Water Management for Agricultural Sustainability in Dry Areas

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Introduction

While nearly 70 percent of the world is covered by water, only 2.5 percent of it is fresh. The rest is saline and ocean-based. Even then, just 1 percent of our freshwater is easily accessible, with much of it trapped in glaciers and snowfields. Globally, agriculture accounts for 80–90% of all freshwater used by humans, and most of that is in crop production. Still, water is the main abiotic stress (Drought) limiting crop production in several regions of the world. In 2030, 47% of the world population will be living in areas of high water stress. Even where water for irrigation is currently plentiful, there are increasing concerns about future availability. The competition from industrial and urban uses is increasing with demographic pressure and rapid industrialization. The scarcity of fresh water is also exacerbated by non-point and point source pollutions, particularly salinization of groundwater aquifers. Global water pollution is on rise as every day two million tons of sewage and industrial and agricultural waste are discharged into the world's water. Seventy percent of untreated industrial wastes in developing countries are disposed into water where they contaminate the existing water supplies.

Currently, according to the UN Food and Agriculture Organization (FAO), an astonishing 60% of the water diverted or pumped for irrigation is wasted—via runoff into waterways or evapotranspiration. This does not have to be the case.

Water conservation

Water conservation encompasses the policies, strategies and activities to manage fresh water as a sustainable resource to protect the water environment and to meet current and future human demand. Population, household size and growth and affluence all affect how much water is used. Factors such as climate change will increase pressures on natural water resources especially in manufacturing and agricultural irrigation.

Why water resource is important?

Water is considered as the most critical resource for sustainable development in most Mediterranean countries. It is essential not only for agriculture, industry and economic growth, but also it is the most important component of the environment, with significant impact on health and nature conservation. Currently, the rapid growth of population along with the extension of irrigation agriculture, industrial development and climate change, are stressing the quantity and quality aspects of the natural system. Because of the increasing problems, man has begun to realize that he can no longer follow a "use and discard" methodology either with water resources or any other natural resource. As a result, the need for a consistent policy of rational management of water resources has become evident.

Global irrigated area has increased more than six fold over the last century, from approximately 40 million hectares in 1900 to more than 260 million hectares (Postel, 1999; FAO, 1999). Today 40% of the world's food comes from the 18% of the cropland that is irrigated. Irrigated areas increase almost 1% per year (Jensen, 1993) and the irrigation water demand will increase by 13.6% by 2025 (Rosegrant and Cai, 2002). On the other hand 8-15% of fresh water supplies will be diverted from agriculture to meet the increased demand of domestic use and industry.

Furthermore the efficiency of irrigation is very low, since only 65% of the water is used by the crop (Fig. 1). To overcome water shortage for agriculture is essential to increase the water use efficiency and to use marginal waters (reclaimed, saline, drainage) for irrigation.

Agriculture currently uses about 70% of the total water withdraw, mainly for irrigation. Although irrigation has been practiced for millennia, most irrigated lands were introduced in the 20th century. The intensive irrigation could provide for the growth of irrigated areas and guarantee increased food production. In the 1980s, the global rate of increase in irrigated areas slowed considerably, mainly due to very high cost of irrigation system construction, soil salinization, the depletion of irrigation water-supplying sources, and the problems of environmental protection. However, as the population is growing at a rapid rate, irrigation is being given an important role in increasing land use and cattle-breeding efficiency. Thus, irrigated farming is expected to expand rapidly in the future with subsequent increase of water use for irrigation. Irrigation is not sustainable if water supplies are not reliable. Especially in areas of water scarcity the major need for development of irrigation is to minimize water use. Effort is needed to find economic crops using minimal water, to use application methods that minimize loss of water by evaporation from the soil or percolation of water beyond the depth of root zone and to minimize losses of water from storage or delivery systems. Nowadays, during a period of dramatic changes and water resources uncertainty there is a need to provide some support and encouragement to farmers to move from their traditional high-water demand cropping and irrigation practices to modern, reduced demand systems and technologies.

