RAINWATER HARVESTING FOR SUPPLEMENTARY IRRIGATION TO RAINFED CROPS

COLLECTE DE L'EAU PLUVIALE POUR L'IRRIGATION COMPLEMENTAIRE AUX CULTURES PLUVIALES

J. Tabatabaee Yazdi,[1] A. Haghayeghi[2] and M. Ghodsi[3]

ABSTRACT

Parallel open ditches across the contours were constructed over a 5,000m^2 flat area so that the runoff could move down and flow longitudinally towards an end collecting channel. In order to achieve maximum runoff efficiency, the whole catchment was covered by plastic sheets. Runoff collected by the end channel was then discharged into the downstream 500m^3 ground storage. A recording data logger was installed at the end of collecting channel for runoff and rainfall measurements. The experimental farmland located next to the runoff catchment was divided into 8 plots from which four plots were irrigated using water from the rainwater harvesting (RWH) system and the rest four replications were treated as control without irrigation.

Experimental farming started in 2005 with planting a commercial wheat variety after first rainfall in November. Rainwater collected during wet season was conducted to the farm land (via an installed pressurized irrigation system) during critical stages of wheat growth. During the first year of study a total of 105mm rainwater were applied during two critical growing periods (35% of required water in addition to the natural rainfall). Compared to the conventional dryland farming, grain yield under the experiment increased by 70%. The second trial of supplementary irrigation was conducted during the next year (2006–2007). It was observed that an equivalent of 150 mm runoff water (58% of required water in addition to natural rainfall) was produced from RWH system and fed to crop during 3 critical growth stages. Compared to the control dryland farming, wheat grain yield increased in the second year by 87%.

Such a production growth is considered very satisfactory since it is far beyond the normal production rate in the neighboring areas and it is also very encouraging because dryland wheat cultivation is a very competitive business in arid and semi arid region of the country.

Key word: *arid and semi arid land, dryland cultivation, rainwater harvesting.*

1,2,3 Researchers, Khorasan Razavi, Agri, and Nat. Res. Research Center. E mail: Tabatabaee_j@yahoo.com

RESUME

Des fossés parallèles à ciel ouvert ont été construits à travers les contours sur une zone de plaine de 5.000 m^2, de sorte que l'écoulement pourrait couler vers le bas et le débit pourrait couler longitudinalement vers un canal de collecte à la fin. Afin d'atteindre une efficacité maximale les eaux de ruissellement, l'ensemble du bassin a été couvert par des feuilles plastiques. Les eaux de ruissellement collectées à la fin du canal ont ensuite été déversées dans l'aval de 500m^3 de stockage au sol. Un enregistreur de données a été installé à la fin de la collecte de canal pour les eaux de ruissellement et pour mesurer les précipitations. La terre agricole expérimentale située à côté du bassin de ruissellement a été divisée en 8 parcelles. De ces parcelles, quartes ont été irriguées avec de l'eau de la collecte des eaux pluviales (RWH) et les 4 parcelles restantes ont été traitées comme des témoins sans irrigation.

La culture expérimentale a commencé en 2005 avec la plantation d'une variété commerciale de blé après la première pluie en novembre. L'eau pluviale recueillie pendant la saison pluviale a été réalisée à la terre de la ferme (via un système d'irrigation installé sous pression) pendant les phases critiques de la croissance du blé. Pendant la première année d'étude, un total de 105mm de pluie a été appliqué à deux périodes critiques de croissance (35% d'eau nécessaire en plus de la pluviométrie naturelle). Par rapport à l'agriculture conventionnelle des terres arides, le rendement en grains sous l'expérimentation a augmenté de 70%. Le deuxième procès de l'irrigation de complément a été réalisé l'année suivante (2006-2007). On a observé qu'environ 150 mm d'eau de ruissellement (58% d'eau nécessaire à part les précipitations naturelles) a été produite à partir de RWH système et a nourrit les cultures pendant 3 phases critiques de croissance. Comparé à la culture de contrôle des terres arides, le rendement en grains de blé a augmenté dans la deuxième année de 87%.

Une telle croissance de la production est considérée comme très satisfaisante, car il est bien au-delà du taux de production normale dans les régions voisines. Il est également très encourageant parce que la culture du blé des terres arides est une entreprise très compétitive dans les régions arides et semi arides du pays.

Mots clés: *Zones terrestres arides et semi arides, culture des terres arides, collecte de l'eau pluviale.*

1. INTRODUCTION

Rainwater harvesting and utilization for supplementary irrigation (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) has been successfully employed in many dry regions by collecting and storing runoff water from neighboring catchment and delivering it to planting area during dry periods (Laura, 2004; Short and Lantzke, 2006 and Qiang, et al., 2006). Rainwater harvesting for dryland agriculture is divided into two major categories (Oweis, et. al., 1999). More conventional rainwater utilization method is based on direct use of collecting runoff for plant irrigation, where as the more promising systems involve an external storage to be used during subsequent dry period or before the next rain occurs. Previous studies have indicated that the direct use of rainwater have not been successful in regions where rainy season does not coincide with irrigation time since it is virtually impossible to store water in the soil from a wet season to the next dry season and there will be crop failures if only soil is used for storage (Cluff, 1980).

