# Increased Wheat Yield by Rainwater Management: A Case Study in Arid Lands of Iran

J. Tabtabaee Yazdi, M.Y. Han, M. Ghodsi and S.A. Haghayaghi

**Abstract** Efficiency of rainwater utilization was evaluated for dryland farming in the North-East of Iran. Runoff collected from a plastic covered catchment was directed into a ground reservoir and used for supplementary irrigation of dryland wheat agriculture. Grain yield was increased by 70 and 87% after fulfilling 35 and 70% of crop water requirements during two successive years, respectively. The results encourage any similar planning for the vast arid zone of the country.

**Key words:** Dryland farming, increased grain yield, rainwater management, runoff enhancement, supplementary irrigation

## Introduction

Rainwater harvesting and utilization for supplementary irrigation has been successfully employed in many dry regions as a means of collecting and storing rainwater from neighboring catchment and delivering it to planting area during dry periods (Laura, 2004; Short and Lantzke, 2006; Qiang et al., 2006). Rainwater harvesting for dryland agriculture is divided into two major categories (Oweis et al., 1999). The more conventional rainwater utilization method is based on direct use of collected runoff for plant irrigation, where as the more promising systems involve an external reservoir to collect runoff (in excess of immediate plant use) for the subsequent dry period or before the next rain happens. Previous studies have indicated that direct use of rainwater has not been successful in regions where the rainy season does not coincide with irrigation time since it is virtually impossible to store water in the soil

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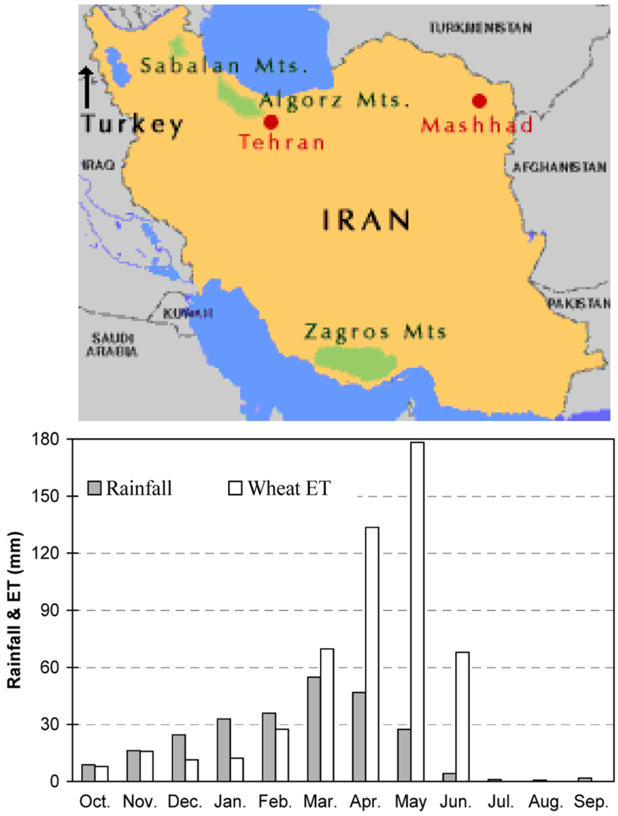


**Fig. 1** Map of Iran with long term average rainfall distribution for demonstration site.

from one wet season to the next and there will be crop failures if only soil is used for storage (Cluff, 1980). The present study demonstrates the effect of rainwater utilization using external reservoirs to provide supplementary irrigation for wheat cultivation in the N-E of Iran (Agriculture and Natural Resource Research Station, Torogh, Mashhad). Yield growth of a native wheat grain was compared for a rainwater harvesting method and traditional dryland farming during two successive years.

## Demonstration Site

The project site is positioned in the N-E of Iran (Mashhad) with average annual precipitation of less than 250 mm, mainly occurring during late winter and early spring times. The role of supplementary irrigation using rainwater could be very crucial since the critical crop growing periods do not coincide with natural rainfall discrepancies. Figure 1 shows a map of Iran and a comparison between rainfall distribution with native wheat water requirements at the project site.