Under scarcity conditions considerable effort has been devoted over time to introduce policies aiming to increase water efficiency based on the assertion that more can be achieved with less water through better management. Better management usually refers to improvement of allocative and/or irrigation water efficiency. The former is closely related to adequate pricing, while the latter depends on the type of irrigation technology, environmental conditions and on scheduling of water application.

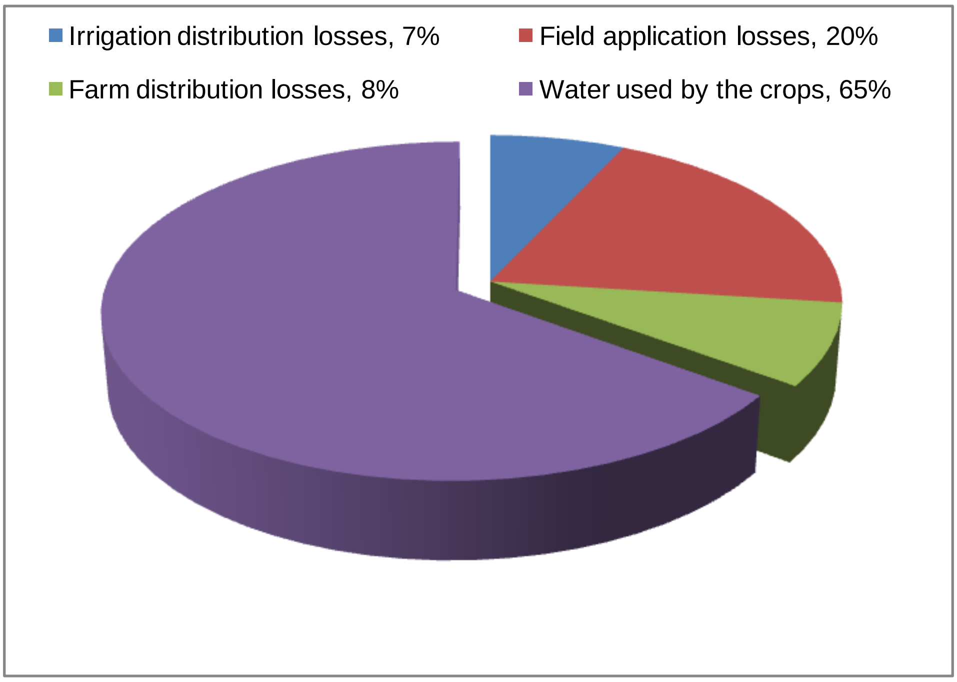

Fig. Water losses in agriculture

It is well known that crop yield increases with water availability in the root zone, until saturation level, above which there is little effect (Hillel, 1997). The yield response curve of specific crops depends on various factors, such as weather conditions and soil type as well as the reduction of the agricultural inputs like fertilizers and pesticides (Fig. 2). Therefore, it is difficult for a farmer to tell at any given moment whether there is a water deficit or not. Since overabundant water usually does not cause harm, farmers tend to “play safe” and increase irrigation amount, especially when associated costs are low. Over-irrigation can cause among others temporal water shortage to other farmers, water-logging conditions for the crop, favorable environment for disease development, loss of nutrients due to leaching or deep percolation, contamination of the aquifers from agrochemicals, reduction of crop yield and deterioration of the quality and increase of production cost.

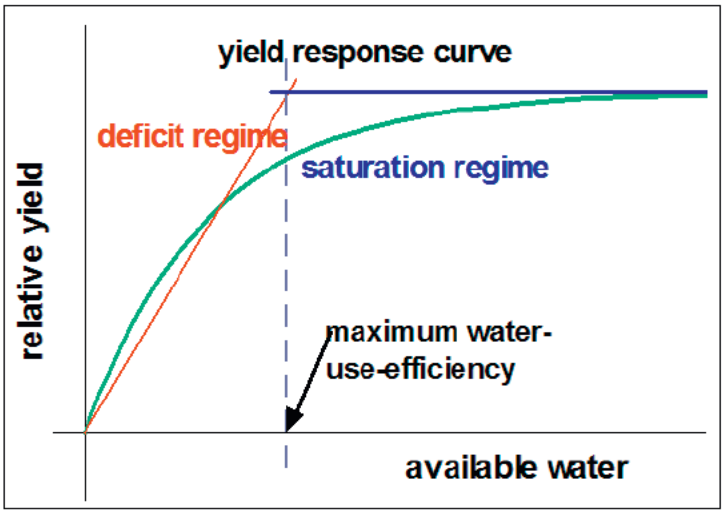

Fig. 2. Plant yield response to water

Goal of water conservation

The goals of water conservation efforts include as follows:

