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Mainstreaming Agricultural and Water Policies for Social Equity and Economic Efficiency

Muhammad Shatanawi, Sawsan Naber and Maisa'a Shammout

University of Jordan, Amman - Jordan

Abstract. The world population, especially those living in developing countries, are faced with two major challenges represented by increasing water scarcity and looming food crises. In order to solve food shortage and secure a high degree of self-sufficiency, many of these countries have considerably expanded irrigated agriculture and this has resulted in over-exploitation and deterioration of water resources. In spite of all investments, the contribution of the agriculture sector to the national economy is declining while food imports are on the increase. In order to solve these problems an integrated approach has to be adopted by mainstreaming water and agricultural policies aimed at social equity and economic efficiency. These policies should also take into account resources conservation and environmental sustainability without compromising the rights of the future generations. Achieving food security with limited water resources is an approach that appears too ambitious but applicable where political will may rely upon strategic planning and scientific support. During the last two decades, scientific and technological advances made it possible to solve many problems in the field of agricultural development. High-tech applications in agriculture e.g. high-tech irrigation systems, soil-less culture, high-yielding varieties, and biotechnology have allowed to increase production by five to ten times. These technologies are becoming feasible with increasing food price and limited water supply. Under these conditions water productivity will be significantly enhanced compared to traditional or protected agriculture.

Keywords. Water policy – Social equity – Economic efficiency – Water resources – Jordan.

Intégration des politiques agricole et de l'eau pour l'équité sociale et l'efficacité économique

Résumé. La population mondiale, en particulier dans les pays en développement, se trouve confrontée à deux défis majeurs représentés par la croissante rareté de l'eau et des crises alimentaires menaçantes. Afin de résoudre le problème de la pénurie alimentaire et d'assurer un niveau élevé d'autosuffisance, dans plusieurs pays on a assisté à une expansion considérable de l'agriculture irriguée, ce qui a déterminé une surexploitation et une détérioration des ressources en eau. Malgré tous les investissements, la contribution du secteur agricole à l'économie nationale va en se réduisant, alors que les importations d'aliments s'accroissent. Pour faire face à ces problèmes, il est nécessaire d'adopter une approche intégrée, en prenant en compte les politiques de l'eau et agricoles qui visent l'équité sociale et l'efficacité économique. Ces politiques devraient également considérer la conservation des ressources et la durabilité de l'environnement sans pour autant compromettre les droits des générations futures. Atteindre la sécurité alimentaire avec des ressources en eau limitées représente une approche qui semble être trop ambitieuse, mais applicable, à condition que la volonté politique soit soutenue par une planification stratégique et l'apport scientifique. Ces deux dernières décennies, les progrès scientifiques ont permis de résoudre de nombreux problèmes dans le domaine du développement agricole. Les applications de haute technologie en agriculture, à savoir des systèmes d'irrigation très avancés, la culture hors-sol, des variétés de haut rapport et les biotechnologies ont permis d'augmenter la production de cinq à dix fois. Ces technologies deviennent de plus en plus applicables vu la hausse des prix des aliments et la disponibilité limitée de l'eau. Dans ces conditions, la productivité de l'eau pourra augmenter considérablement par rapport aux systèmes de culture traditionnels ou sous couverture.

Mots-clés. Politique de l'eau - Équité sociale - Efficacité économique- Ressources en eau – Jordanie

I – Introduction

Water is one of the five largest markets in the world. It is estimated that over \$350 billion are spent annually on generating and delivering water for human consumption, industry and agriculture.

Expenditure is growing by seven percent yearly because of population growth, a higher standard of living, a decline in available groundwater sources and climate change leading to drought conditions worldwide.

As water demand grows and resources shrink, new technologies are needed to increase the supply. In the year 2006, over \$50 billion were invested in infrastructure and technological solutions in an attempt to meet the challenge of the growing water demand.

The world water shortage is generating attractive opportunities and is encouraging the growth of global business activities.

