# Increasing Water Use Efficiencies through Participatory On-Farm Water Management Practices

## A Key Element to Establish Co-Existence of Agricultural and Environmental Demands


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### Abstract

Lake Uromiyeh Basin in northwest of Iran is a classic closed drainage basin. Economy of basin is strongly dependent on agriculture. The Lake has been declared a National Park, Ramsar site and UNESCO Biosphere Reserve. During the last two decades, pressures on natural resources of basin have grown due to non-sustainable human activities. Therefore, ecosystem has been severely degraded. Future of agriculture and Lake Uromiyeh National Park is under severe threat because of increasing water abstractions for irrigation. There is an urgent need to improve low irrigation efficiencies (35%). Iran Government has formulated a policy to control water overuse. Implementation of the policy requires cooperation and acceptance of farmers, who will have to adjust their traditional irrigation practises. Therefore, several studies, including Pilot Water Management Studies, have been carried out in the area with objective to determine which irrigation methodologies and management practices reduce water use while assuring similar or increased yields. Results show that upon improvement of on-farm water management practices 29-38% less water would be used, while 14-29% higher yields are achieved. The increase in application efficiency equals 1900-2300 $m^3$/ha water saving in a cropping season. There is about 335500 hectares of lands throughout the Basin under irrigated agriculture. Supposing a minimum sound value of 2500 $m^3$/ha of water saving in a cropping year through efficiency improvement roughly 839 MCM water would be potentially saved. It would easily be concluded that finding and employing improved on-farm irrigation water management practices would result in considerable impacts on agricultural water demand in the area, providing ample scope for co-existence of agricultural and environmental demands for water in the basin.



***Keywords:*** ***Water Use Efficiency, Application Efficiency, On Farm Water Management, Participatory Management, Agricultural Demand, Environmental Demand, Lake Uromiyeh***

# 1 Introduction

The Government of Iran (GoI) is pursuing a policy of modernisation and expansion of the irrigated area with the objective to assure an increase of the agricultural production and farmers' incomes. This development has as side effect that the scarce water resources are increasingly strained. In the traditionally irrigated areas the farmers, who are used to a little and unreliable water supply, tend to over supply water to the crops in modern irrigation schemes. This over-supply limits the potential area that can be brought under irrigation and has led to an increasing extension of areas affected by waterlogging and salinity.

The Lake Uromiyeh Basin (51,000 $km^2$) is located in Northwest of Iran. It is a classic closed drainage basin. The economy of the basin is strongly dependent on agriculture. The Lake is also one of the most important and valuable aquatic ecosystems in Iran and it has been declared a National Park, Ramsar site and UNESCO Biosphere Reserve. During the last two decades, pressures on the natural resources of the Lake have grown as a result of non-sustainable human activities (agricultural intensification, water resources developments, and etc.). As a result the ecosystem has been severely degraded, such that its capacity to deliver social, economic and environmental benefits is under real threat. One of the main indicators of the severity of the problem is shortages of the irrigation water due to low irrigation efficiency. The future of agriculture and of the Lake Uromiyeh National Park is under severe threat because of increasing water abstractions for irrigation. There is an urgent need to raise awareness of the ecosystem problems, to improve the low irrigation efficiencies (35%), and to enhance farmers' participation in water management.

The GoI has formulated a policy for the control of overuse of water. This policy consists of (i) determining per climatological zone the (reasonable) water requirements for major crops, and (ii) delivering plus invoicing the thus determined amount of water on volumetric basis to farmers. This policy is expected to provide incentives to farmers to reduce water-use. The implementation of the policy will require cooperation and acceptance of farmers, who will have to adjust their traditional irrigation practises.

Several studies, including Pilot Water Management Studies (PWMS), have been carried out in the area with the objective to determine with which irrigation methodologies and management practices water use can be reduced while assuring similar or increased yields. The outcome of the studies forms the basis of guidelines for reduced water use on on-farm level. In order to assure that the resulting guidelines are realistic and can be implemented by farmers, the studies have been carried out in a participatory way in a farmer's environment.

# 2 Methods and Materials

## 2.1 General

The concept of the PWMS is schematically shown in Figure 1. The final objective, reduced on-farm water use, is shown in the top of Figure 1. After a first cycle the same process could be followed again for further improvement and higher technology levels incorporation as indicated by the dotted arrow.