- Sustainability: To ensure availability for future generations, the withdrawal of fresh water from an ecosystem should not exceed its natural replacement rate.
- Energy conservation: Water pumping, delivery and waste water treatment facilities consume a significant amount of energy. In some regions of the world over 15% of total electricity consumption is devoted to water management.
- Habitat conservation: Minimizing human water use helps to preserve fresh water habitats for local wildlife and migrating waterfowl, as well as reducing the need to build new dams and other water diversion infrastructures

Strategies for water conservation

In implementing water conservation principles there are a number of key activities that may be beneficial.

- Any beneficial reduction in water loss, use and waste
- Avoiding any damage to water quality.
- Improving water management practices that reduce or enhance the beneficial use of water.

Perspective of irrigation development

In order to make the optimum use of the available water resources, certain policies will need to be observed. These are:

- Making the maximum use of rainfall for raising crops, utilizing irrigation for making up deficiencies.
- Adoption of the most suitable cropping pattern from consideration of soil, climate and availability of irrigation supplies.
- Making the most efficient use of irrigation supply by minimizing losses in conveyance by lining and adoption scientific method of irrigation on prepared fields.
- Development of irrigation supplies for maximum overall production and not necessarily maximum yield.
- Reuse of water to the extent feasible
- Conjunctive use of surface water and groundwater in accordance with precipitation, phreatic and fluxial water as well as rainfall and dewfall along with conserved/residual soil moisture.

Improving water efficiency in irrigation

Irrigation is necessary when plants cannot satisfy all their water needs through natural precipitation – this practice is also called deficit irrigation. Therefore, an ideal irrigation effort aims to cover the deficit between a crop's optimal water needs and what it can take up through natural means. For a given location and climatic and soil conditions, the efficiency of water irrigation practices can be improved by making the right decisions regarding:

- Crop type
- Irrigation scheduling
- Irrigation method
- Soil enhancement measures
- Source of water

Crop water needs

Crops differ both in terms of their daily water needs and the duration of their total growing period. Consequently, crop type is a chief factor influencing irrigation water needs. Crops with high daily needs and a long total growing season require much more water than those with relatively lower daily needs and shorter growing seasons. Therefore, a key step towards reducing irrigation water needs is selecting those crop varieties that have a lower water demand but that still provide sufficient added value.

Table 1: Water needs of field crops in peak period as compared to standard grass

Water requirement as compared to ordinary grass				
30% less	**10% less**	**Same**	**10% more**	**30% more**
Citrus	Cucumber	Carrots	Barley	Paddy rice
Olives	Radishes	Crucifers (Cabbage, Cauliflower, Broccoli, etc.)	Beans	Sugarcane
Grapes	Squash		Maize	Banana
			Flax	Tobacco
			Small grains	Nuts and fruit trees with cover crops
		Lettuce	Cotton	
		Mellons	Tomato	
		Onions	Eggplant	
		Peanuts	Lentils	
		Peppers	Millet	
		Spinach	Oats	
		Tea	Peas	
		Grass	Potatoes	
		Cacao	Safflower	
		Coffee	Sorghum	
		Clean cultivated nuts & fruit trees	Soybeans	
			Sugarbeet	
			Sunflower	