Most of the Mediterranean countries, especially in the South and the East, are faced with water shortage dilemma due to the increasing gap between supply and demand. The gap will increase more in the future due to population growth, improved standard of living, urbanization and industrialization. Water demand is growing at an accelerating rate while supply is fixed and limited, thus creating an imbalance. In order to reduce the gap and to balance the water equations, governments often resort to the hard bath solution trying to bring additional water resources or to reallocate the agricultural share to other sectors. The option of bringing additional resources is expensive because most of the cheap resources have been completely exploited. Therefore, these countries are faced with the option of shifting water allocated to agriculture to use in the domestic and industrial sectors. The argument for such a strategy is that agriculture is less efficient and its contribution to the gross domestic product is very low. This argument did not take into consideration the social dimension in terms of social equity and political stability.

Many have recently recognized that the availability of water for irrigation purposes in rural areas has a significant impact on poverty and social equity. The direct impact is represented by increase in crop yield, productivity and farm income while the indirect effects are measured by evaluating rural employment, economic multipliers and immigration. Furthermore, equity which recognizes the population heterogeneity should also be achieved in the field of irrigation along with poverty and gender.

Solving the water dilemma requires the integration of technical, economic, environmental and social solutions. Adapting the technical processes takes time due to economic and social reasons which are solely related to education and poverty. Such an option needs financial capability and a high education level; both requirements could not be met in developing countries. On the other hand, building desalination plants, transporting water from remote areas and water conveyance schemes require huge investment which is beyond the capacity of many developing countries. Therefore, it would be cheaper for these countries to adopt the demand management approach through water conservation and system efficacy. The problem is not only confined to technical and economic aspects because environmental pollution is also an issue of serious concern. Besides scarcity, water degradation due to over-pumping and diverting treated effluent to surface water are becoming an additional problem.

Water resources have only a limited capacity to match the burgeoning population growth. Surface runoff can be captured and stored for a short-term net gain, as can redirecting and damming surface water and reusing or reallocating water supplies to more critical or higher value uses. Exploiting deep groundwater reserves, however, consumes a non-renewable resource and the currently available desalination technology is prohibitively expensive for all but the wealthiest states in the region.

None of the above-mentioned remedial measures will adequately expand the resource base enough to meet the expected future demands. Given the unlikelihood of dramatically expanding water resources in the region, there are primarily six ways to address the water shortage problem:

1. inter-basin transfer;
2. reallocation;
3. water conservation;
4. wastewater reuse;
5. institutional innovations;
6. technological breakthroughs.

II – Water Challenges

Many countries, south of Europe and south-east of the Mediterranean, are faced with water shortages, scant rainfall, climate change and frequent drought. The existing water resources are also in short supply when measured against population. The average population growth rate in the southern and eastern Mediterranean region, among the highest in the world, is bringing about a strong water demand. According to predictions, water demand will more than double between 2010 and 2050 in Jordan and Oman, and will increase by half in Morocco, Tunisia, Egypt, Sudan and Yemen.

In addition to scarcity and quality problems, several researchers (Shatanawi, 2007; Abu Zeid and Hamdy, 2002), have identified other challenges that the Mediterranean countries are going to face, which can be listed as follows:

1. Water scarcity compared to population growth;
2. Inefficient management of water resources, especially in the irrigation sector;
3. Lack of data and information about water resources;
4. Overlap between water policy and other related policies like agriculture;
5. Deterioration of water quality and increase in pollution sources;
6. Growing gap between the supply and demand;
7. Ambiguity of roles and mission of water resources institutions;
8. Lack of available funding for scientific research;
9. Urgent need for human resources development and capacity building;
10. Absence of the private sector and civil society in participation in water management;
11. Problems associated with shared water resources;
12. Absence of clear water policies and associated strategies and action plans in many countries;
13. Needs for adopting effective public awareness programmes;
14. Limited use of new technology in irrigation;
15. Groundwater pumping in excess of natural recharge rates.

