivity as well as reducing water losses.

Use of Reclaimed Water

Reclaimed wastewater has become a significant source of the water resources in many countries of the Mediterranean like Jordan were it contribution to the irrigation sector has reached about 15% in 2005 and will reach 40% by the year 2020. Research in this area is scattered and is limited to treating this source as low quality water. Research in this regards should be extended to include long-term impact of using the reclaimed water on soil and the environment, changes in on-farm practices

especially those related water use efficiency, adopting more high value crops and social and economical impact of the reuse of treated effluent. The research should focus on finding appropriate tools to help farmers to overcome problems that will face them and the sector and to develop new attitude and behavioral patterns.

Desalination of Brackish Water

The area of the Mediterranean, especially the south has a significant reserve of saline water that is considered a potential resource in the future. It is possible to irrigate certain crops with this kind of water provided that the soil exhibits good drainage conditions while applying extra water for leaching purposes. Research results have shown that there are few success cases where the production is economically feasible. The reduction in yield of up to 50% may not justify the investment provided for the irrigation and drainage systems as well cost of pumping and delivery. There are few cases where it is possible to irrigate fodder crops in sandy soils with good natural drainage system.

An alternative to that would be to desalinize this water in which the cost is justified. Experience from the Jordan Valley has shown that the cost of desalination of saline water (2000 to 5000 ppm) can reach as low as 0.2 $/m3 using medium size reverse osmosis plants with a capacity of 40 to 50 m3/hr. Irrigation with the blended water of 500 ppm has increased the yield of high consumptive crops more than twice. Banana yield has increased from 20 ton/ha to 40 ton/ha with good quality produce while the irrigation water requirements have been reduced from 2500 mm to 1800 mm.

The investment can be farther justified if this water is used to irrigate seedling nurseries and cash crops like strawberry. Therefore, new research ideas should be explored on conducting comparative studies, reducing the cost of desalination, and evaluating the environmental and economical impact.

Deficit Irrigation

Deficit irrigation means applying less water than cumulative ET, thereby allowing roots to utilize stored soil water in the winter or pre-season irrigation. Therefore, the irrigation water requirements in early irrigation in the spring season can be less than that indicated by ET calculation. Also, deficit irrigation may be regulated for the rest of the season avoiding critical periods. Such management practices results in water saving in irrigation without affecting or reducing yield. There are two types of deficit irrigation; sustained and regulated. In sustained deficit irrigation, the irrigation is reduced during the whole season while regulated deficit irrigation starts with normal irrigation and then gradually irrigation is reduced. Regulated deficit irrigation is an irrigation strategy based on limiting non beneficial water losses by reducing the amount of water for crop during non-critical phonological stages. The deficit irrigation is controlled during times when the adverse effects on productivity are minimized. There are a lot of research activities on DI that are going on field crops and vegetables. Field demonstration conducted by Shatanawi and the French agriculture Mission in Jordan (1996) showed that 40% reduction in water consumptive from the farmer's practices did not affect the yield. Observation and communication with some farmers concluded that reducing water application by 30-40% during drought years did not reduce yield economically. However, research on fruit trees is limited and should be evaluated in estimating the actual ET under deficit irrigation in order to maximize the water unit productivity. Such research should include applying different level of irrigation while measuring the soil moisture content and leave water potential.

It is worth mentioning at this point that EU has supported a research project on deficit irrigation entitled “Deficit Irrigation for Mediterranean Agricultural Systems (DIMAS)”. The objective of this project is to evaluate the concept of deficit irrigation (DI) as a means of reducing irrigation water use while maintaining or increasing farmers profits. The DI concept will be the subject of multidisciplinary research at different scales, geographic locations, and with different perennial and annual crops. The objective will be to develop a workable, comprehensive set of irrigation (DI) strategies that can be disseminated quickly among the various agricultural systems of the Mediterranean Region. The project addresses directly the first topic of the FP6- INCO-2002-B1.2 specific measure, ‘research on sustainable irrigation, including deficit irrigation’. Eleven partners from seven different countries (Greece, Italy, Jordan, Morocco, Spain, Tunisia and Turkey), including research and water association institutions will work for three years on the project. Their main activities will be: a) the development of

a general summary model of crop yield as a function of water supply, b) the validation of the model for the main irrigated annual (wheat, sunflower, cotton,) and perennial crops (olive, pistachio, citrus), using common research protocols, c) a survey on physical, socio-economic and cultural conditions for each crop and irrigated area, and d) scaling up by combining the yield model with economic optimization modules that will generate optimum DI strategies compatible with the specific socio-economic characteristics of each area under study.