Table 2: Indicative values of the total growing period for different crops

Crop	Total growing period (days)	Crop	Total growing period (days)
Alfalfa	100 – 365	Millet	105 – 140
Banana	300 – 365	Onion green	70 – 95
Barley/Oats/Wheat	120 – 150	Onion dry	150 – 210
Bean green	75 – 90	Peanut	130 – 140
Bean dry	95 – 110	Pea	90 – 100
Cabbage	120 – 140	Pepper	120 – 210
Carrot	100 – 150	Potato	105 – 145
Citrus	240 – 365	Radish	35 – 45
Cotton	180 – 195	Rice	90 – 150
Cucumber	105 – 130	Sorghum	120 – 130
Eggplant	130 – 140	Soybean	135 – 150
Flax	150 – 220	Spinach	60 – 100
Grain/small	150 – 165	Squash	95 – 120
Lentil	150 – 170	Sugarbeet	160 – 230
Lettuce	75 – 140	Sugarcane	270 – 365
Maize sweet	80 – 110	Sunflower	125 – 130
Maize grain	125 – 180	Tobacco	130 – 160
Mellon	120 – 160	Tomato	135 – 180

Table 3: Approximate values of seasonal crop water needs

Crop	Crop water need (mm/total growing period)
Alfalfa	800 – 1600
Banana	1200 – 2200
Barley/Oats/Wheat	450 – 650
Bean	300 – 500
Cabbage	350 – 500
Citrus	900 – 1200
Cotton	700 – 1300
Maize	500 – 800
Mellon	400 – 600
Onion	350 – 550
Peanut	500 – 700
Pea	350 – 500
Pepper	600 – 900
Potato	500 – 700
Rice (paddy)	450 – 700
Sorghum/Millet	450 – 650
Soybean	450 – 700
Sugarbeet	550 – 750
Sugarcane	1500 – 2500
Sunflower	600 – 1000
Tomato	400 – 800

Irrigation scheduling

Irrigation scheduling is the decision making process for determining when to irrigate the crops and how much water to apply. It forms the sole means for optimizing agricultural production and for conserving water and it is the key to improving performance and sustainability of the irrigation systems. It requires good knowledge of the crops' water requirements and of the soil water characteristics that determine when to irrigate, while the adequacy of the irrigation method determines the accuracy of how much water to apply (Fig. 3). In most cases, the skill of the farmer determines the effectiveness of the irrigation scheduling at field level. With appropriate irrigation scheduling deep percolation and transport of fertilizers and agro-chemicals out of the root-zone is controlled, water-logging is avoided, less water is used (water and energy saving), optimum soil water conditions are created for plant growth, higher yields and better quality are obtained and rising of saline water table is avoided. In water scarce regions, irrigation scheduling is more important than under conditions of abundant water, since any excess in water use is a potential cause for deficit for other users or uses.

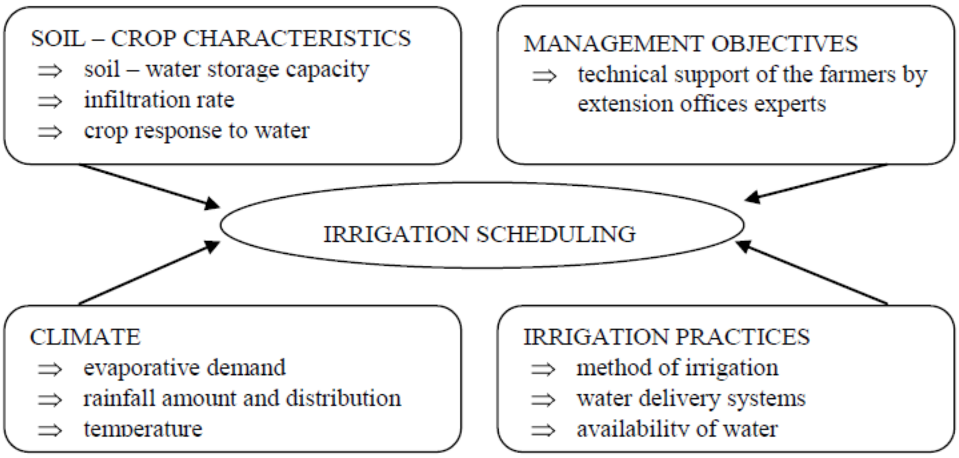

Fig. 3. Irrigation scheduling components

Irrigation methods

Once the quantitative and temporal characteristics of optimal water demand have been determined, a method that can make such water available in the most effective way should be selected.