1. Responses to water challenges

1. Adopt an integrated approach to water resources management in service delivery:
 - consider water as a holistic resource with competing demands;

- promote service delivery on the basis of water user demand and their repayment capacity;
 - support private and public water service providers that create economic incentives for sustainable water use.
2. Raise water tariffs, without excluding targeted subsidies to the poorest. This is critical to:
 - promote savings of water use by increasing tariffs;
 - set water charges to cover operation and maintenance costs;
 - ensure financial sustainability of water service providers (irrigation and drinking);
 - save water for ecological reserves and environmental purposes.
 3. Promote policy reforms to encourage farmers to shift to irrigated crops, which provide a higher value per unit of water:
 - priority should be given to crops requiring less water;
 - with globalization, the ‘virtual water’ concept becomes an important factor in agricultural trade;
 - given water scarcity, promotion of export crop production should not be based on foreign currency needs but driven by the implications for water resources sustainability.
 4. Adopt a sustainable groundwater use strategy: Groundwater control legislation should be issued and enforced to regulate the use of groundwater resources based on the following principles:
 - underground water is owned and controlled by the State, and land ownership does not include groundwater ownership;
 - extraction and use of underground water is authorized by a license to the landowner;
 - the 2002 Jordanian Underground Water Control By-Law is a good example.
 5. Decentralize water management responsibility:
 - The management of water distribution networks (except primary canals) should be decentralized and turned over to farmers;
 - decentralization should include poor farmers as members of water user associations.
 - changes in behavioural and social patterns need to be fostered to conserve water (public awareness).
 6. Promote cooperation for sustainable management of transboundary water resources:
 - shared ground and surface water resources need to be jointly assessed and monitored (in terms of quantity and quality);
 - concerted action plans should be adopted for sustainable use of shared water resources;
 - the ongoing experience of many European countries in managing their shared rivers could be useful to others. Also, the experience of Egypt in building cooperation with other riparian countries based on mutual benefits.

III – Integrating policies

In many countries irrigated agriculture policy is usually formulated without coordination with the irrigation and water policy. In many instances one can find contradiction or agreement between statements of the two policies.

At farm level, where water conservation is needed, the responsibility is lost between the Ministry of Water and Irrigation and the Ministry of Agriculture. There are many examples, for instance in Jordan, Syria and Egypt. The situation in countries like Morocco, France, Spain and Italy is much better because small-scale irrigation water projects, including dissemination and on-farm irrigation systems, are the responsibility of a single agency as the Ministry of Agriculture. To insure integration and harmonization of the two policies, the following steps shall be considered:

- promoting major water policy reforms;
- adopting water-saving technologies in irrigated agriculture;
- applying water-saving technologies in rainfed agriculture;
- formulating Irrigation water conservation measures within the policy framework;
- developing advanced agricultural technology.

IV – Adaptation to water scarcity

Governments and societies should cope with water scarcity by adapting to existing conditions and taking certain measures. For example, the city of Los Angeles has grown by one million people since 1970, but it still uses the same amount of water transported from Northern California and groundwater from adjacent areas. Similarly, the city of Amman has grown by 50% since 2000, but it still uses the same amount of water of about 120 MCM. Farmers in the Jordan Valley have adapted to water shortages by relying on deficit irrigation, changing cropping pattern and utilizing high-tech micro-irrigation. Water conservation is the most cost-effective and environmentally sound way to reduce the growing water demand and to save energy. Water uses in many countries are exceeding by far the international standard because of high water losses and low irrigation efficiency. There is no actual data on water losses in the network, at farm level or in the other sectors like tourism, industry and recreation. Water conservation and efficiency improvement play a major role in mitigating the problem of water scarcity and shall be given high priority in the region. The trend is to increase supply by building additional desalination units and exploiting the already depleted groundwater. Both measures are costly and they adversely affect the marine environment. A simple way of managing water resources consists in following a systematic water conservation approach in a planned manner in all sectors of demand. Examples from different countries around the world should be examined for gain knowledge of how water is being effectively used.

Therefore, governments should undertake all necessary measures leading to the establishment of a comprehensive programme for water conservation, reduction of water losses and improvement of water use efficiency in all sectors. To implement such a policy, the agencies concerned shall pursue a systematic planning strategy according to the following principles:

- establish investment programs to raise irrigation efficiencies and review water charges, considering sustainability, environment and equity;
- create public awareness entities to carry out programmes aimed at encouraging the use of water saving devices and transfer them to users;
- review the possibilities of using low quality water for industrial purposes and encourage recycling of water as long as it is feasible;

- conduct surveys to determine the types of losses along the water distribution network;
- enhance the management and operation skills of managers and technical staff in the municipal sector;
- improve information provided to farmers through extension services;
- provide support to research institutions to enhance their activities related to the determination of crop water requirements, irrigation water management, and optimum water use;
- review relevant laws and regulations in order to promote water conservation.