The right-hand side shows the methodology to reach this objective, starting with the problem diagnoses in which main constraints to reach efficient irrigation are identified. The problem diagnostics are used as basis for the participatory design of solutions. The solutions are subsequently implemented for on farm testing, which is followed by an evaluation of the tests. The evaluation are used to improve the design and, if the evaluation is positive, the solutions can be disseminated through demonstration and extension, which will eventually lead to improved irrigation and reduced on-farm water use.

## 2.2 Selection of Pilot Areas

The on-farm water management studies were carried out in Pilot Areas (PA), which are as much as possible representative for the sub-basins, therefore, 1) the activities took place in a sub-basin in which there is a clear hydraulic or hydrological relation between the irrigation demands and the existing wetland(s); 2) the irrigation systems were well defined and functioning; 3) there were possibilities for improved integrated management of both the agricultural area and the wetland(s); 4) the activities of the program were in line with existing programs or plans of the Agricultural Service Centre; 5) the irrigation system was a river water related system (surface water) to emphasize the relation between irrigation and wetland; and 6) the activities were in line with the wishes of the involved farmers.

It appeared to be difficult to find areas that combine, representativeness for the sub-basins, a farming population which is interested in, and continues to be motivated for development of new technologies, and which contains one irrigation inlet and one drainage outlet for easy measurement of water balances. Nonetheless two sub-basins were selected; Gadar (Naghadeh plain) and Mahabad. In each sub-basin, 3 farms were selected forming the PAs (15.4 ha in Gadar and 8.1 ha in Mahabad) and one farm was selected as Reference (Control) Area (3.1 ha in Gadar and 2.1 ha in Mahabad).

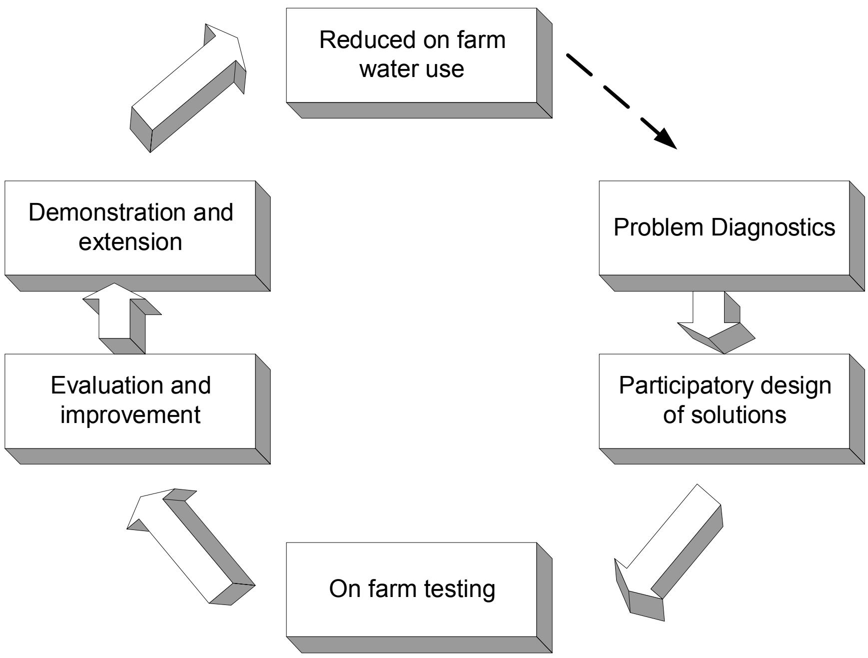


Figure 1. Conceptual framework of the PWMS

## 2.3 Preparation of the Trials

Data on general characteristics of the sub-basins such as water availability, soils, cropping patterns, climate, and crop water requirements were collected, and supplemented with new observations. On-farm irrigation and drainage infrastructure in the PAs was improved, measurement structures were installed, detailed maps of the areas were prepared, and samples of water and soil were taken to describe the general physical conditions.

### 2.4 Diagnostics

The irrigation techniques practiced in studied sub-basins were investigated and assessed in general and around the PAs more specifically. Interviews were conducted with farmers of the PAs and in the Reference Areas (RA). The monitoring focused on cropping patterns, yields, irrigation techniques and constraints with respect to irrigation and agricultural production. In several workshops and field sessions, a participatory problem inventory of present irrigation practices and the related problems was carried out, with farmers, and City Jihad Agricultural Management (CJAM) and Agricultural Service Center (ASC) staff. The diagnostic outcomes formed the basis for the design of the treatments. During the study period, a qualitative understanding of the causes and effects of over-application of irrigation water at farm level for the dominant crop (sugarbeet) has been developed. This understanding is summarized in the problem tree shown in Figure 2.