The results of the project will provide recommendations for reducing irrigation water use while ensuring the sustainability of irrigated agricultural systems in the Mediterranean basin. Feedback with project end-users will take place via participation of farmers associations and irrigation water agencies who will contribute their expertise in managing water scarcity, thus ensuring that all relevant issues are addressed.

Irrigation Techniques

The efficiency of the on-farm water use and the water productivity can be increased with improved irrigation techniques. Innovation in this area should be pursued between researchers and the irrigation industry. Although micro irrigation is known to be high efficient irrigation system but experience shows that if the system is not well design and not operated probably, the efficiency can be as low as 50%. In addition to that, research on irrigation accessories such as filters, pressure regulators should be incorporated into the system design and management. In this area, the use of sand filter with proper sand gradation automatic filter systems, emitters, acid and chlorine injection should be tested and experimented on crops highly sensitive to water stress. For other irrigation systems like surface irrigation and sprinkler irrigation, there is a high potential for innovation such as molding of surface irrigation, irrigation cut back and surge flow irrigation. The design of all irrigation system should provide flexibility and simplicity required for successful operation under different soil variables and topographic variation. Research should be oriented toward proper and careful selection of pumps, pipes and on-farm sprinkler equipment in order to sustain high uniformity at a specified application rate. The research in irrigation system should also concentrate on the energy aspect by introducing and testing low pressure micro and sprinkler irrigation in order to reduce the cost of operation and maintenance. Technology so far, has produced sprinkler system of low energy precision application (LEPA) and low pressure compensating emitters that can give high uniform application rate and efficient irrigation. A probably designed and managed system incorporating all of the above technology can have efficiency as high as 98%. Research should be further pursued to explore along with the industry new technology that can save in water and produce uniform irrigation.

EDUCATION AND TRAINING OPTIONS

The overarching goal in promoting the efficient and the effective management of water is the investment in human resources development. The venue in this regards has many options ranging from University diploma and higher graduate research to in-job training and tailor training programs. Most universities in the region offer B.Sc degrees and M.Sc Degrees in water and irrigation and few Ph.D programs. However, capacity building is not only limited to new graduate and extension agents but should be extended to the decision makers, legislators and stakeholders.

Training on the state of art on water management can help in establishing water resources management agencies and creation of irrigation advisory units. Experience from Jordan has shown that farmers receiving training from the University of Jordan in irrigation scheduling and management have reported improvement in irrigation efficiency by 30% (Shatanawi, 2004). The link between farmers and educators as well as researcher should be the responsibility of the extension services who will convey the result of the research to the farmers. Therefore training of extension personal will facilitate the flow information to the stakeholder groups such as water user associations. They should be also trained to carry on activities such as managing demonstration sites, organizing working session with farmers groups, hosting educational opportunities for professional, disseminating information and encouraging individuals to participate in improving water use efficiency and productivity. The results of the demonstration programs that have been undertaken on pilot basis, aiming at improving on-farm water use efficiency can be disseminated by extension services.

The irrigation sector in many countries of the Mediterranean needs high quality extension services with innovative ideas to translate policies into action plans. The extension services should not be limited to the public sector but the various irrigation companies and private agricultural enterprises who are using the state of art technology must all of them take action in training extension services as well as farmers.

INFORMATION AND TECHNOLOGY TRANSFER

Information is considered a key element in the day to day management, decision making and undertaken current and future water balance and flow. The flow and availability of information to researchers, operators and farmers is also of prime important to determine irrigation scheduling by farmers and water delivery schedule by farmers. There are different levels of information required. For operators of the irrigation system at the project, it is necessary that information regarding flows of surface water and reclaimed wastewater, and stocks of groundwater be available at the present and future. This kind of information coupled the projected cropping pattern and agro-climatic data can help in better water allocation and optimization, thus improving water use efficiency and productivity. The role of the irrigation authority should not be limited to operation at the sub-unit level, which is responsibility of the farmers group, but they should work at higher level of planning and management at the project level. The Water Management and Information System (example from the Jordan Valley) can provide such a model for irrigation districts.