On the other hand, the following measures have proved to be effective in promoting water conservation:

- utilization of efficient water saving devices for domestic and irrigation purposes;
- use of treated waste water for irrigation (Jordan, Tunisia);
- increasing adoption of new precision irrigation and drainage systems;
- promotion of low-cost water-harvesting technologies (Jordan, Tunisia);
- adoption of conservation tillage and planting on raised beds to use irrigation water more efficiently (Cyprus, Jordan);
- exploitation of available technology for saline water use (the research results of the International Centre for Biosaline Agriculture [ICBA] and IAM-Bari which tested this technology);
- enhancement of small-scale and supplemental irrigation systems to increase productivity of rainfed agriculture (Syria);
- more efficient crop sequencing and timely planting to achieve significant savings in water use;
- development of new low water-requiring crop varieties by research institutions, some of which are already available.

1. 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 design many existing projects. In these projects, the system capacity and the delivery schedule allow for overirrigation most of the time. FAO Irrigation and Drainage Paper No 56 suggested a new procedure to calculate ET based on the revision of previous methods. Although FAO procedure is general, the results of field trials showed that about 20% of ET was overestimated by previous methods. For example, the average peak ET for citrus in the northern part of the Jordan Valley was estimated at 5.4 mm/day using FAO methods compared to the previous calculation of 6.5 mm/day according to Blaney-Criddle method. The results of recent research (Shatanawi *et al.*, 2006) and the farmers' practices in the same area showed that average ET, using micro irrigation, dropped to about 4.8 mm/day without any impact on the produce quality and quantity.

On the other hand, crop requirement to near maximum yield is determined by plant physiology although there are some related management factors, manipulating the microclimate environment, that can provide certain advantages. For example, the irrigation requirement of open field vegetables may be up to twice or three times more than that of crops grown under plastic houses. A complementary approach consists in selecting the planting time and growing seasons to minimize the atmospheric demand for water consumption. Another possible action

aimed at reducing ET is changing the cropping patterns in favour of high-value crops intended for export, that have a relatively lower water requirement.

With the new technologies available, e.g. real time automatic weather stations and modern devices as the Eddy correlation, it would be possible to determine the exact amount of daily ET. The use of remote sensing data based on satellite images, coupled with ground truthing, made it possible to determine ET and crop coefficient 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 water management 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 conditions. Intensive measurement campaigns with the eddy correlation equipment will lead to combine ground and satellite measurements into models, to ultimately produce simple methods to assess evapotranspiration (ET) over large areas.

The accurate assessment of actual ET in selected crops during the growing season will help validating models and updating the crop calendar and crop water requirements. Also, remote sensing of crop extension and evolution during the growing season will make it possible to measure the actual acreages of the different crops. Refining existing methods for simple ET estimation will allow deriving ET maps from satellite data. This research line will continuously update information that can be revised annually based on agro-climatic conditions: “more crop per drop”, or “increase water productivity”. However, this goal may be achieved by improving agronomic practices not reducing water use. Searching for a more efficient water use entails overcoming the concept of irrigation efficiency and looking for the water passways to identify where water may be saved.

2. Precision Irrigation

The issue of irrigation scheduling (when to irrigate and how much water to apply) is a matter of delivery schedule and farmer's decision. With soil moisture sensors and stem water potential devices available, 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 on the leaves or fresh stems, may be connected to an electronic control panel that can indicate to the farmers the irrigation needs. Research on how 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 and incorporated into the design of various irrigation systems. In surface irrigation, laser land levelling can insure good distribution uniformity and improved irrigation efficiency. When pressurized irrigation systems are applied, an automatic control panel can be used. Also, leaks and uneven distribution of irrigation water along the laterals and subunits can be detected easily. The introduction of this technology will certainly improve irrigation efficiency and water productivity and reduce water losses as well.