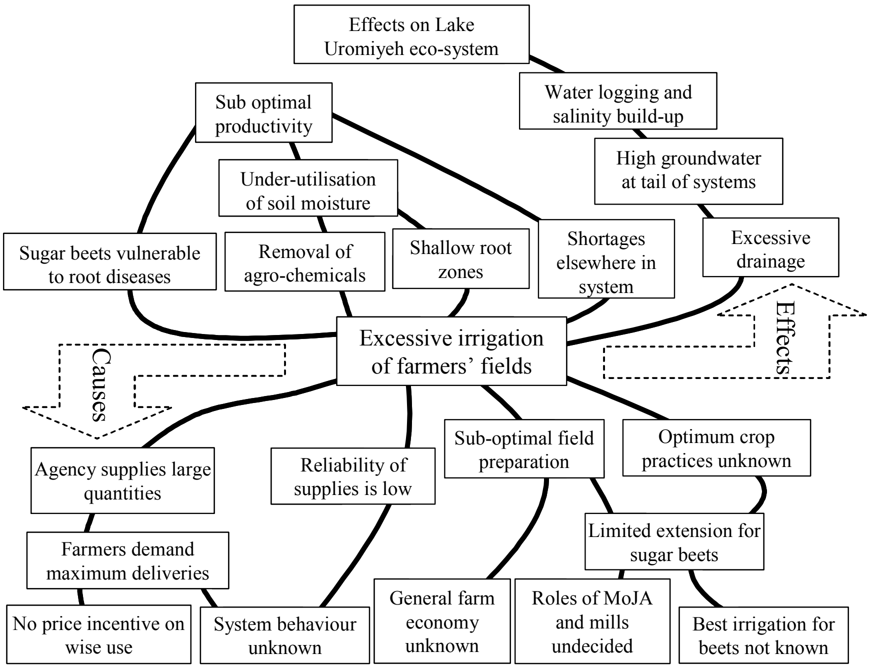


Figure 2. Problem tree analysis of excessive irrigation of sugarbeet in study areas

### 2.5 Design of the Trials

The trials are to be replicable, in order to be of any use to farmers. Therefore, the designs were based on the following considerations:

1- Trials were based on participatory problem analyses and development of solutions;
2- The trials were carried out under on-farm conditions;
3- The treatments were responsive to pressures from the environment. Irrigation frequencies could be adapted in response to climatic conditions, and on basis of experiences gained during the progress of the studies;

#### 2.5.1 Participatory Approach

The participatory problem diagnostics in workshops and field sessions with all stakeholders at the sub-basin level ensured that the studies are directed at actual shortcomings of the currently employed techniques. Participatory design of the treatments assures that treatments are applicable under current conditions and deemed relevant by the farming population.

Cooperation of stakeholders of agricultural water in pilot studies is of utmost importance to the success of on-farm water management studies. Thus, coordination had been made, and discussions and negotiations had been held during several sessions and meetings with all stakeholders, so that a smooth progress of studies was assured. Also, it is believed that by working closely with the farmers, a foundation is laid for subsequent effective extension and dissemination of results. Main stakeholders of the studies were farmers, ASC and CJAM offices, Provincial Jihad Agriculture Organization (PJAO), Provincial Water Authority (PWA), City Water Bureaus (CWB) and City Environmental Protection Directorate (CEPD).

#### 2.5.2 On-Farm Testing
The trials were carried out under farm conditions in farmers' fields. This guarantees that the developed techniques and recommendations are applicable under the farmers' conditions.

#### 2.5.3 The Treatments, a Process Approach
In Gadar and Mahabad sub-basins, respectively, four and three treatments were tested out, arranged according to increasing deviation from normal farmers' practices. Each treatment was carried out in triplicate. Treatments were defined in workshops and adapted during field sessions. The treatments were mainly based on the earlier mentioned problem diagnosis. Although the treatment design was closely adhered to, the trial management allowed for a certain degree of flexibility to make maximum use of lessons learned on the effects of the trials. Thus, irrigation frequencies and amounts were adjusted as experience was gained.

Considering the field situation of the sugarbeet cultivation, it was decided that adjusting length of run; deepening furrow in Mahabad area; increasing the number of furrows to be irrigated simultaneously and alternating irrigation of furrows in two subsequent irrigations would be the factors to be tested out. These trials have been discussed with farmers and local officials and were agreed upon. It can be added that part of the motivation of farmers to take part in the trials was that this would ensure that they could deliver their produce to the sugar mills.