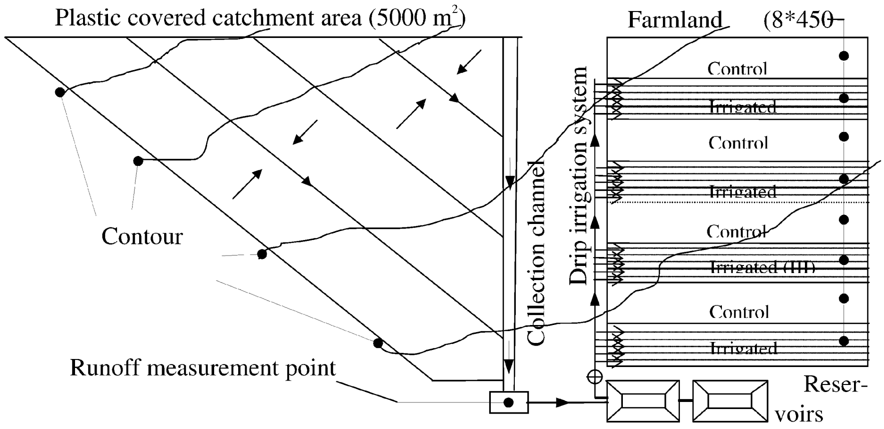


**Fig. 2** Schematic diagram of demonstration RWH system.

In order to examine the effectiveness of rainwater utilization, a 5,000 m$^2$ flat area (sloping 1%) was rippled, cleaned and shaped as a series of sloping roads so that the runoff could be directed from side slops and flow longitudinally towards an end collecting channel (Figure 2). The whole catchment was covered by 10 m wide plastic strip sheets to acquire maximum runoff efficiency. Runoff collected by the end channel was discharged downstream into a 500 m$^3$ ground storage via a sediment trap. A sharp crested rectangular weir along with a recording water level data logger was installed at the end of the collecting channel for runoff measurements with 15 minute intervals. Rainfall distribution was simultaneously recorded in the nearby local meteorological station.

The experimental farmland was located next to the runoff catchment and consisted of a series of eight scaled plots with a dimension of $6 \times 85$ m$^2$. Following a randomized completely block design, four plots were considered for supplementary irrigation and the remaining four replications were accounted as control (without irrigation). In an effort to conserve more water, a drip irrigation system was used with 4 l/hr/m discharge capacity. Collected rainwater was pumped from the reservoir into the 50 mm diameter distribution pipe, after passing through a filter and metering device. The main distribution pipe was connected to the irrigation tapes at the upstream side of cultivated plots (Figure 2).

Physical and chemical soil properties were measured using samples taken from 0–30 cm and 30–60 cm depth at different places and the results are shown in Tables 1 and 2. It was observed that the soil texture is loamy and has no salinity or acidity problem. The water holding capacity of local soil along the 60 cm root zone depth was equal to 72 mm.

**Table 1** Physical characteristics of the local soil.

| Depth (cm) | Soil Texture | Bulk Density ($g/cm^3$) | Field Capacity (gravimetric percent) | Wilting Point (gravimetric percent) |
|---|---|---|---|---|
| 0–30 | Loam | 1.57 | 18.7 | 11.2 |
| 30–60 | Loam | 1.42 | 21.4 | 12.9 |

**Table 2** Chemical characteristics of the local soil.

| Depth (cm) | pH | Electrical Conductivity (dS/m) | Sodium Absorption Ratio (SAR) |
|---|---|---|---|
| 0–30 | 7.55 | 2.66 | 0.53 |
| 30–60 | 7.50 | 3.20 | 2.1 |

## Wheat Cultivation Using Rainwater Irrigation

Rainwater irrigation farming started in the year 2005 with the planting of a commercial wheat seed (Azar 2 cultivar) using 120 kg/ha seed right after the first rainfall in November 2005. A complete process of farming preparation and controls including disinfection and fertilization was undertaken. In order to evaluate the efficiency of rainwater management for dryland farming, a supplementary irrigation program (defined as application of a limited amount of water to the crop when rainfall fails to provide sufficient water for plant growth to increase and stabilize yields; Oweis et al., 1999) was planned. Rainfall data during the wheat growing period for two successive years (2005–2007), along with the monthly wheat evapotranspiration (obtained from Farshi et al., 1997) are shown in Figure 3. From a total of 420 mm wheat water requirement, 116 mm were provided from direct rainfall. If the remaining part of plant water potential had been harvested from the surrounding catchment, the maximum yield could have been obtained.

Taking into account the total irrigation time, applied during two critical growing periods (29 April 2006 at the wheat booting stage with an equivalent of 80 mm and on 18 May 2006 at grain filling time with an equivalent of 25 mm) a total of 215 $m^3$ of water was allocated for plant growth (35% of extra water required in excess of natural rainfall). Compared to the conventional dryland farming which was undertaken in control plots, grain yield was increased by 70% (from 978 kg/ha in the dryland plots to 1,651 kg/ha for irrigated plots) (Table 3).