3. Use of Reclaimed Water

Reclaimed wastewater has become a significant water source in many Mediterranean countries like Jordan, where its contribution to the irrigation sector has reached about 15% in 2005 and will come up to 40% by the year 2020. Research in this area is scattered and limited to treating this source as low-quality water. Therefore, it should be extended to include the long-term effects of reclaimed water use on the soil and the environment, changes in on-farm practices, especially those related to water use efficiency, adoption of higher-value crops and the social and economic

impacts of treated effluent reuse. Efforts should be made to develop appropriate tools to help the farmers and the whole farming sector overcoming problems in the future and encourage new attitude and behaviour patterns.

4. Desalination of Brackish Water

The Mediterranean region, especially the South, displays considerable reserves of saline water that are considered a potential resource for 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 stories where production proves to be economically feasible. The yield reduction up to 50% may not justify the investment made for the irrigation and drainage systems and the pumping and delivery cost. 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 desalinate this water where the cost is justified. Experience from the Jordan Valley shows that the cost of saline water (2000 to 5000 ppm) desalination 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 500ppm blended water can increase the yield of high water-consuming crops more than twice. Banana yield increased from 20 ton/ha to 40 ton/ha with good quality produce, while irrigation water requirements were reduced from 2500 mm to 1800 mm.

The investment can be further justified if this water is used to irrigate seedling nurseries and cash crops like strawberry. Therefore, new research lines should be explored conducting comparative studies in order to reduce desalination cost and evaluate the environmental and economic impact.

5. 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, irrigation water requirements for early irrigation in the spring season can be less than those indicated by ET calculation. In addition, deficit irrigation may be regulated for the rest of the season avoiding critical periods. Such management practices result in water saving for irrigation without affecting or reducing the yield. There are two types of deficit irrigation: sustained and regulated. In sustained deficit irrigation, irrigation is reduced throughout the whole season, while regulated deficit irrigation starts with normal irrigation and then, irrigation is gradually reduced. Regulated deficit irrigation is an irrigation strategy based on limiting non-beneficial water losses by reducing the crop water amount during non-critical phenological stages. Deficit irrigation is controlled in the periods when adverse effects on productivity are minimized. Extensive research on DI that is being done on field crops and vegetables. Field demonstrations carried out by Shatanawi and the French Agriculture Mission to Jordan (1996) showed that a 40% reduction in water consumptive use from the farmers' practices did not affect the yield. Observation and communication with some farmers led to conclude that reducing water application by 30-40% during drought years did not reduce the yield economically. However, research on fruit trees is still limited and it should be based on the estimation of the actual ET under deficit irrigation in order to maximize the water unit productivity. This research line should include the application of different irrigation level while measuring the soil moisture content and the leaf water potential.

In this respect, it is worth mentioning that the 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 the farmers' profits. The DI concept will be a subject of multidisciplinary research at different scales, geographic locations, and on different perennial and annual crops. The objective will be the development of 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 that will contribute their expertise in managing water scarcity, thus ensuring that all relevant issues are addressed.

6. Irrigation Techniques

On-farm water use efficiency and water productivity can be increased through improved irrigation techniques. In this area Innovation should be pursued jointly by researchers and the irrigation industry. Although micro-irrigation is known to be a highly efficient system, experience shows that if the system is not well designed and not operated probably, efficiency can be as low as 50%. In addition, 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 e.g. surface irrigation and sprinkler irrigation, there is a high potential for innovation such as moulding of surface irrigation, irrigation cut back and surge flow irrigation. The design of all irrigation systems should provide the flexibility and simplicity required for successful operation under different soil variables and topographic variation. Research should be oriented towards proper and careful selection of pumps, pipes and on-farm sprinkler equipment in order to sustain high uniformity at a specified application rate. Research in irrigation systems should also concentrate on the energy aspects by introducing and testing low-pressure micro and sprinkler irrigation in order to reduce the operation and maintenance costs. So far, technology has produced sprinkler systems of low energy precision application (LEPA) and low pressure compensating emitters that can provide a high uniform application rate and efficient irrigation. A properly designed and managed system, incorporating all the above technology can reach efficiency as high as 98%. Research should be further pursued to explore with the industry the new technology that can save water and produce uniform irrigation.