The on-farm irrigation management trials during the season 2004 include the following alternative treatments: 1) *Farmer's Water Management*: Neither change nor improvements will be made in this treatment. When located in pilot farms, these are considered as *Internal Reference* and when they are located in reference farms, they are considered as *External Reference*, 2) *Shortening of the Furrow Length*: It is expected that the water application can be more uniform if shorter furrows are used, 3) *Less Discharge per Furrow*: Irrigation gift spread over 1.5 times more furrows than under farmer management. The reduced volumes needed more time to reach the end of the furrow permitting a higher percentage of infiltration in the rootzone, 4) *Alternate Furrow Irrigation*: In the first irrigation turn, the odd numbered furrows are irrigated, while in the second turn the even numbered furrows receive water. It is a good recommendation for heavy soils, and it seems to have a better on-farm water distribution while using less water, 5) *Deepening Furrows*: This would possibly increase infiltration, as crusts are broken and as there is a slightly larger contact surface. This treatment will only be considered in Mahabad area. The trials were undertaken under farmer management, with reference plots inside and reference areas outside the fields where the trials took place.

### 2.6 Monitoring

#### 2.6.1 The Water Balance
For the water balance of the trails the following measurements were carried out: 1) Inflow of water into the field, 2) Precipitation, 3) Outflow (drainage) from the field, and 4) Soil water content (through tensiometer readings). Water balance calculations were made for all irrigation intervals based on the above measurements and calculated crop evapotranspiration on basis of actual weather data.

#### 2.6.2 The Salt Balance

It should be noted that due to this fact that irrigation waters in both sub-basin areas have very insignificant EC and TDS values, therefore, no measurement on salt and salinity was planned and conducted. In this respect, salinity of soils of pilot and reference areas were measured before and after irrigation season to investigate the overall irrigation impact on soil salinity.

#### 2.6.3 Agronomic Growth Parameters

The agronomic growth parameters were monitored by observation of the uniformity of crop stand and the development of: 1) Crop density through time, 2) Crop height through time, and 3) Crop yield.

#### 2.6.4 Comparison to Reference and Sustainability

The results from the treatments were compared to Reference Areas (RA), where measurements were carried out in fields subject to normal farmers' practices.

Besides these measurements sustainability is monitored through measuring pH of the soil as an indicator of sodification, and through qualitative (semi quantified by counting of rills) observations of soil erosion.

#### 2.6.5 Measurements and observation techniques

The *volume of water entering* fields was measured with 6" Parshall flumes. *The volume of water flowing out* of the fields was measured with v-notches and 2" Parshall flumes. *Soil salinity* was determined by measuring the electrical conductivity of the saturation extract ($EC_e$) in both sub-basins. *Soil water* tension was measured by tensiometers. These measurements were used to evaluate the water storage capacity of the soils for determination of optimal irrigation scheduling and evaluation of application efficiency and water shortages. For the *agronomic parameters* the number of plants and average height in cm was recorded for each field in three sample squares (2m*2m), selected to monitor variation in the crop development over the field. Yield was recorded for the same sample squares. Yields were also measured for the entire field. Finally, production *costs* and *benefits* were recorded.

#### 2.6.6 Indicators for result evaluation

The results of the treatments were analyzed through the following indicators:

1- Indicators of the main objective of the PWMS; use of less water maintaining similar yields: 1) Water use, and 2) Yields (Root and Sugar);
2- Indicators of the efficiency of irrigation and water use: 1) water use efficiency or water productivity (Kg of product per $m^3$ of water), 2) monetary water productivity (Net income per $m^3$ of water), 3) delivery efficiency (amount of infiltrated water as a percentage of total delivered water), and 4) application efficiency (amount of water stored in the soil as a percentage of the total delivered water);
3- Indicator of the farmers income: 1) Net benefit (gross benefits-costs);
4- Indicators of the sustainability of more efficient water use: 1) the change in rootzone (soil) salinity ($EC_e$), and 2) the change in rootzone (soil) pH; As mentioned in sections 2.6.2 and 2.6.4, these two factors are compared farm- wise due to irrigation water good quality.

These indicators were averaged for the different treatments and compared between the treatments and with the reference areas. Limited number of replications, and the influence of other factors impacting on the indicators, which can not be excluded, does not warrant the use of a very refined method of statistical analysis, therefore, differences between the treatments and with the reference in yields and water use were analyzed using One Factor Randomized Complete Block Design method. In the middle and at the end of the season experiences, thus far, and results were discussed with PA farmers and CJAM/ASC personnel in field and office workshops.