Soil enhancement measures

In addition to the inherent efficiencies of different irrigation methods, a number of additional soil enhancement approaches can be considered to improve the efficiency of irrigation practices.

Proper field leveling, in order to allow the water to travel in an optimum speed, is an approach that assists uniform distribution of water and reduces runoff, particularly in surface and sprinkler irrigation. Furrow diking, which allows the capture of irrigation or precipitation water in small earthen dams within furrows, is another approach that can reduce runoff and increase the effectiveness of irrigation.

Water savings can also be achieved through residue management and conservation tillage, where the amount, orientation, and distribution of crop and plant residue on the soil surface are managed. These practices improve the ability of the soil to hold moisture, reduces water run-off from the field, and reduces surface evaporation. Because conservation tillage can cause disturbances in furrow irrigation systems, they are better suited for fields using sprinkler or drip irrigation.

Water use efficiency can also be increased through appropriate measures in water distribution systems. Where water is delivered to fields by canals, for example, lining of the canal surface – by compacted clay or concrete – can drastically reduce water seepage. Covering the canals or putting them underground can further decrease evaporation losses.

Alternative water sources

Rainwater harvesting is an increasingly popular approach in those parts of the world where short periods of heavy precipitation are often followed by long stretches of dryperiods. Rainwater harvesting is successfully used in parts of India co-habited by multiple small-scale farmers.

Utilizing treated wastewater is another approach that can provide a feasible alternative source for irrigation water. With the use of modern technology, domestic wastewater can be treated to meet strict health and environmental guidelines, allowing safe use in irrigation. Conventionally, however, use of treated wastewater in irrigation practices has only been possible in farms located in close proximity to cities or towns that are large enough to operate an effective wastewater treatment system. Treated wastewater is already used in irrigation in Jordan and Tunisia and in landscaping in member countries of the Gulf Cooperation Council. With advancements in wastewater treatment technologies, use of treated wastewater on a smaller scale and in a distributed mode is becoming feasible.

Positive effects of increased irrigation efficiency

- A larger area can be irrigated with the same volume of water.
- The competition between water users can be reduced.
- The effect of a water shortage will be less severe.
- Water can be kept in storage for the current (or another) season.
- Groundwater levels will be lower, which can lead to lower investments costs for the control of waterlogging (flooding) and salinity.
- There will be less flooding.
- Better use will be made of fertilizers and pesticides and there will be less contamination of groundwater and less leaching of minerals.
- Health hazards can be reduced (especially arsenic problem).
- Energy can be saved.

Various on-farm water conservation methods for sustainable agriculture

1. Drip, or Micro-Irrigation

Drip irrigation delivers water (and fertilizer) either on the soil surface or directly to the roots of plants through systems of plastic tubing with small holes and other restrictive outlets. By distributing these inputs slowly and regularly, drip irrigation conserves 50-70% more water than traditional methods while increasing crop production by 20-90%. The water and fertilizer are also more easily absorbed by the soil and plants, reducing the risks of erosion and nutrient depletion.

2. Bottle Irrigation and Pitcher Irrigation

Buried clay pot (olla) irrigation is an ancient technology that uses a logical idea. By burying a porous clay pot up to its neck, and filling it with water, a gardener has a 70 percent efficient watering system. Water weeps slowly out of the pot and moistens an area about one-half the diameter of the olla. Since soil is not saturated, the environment created is very healthy for the plant roots, which form a mat around the olla. (Many modern gardeners kill plants by overwatering.)

3. Using drought tolerant crops

Grow the right crop for the growing region. Regions which suffer water shortages are wise to plant crops which are more tolerant to drought. For example, finger millet, pearl millet, cowpea, lentils, amaranth, various sorghums, African rice, Ethiopian oats, irregular barley, mung beans and many grasses. Ideally, researchers would be working with all of the crops on this list to improve the seeds for our crop requirements of tomorrow.

4. System of rice intensification (SRI) or System of crop intensification (SCI) or System of root intensification (SRI)

These practices save a considerable amount of water and also increase yield.