7. Exploitation of Saline (brackish) Water

Many parts in the region, like Jordan, possess considerable reserves of underground saline water with a variable salt concentration. To date many studies have been carried out to investigate whether this water can be used for irrigation. It was found that certain crops, such as cotton, tomato and melon, readily tolerate saline water (up to 7-8 dS/m electric conductivity, equivalent to salinity of 0.41-0.47% NaCl). For certain crops, there is no doubt that saline water can be used for irrigation instead of fresh water. However, to minimize salt accumulation around the plant roots and facilitate leaching away of salts that do accumulate, it is essential i) to use drip delivery systems and ii) to cultivate the plants in soil-less media or light soils (sandy or loamy-sandy soil).

8. Development of High Agro-Technology

Water constraints and a varied climate should stimulate the development of unique agro-technology, based on high-quality standards according to updated international production and food-safety regulations. Irrigation technology, fertigation, development of greenhouse equipment, seed propagation, fertilizers and pesticides has enabled new agriculture to prosper in adversity. In addition, farmers have learned to develop high value-added and innovative farm products that allow them competing in markets with lower-cost producers. Proper water management, reuse of treated effluent and desalinated water could help the region overcome drastic shortages.

Promotion of advanced agricultural technology would lead to enhance irrigation efficiency, increase agricultural yield and improve quality of life and environmental conditions. The use of soilless media and water-wise gardening have proved to be a determining factor to reduce water consumption significantly.

9. Recycling of Drainage Water

In soilless media culture, the typical leaching fraction which could be applied to remove accumulated salts is between 30% and 50%. As a result, one third to one-half of the applied water drains out, carrying 130 mg/l nitrogen, 2- mg/l phosphorus, and 140 mg/l potassium as well as natural salts. Approximately 1,000 kg of nitrogen, 1,600 kg of chloride and 800 kg of sodium are leached from one hectare of substrates and this is a potential polluting factor for more than 1000 hectares of groundwater. In the last few years, around 25% of the greenhouses using soilless substrates have shifted from open to closed irrigation systems. This shift is even more impressive in rose production, where drainage water is recycled in over 50% of the greenhouses.

Nutrient recycling by reusing water drainage in soilless cultivation appears to be the most logical solution: approximately 50% of water and fertilizer inputs are saved, because of reduced tap-water supply and improved nutrient availability to the plants. The potential pollution of the aquifer from the open irrigation system is reduced. The transition from an open to a closed irrigation system unexpectedly resulted in yield increase and higher fruit and flower quality, due to the higher fertigation control and monitoring applied in the new technology.

V – Adaptation to climate change

Many hydrological models have suggested that most Mediterranean countries will cope also with the effects of climatic change not only as regards water resources supply but also in terms of increasing water demand. In addition to the traditional solutions applied to take up the water scarcity and climate change challenges, it should be appropriate to get a better understanding of these effects and to take some relevant actions by:

- formulating national policies to adapt to the effects of climate change;
- using a decision support system to predict the climate change and its impact on agriculture;
- creating scenarios and models to study the effect of climate change on rivers and groundwater aquifers;
- handling shared water resources issues in diplomatic ways taking into consideration the expected climate changes;
- utilizing efficiently flash floods in water harvesting, artificial recharge of groundwater and promoting vegetation cover in arid areas.

VI – Conclusion

The expanding urban population, as well as the political developments, will likely reduce further fresh water supply for agriculture. The solution lies in the desalination of brackish water and high-level water reclamation. A more significant part of annual crops will be grown under cover, where recycling will become routine. The concepts of ultra-low irrigation rate and vegetable monitoring should be further examined for their contribution to higher efficiency of water utilization. Integration between agriculture and water policies should be strengthened in order to ensure high water productivity and efficiency. To cope with water scarcity and climate change, certain measures could be adopted. Therefore, one of the future solutions to water shortages is to adopt water policies, water-saving technology in irrigated and rainfed agriculture. Irrigation water conservation measures should be formulated within the policy framework and in parallel to the development of high agro-technology.

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