Research and technology transfer institution can play an important role in utilizing the field and climatic data, information of crop pattern and meteorological data into daily out put that can be used by farmers. An example on that is the Irrigation Information System established by the National Center for Research and Technology Transfer (NCARTT) where the whole country is covered by a network of automatic weather stations. Daily ET is calculated for different location from the data transmitted from these stations using the FAO method of paper 56.

On the other hand, expansion of pilot projects and demonstration farms will help in obtaining accurate information on the impact of improved irrigation practices on water use and economic return of unit volume of water. They will serve as a venue for comprehensive extension and technology transfer programs. The demonstration sites of concentrated water practices could be divided to cover the different climatic zone of any region. Demonstration activities can include the following:

1. Demonstration on micro irrigation operation and maintenance.
2. Demonstration of deficit irrigation strategies.
3. Demonstration of winter soil moisture conservation technique.
4. Demonstration on optimum irrigation practices.

Each country should have an entity responsible to coordinate national agriculture research on water management and technology transfer activities. The entity can act as a focal point for capitalizing and facilitating information and technology transfer including social and economic marking. The focal points should work among a network of partners such as universities, irrigation authorities, extension services and other environmental societies.

The experience of the Scientific Irrigation Scheduling Services (SISS) from California State and Washington State can be technically adopted by some countries. SISS are enterprises that market full service or self service SIS products such as a low cost tensiometers, water marks and portable soil water sensors (Neutron Probe). Also, the technology of Aqua-Card have been widely used in Italy could be adopted by other Mediterranean countries.

CONCLUSIONS

Many countries in the region are characterized by limited water supplies while providing additional resources will be an expensive option. Therefore, efforts in the optimal management of water resources should concentrate on the demand side management. As the agricultural sector is consuming the bulk of water supply, good management of irrigation water can be translated into significant amount of saving in the water resources. In addition, the agriculture sector will be most affected by water shortage and would be asked to give water to other uses such as the domestic and

the industrial sector. Therefore, increasing the efficient use of water in the agricultural sector would be an overarching goal in changing certain policies or adopting new ones with the objectives of improving on-farm water management and maximize agricultural return per unit of water. Optimization of water use at the farm level involves getting the maximum value output for minimum amount of water. There are several activities that can be carried out to achieve this goal ranging from field management practices by the farmers to water management approach by decision makers. However, these activities can attain high degree of success if it is supported by good research programs and extension services where both need the availability and flow of information.

Research program and activities should be oriented towards the adoption of improved technologies, management practices and policies which contribute to the national development as well as addressing the problems and needs of the irrigated agriculture. Research projects must be planned and formulated in such a way that these activities are directed towards effectively conserving and managing the national resources utilized in agricultural development so it would not contribute to the loss of and/or deterioration of these resources.

In order to cope with future challenges facing irrigated agriculture, research and technology transfer, system must be capable of responding to the needs of an increasingly more sophisticated and more competitive agricultural sector. Research projects will be demand driven and should be applied and/or adaptive in nature. In order to ensure the most efficient use of the limited resources available for research and technology transfer activities, project should be multidisciplinary in their approach.

The role of institutions and agencies engaged in agricultural research must be clearly defined, along with the areas of research and technology transfer they are capable of implementing and carrying out. Agricultural research should take into consideration population increase, changing consumer habits, limited water resources and the need to increase water use efficiency and improve production practices to reduce production costs and increase the competitiveness of the production.

The goal of research and technology transfer in the area of irrigated agricultural is to achieve an efficient and economic production, diversification and marketing crops for domestic and export market. In order to achieve the above goals, research strategy and technology transfer activities should be directed towards the following objectives:

1. Improve water use efficiency
2. Utilize non-traditional water resources
3. Intensify cropping systems
4. Improve and test new management practices

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