5. Subsurface Irrigation Systems

Advantages of subsurface irrigation systems include:

- Water savings
- Improved crop yields

- No surface evaporation
- No soil and nutrient run-off
- Nutrients can be applied at the root
- There is less disease and fewer weeds
- It requires less labor
- Produces uniform moisture at the root zone
- Reduced amount of energy is required for pumping
- Furthermore, they are especially suitable for hot, windy regions.

6. Water storage

Holding ponds or small storage tanks on small farms can also be fed through canal irrigation. They can collect the water when it is available to be used by the farmer — when needed or when it is a convenient time to irrigate.

7. Black plastic mulch, and organic mulches

Black Plastic Mulch, and Organic Mulches Can Save 25% in Water Requirements. In addition to providing water conservation, this synthetic mulch controls weeds and warms the soil, making for an earlier crop. The black plastic mulch can be covered with hay or straw to protect crops from excessive heat later in the summer.

8. Recycle wastewater

Wastewater can be recycled and reused for agriculture. Urban wastewater that is treated adequately can be recycled into rivers where it can be reused downstream. Nations which reclaim the highest percentage of their wastewater include Israel, Spain, Australia, Japan, Middle East, Mexico, Latin America, Caribbean, and the U.S.

9. Rain water harvesting

In addition to harvesting rainwater from roofs, there are methods to harvest rainwater in the soil. The goal is to prevent runoff by encouraging water infiltration into the soil, and then minimizing evaporation.

10. Collecting fog or mist

Some call it harvesting water from thin air. This ancient practice, evident in archaeology of Israel and Egypt is being revived again today. By using nets strung across mountain passes, or stretched on poles located in foggy areas, gravity collects clean potable water for local residents. Water droplets attach to the netting and run down into gutters beneath the nets. The collected water may be further collected into tubes, taking it to a lower village or point of water storage. One square meter of netting can provide five liters of water per day.

11. Deficit irrigation

In deficit irrigation, the goal is to obtain maximum crop water productivity rather than maximum yield. By irrigating less than a crop's optimal full requirement, you might reduce the yield by 10%, but save 50% of the water. With supplemental irrigation to rainfed crops in dry lands, a little irrigation is selectively applied during rainfall shortages and during the drought-sensitive growth stages of a crop. (These important stages are the vegetative stages and the late ripening period.)

12. Using less water to grow rice

Paddy rice consumes far more water than any other cereal crop, although much of this water is recycled. It also is the staple grain for half the people of the world. Three-fourths ($^3/_4$) of the rice produced comes from irrigated fields, and irrigated rice uses up to 39 percent of global water withdrawals for irrigation. It takes about 2,500 litres of water to produce 1 kg of rice.

Ways found to reduce water use in rice growing are:

- System of Rice Intensification (SRI)
- Alternate Wetting and Drying [AWD] lets fields fall dry for a number of days before re-irrigating them, which can maintain yields with 15-30% of water savings. In Bangladesh, the AWD technique reduced water consumption by 30-50%.
- Aerobic rice is grown in water-scarce regions, without ponded water and saturated soil. It uses 50% less water, and produces 20-30% less yield.
- New varieties like short-season rice significantly reduce water use. Rice produced 40 to 45 years ago required 160 days from seed to harvest, compared to 135 days for short-season varieties which has reduced the amount of water needed by about 20% over the last 30 years.
- Finally, to achieve more 'crop per drop,' wheat and crops that do not grow in flooded areas have the potential to produce food with less water. A rice field takes 2 to 3 times more water than a wheat or corn field. So, it is possible that in the future wheat might supply a growing share of the world's staple grain.

13. Agroforestry

Agroforestry, or using trees as part of the agricultural landscape, can improve water and soil quality and reduce evaporation rates. Different plants can trap water from different layers which facilitate proper use of water. The trees drop leaves and twigs which improve soil quality so that rainwater infiltrates better. Many crops are shade tolerant.

14. Reduce food waste

Food wasted is water wasted and so much more. More than 30 percent of the food produced is lost or wasted. Food waste can be lessened through improvements in every step of the supply chain – storage, transportation, food processing, wholesale, and retail. The consumer must learn to purchase and eat wisely, so as not to waste.