A second trial for supplementary irrigation practice was conducted during the next year (2006–2007). Rainfall record was compared with wheat evapotranspiration in Figure 4. It was observed that in this year a total of 159 mm (from total 420 mm crop water requirement) was produced from natural rain. Three supplementary irrigations were carried out at critical crop growing stages with total volume of 310 $m^3$ (5, 24 and 31 May 2007, in booting stage, milky and doughy stages of grain filling period with irrigation height measured as 35, 55 and 60 mm, respectively). It

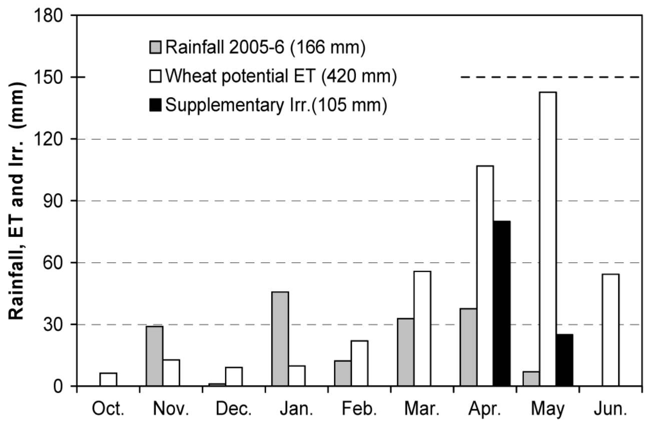


**Fig. 3** Rain, ET and irrigation height (2005–2006).

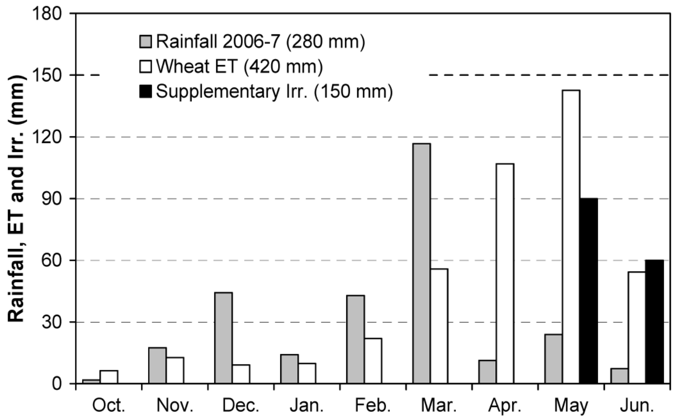


**Fig. 4** Rain, ET and irrigation height (2006–2007).

means that around 58% of the required excess water was acquired by the current water harvesting system. Compared to the control dryland farming, wheat grain yield increased in the second year by an average of 87% (i.e. from 744 kg/ha in control plots to 1,394 kg/ha in the irrigated areas) (Table 3). Such a production growth is certainly encouraging since it is beyond the normal within the neighboring area and more importantly because dryland wheat cultivation is very competitive farming in arid and semi-arid regions of the country.

It can be proved that the increasing grain yield in the irrigated treatments have been mainly due to increasing mean grain weight and mean grain number per unit area in comparison with control plots.

**Table 3** Response of grain yield to supplementary irrigation.

| Year | Dryland (Control) (kg/ha) | Supplementary Irr. (kg/ha) | Response (%) |
|---|---|---|---|
| 2005–2006 | 975 | 1651 | 70 |
| 2006–2007 | 744 | 1394 | 87 |

## Conclusions

Water shortage and consequent decrease of food production has seriously endangered people living in arid part of the world. This problem has been partially addressed by the concept of rainwater management which implies a decentralized and participatory approach for rainwater utilization, taking advantage of vastly available unused land in targeted areas. A crop's required water in excess of natural rain can be harvested from a neighboring area and reserved for subsequent dry periods or between occurrences of rain. This practice has led to dependence on conventional dryland farming that increases a specific crop's productivity, but which is not otherwise beneficial. The present research was one of the first systematic attempts to examine the effect of some of the case dependent parameters such as climate and soil type in a real scale rainwater utilization system in the N-E of Iran.

Following installation of the project's components (including 5,000 $m^2$ plastic cover catchment, 500 $m^3$ ground reservoir, conveying channel, drip irrigation system and 4,000 $m^2$ farming area) supplementary irrigation was conducted over alternative wheat cultivated scaled plots and grain yield was compared with control dryland plots for two successive years.

The results give indication of how to cope with two important dryland problems of rainfall shortage and the mismatch of rainy seasons with plant requirements. It is in agreement with other research results in the fact that, if the minimum water required for the critical time of a crop growing period can be harvested from preceding rainfalls, the overall grain yield can be increased considerably. The research outcomes give hope to many local farmers who cannot recoup their expenses following conventional dryland farming processes.

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