### 2.6.7 Demonstration and Extension

An important aspect of the on-farm water management studies is to use the areas for demonstration of improved on-farm irrigation. Thereto, the areas were chosen in easily accessible places. Each treatment and repetition in the PA is indicated on specially installed signs. Organized trips for different groups of farmers and Ministry of Jihad Agriculture (MoJA) personnel were planned. Also during yield delivery to sugar mills signs were prepared and hung on trucks to single out the studies results. The results of the studies were discussed in evaluation workshops and field sessions with farmers, extension agents, ASC, CJAM, PJAO, PWA, CWB and CEPD staff.

## 3 Results

Results of PWMS studies on sugarbeet cultivation during spring cropping season 2004 in Gadar and Mahabad subbasins incorporating aforementioned methodology are shown in Table 1. The table shows amount of total water used, amount of produced yield both for root and sugar, water use and application efficiencies and net benefit obtained in PA and RA in each subbasin. The table also shows the percentage of improvement of these parameters in PAs comparing to RAs.

Table 1: Summary of Results of PWMS in Gadar and Mahabad Subbasins in Spring 2004

| Subbasin | Farm | Water Use | Yield (Ton/ha) | | Efficiencies | | Net Income |
|---|---|---|---|---|---|---|---|
| | | | | | Water Use | Application | |
| | | ($10^3$ $m^3$/ha) | root | sugar | (kg/$m^3$) | % | ($10^6$IRR/ha) |
| Gadar | PA | 3.7 | 62.1 | 10.6 | 16.6 | 73 | 16.4 |
| | RA | 6.0 | 54.7 | 9.4 | 9.6 | 51 | 13.7 |
| | Improvement (%) | 38 (-) | 14 | 13 | 73 | 43 | 20 |
| Mahabad | PA | 4.7 | 37.5 | 7.3 | 8.1 | 65 | 11.2 |
| | RA | 6.6 | 29.1 | 5.6 | 4.6 | 39 | 7.3 |
| | Improvement (%) | 29 (-) | 29 | 30 | 76 | 67 | 53 |

Moreover, measurements of environmental indicators in all fields show that improvement of irrigation efficiencies has resulted in no potential hazard regarding soil salinity, soil structure deterioration and water table uprise. These facts guarantee sustainability of the improved techniques.

## 4 Discussion and Conclusion

Studies have been conducted on dominant crop, sugarbeet, in Naghadeh and Mahabad plains in the Lake Uromiyeh Basin. Results show that upon improvement of on-farm water management practices, resulted from very small changes on current practices with insignificant cost increase (less than 5 percent) and without incorporation of any sophisticated technology, about 29-38% less water would be used, while 14-29% higher yields have been achieved. As a result application and water use efficiencies would be increased by 43-67% and 73-76%, respectively. The increase in application efficiency equals 1900-2300 $m^3$/ha water saving in a cropping season. Several other PWMS studies on different dominant crops including wheat, soya, maize, and silage in different basins incorporating the same methodology have resulted in similar results. As mentioned previously, the participatory problem diagnostics have ensured that the studies are directed at actual shortcomings of the currently employed techniques. Also the participatory design of the treatments has assured that treatments are applicable under current conditions and deemed relevant by the farming population. Moreover, since the trials were carried out under real farm conditions by farmers and in farmers' fields the applicability of the developed techniques and recommendations under the farmers' conditions have been guaranteed from both economical and technological points of view. This ensures that the developed techniques are affordable by farmers resulting in more effective and broader extension and dissemination of the outcomes.

There is about 194000 hectares of irrigated lands throughout the Basin that utilize surface water resources. Also, total area under irrigated cultivation throughout the Basis is about 335500 hectares. Regarding existence of two cropping seasons in some areas, climate influences and existing higher efficiencies in areas with groundwater resources one may conclude that a minimum sound value of 2500 $m^3$/ha of water would be saved potentially in a cropping year through efficiency improvement. This results in roughly 839 MCM water saving in the basin. This figure is just a rough value of possible potential water saving in irrigated lands. According to above rough estimation in the whole Lake Uromiyeh Basin, it would easily be concluded that participatory finding and employing improved on-farm irrigation water management practices would result in considerable impacts on agricultural water demand in the area. This provides ample scope for co-existence of agricultural and environmental demands for water in the basin.

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