Present study demonstrates the effect of rainwater utilization using external reservoir to provide supplementary irrigation for wheat cultivation in Mashhad (N-E of Iran). Yield of a native wheat variety was compared for rainwater harvesting method and traditional dryland farming.

2. DEMONSTRATION SITE

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

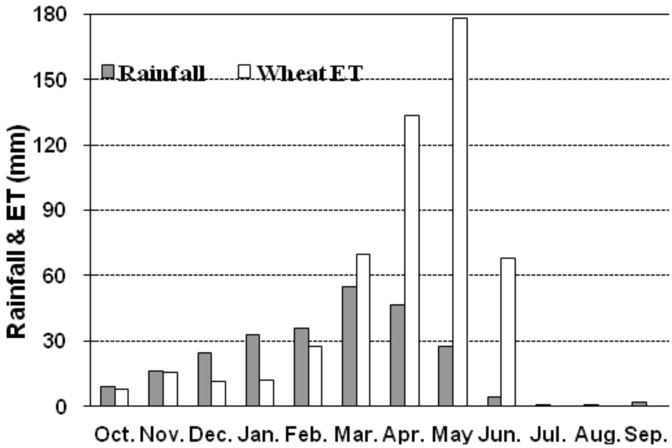

Fig. 1. Distribution of rainfall and wheat water requirements

In order to examine the effectiveness of rainwater utilization, a 5000 m^2 flat area (slope 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 (Fig. 2). The entire catchment was covered by plastic sheets to acquire maximum runoff efficiency. Runoff collected by the end channel could be discharged into the downstream 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 collecting channel for runoff measurements at 15 minute intervals. Rainfall distribution has been simultaneously recorded in the nearby local meteorological station.

The experimental area located next to the runoff catchment was converted into a series of 8 plots with dimension of 6* 85 m^2. Following a randomized completely block design, four plots were given supplementary irrigation and the rest four replications were treated as control (without irrigation). Drip irrigation system was used with 4 lit/hr/m discharge as a water conservation measure. Collected rainwater could be pumped from 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 (Fig. 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. 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.

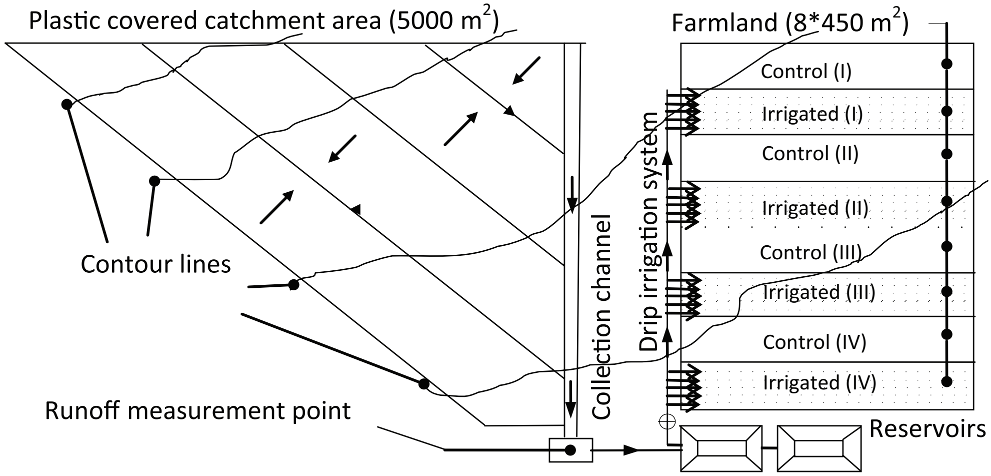

Fig. 2. Schematic diagram of demonstration RWH system

Table 1. Physical characteristics of the local soil

Depth (cm)	Soil Texture	Bulk Density (g/cm³)	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

3. WHEAT CULTIVATION USING RAINWATER IRRIGATION

Wheat cultivation using harvested rainwater for supplemental irrigation started in 2005 with planting a commercial wheat variety (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 was planned. Rainfall data during 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 was provided from direct rainfall. If the remaining part of plant water need could be harvested from the surrounding catchment, the maximum yield could have been obtained.

Taking into account the total irrigation time, irrigation was given during two critical growth stages (29, April 2006 at the booting stage with an equivalent of 80 mm and on 18, May 2006 at grain filling stage with an equivalent of 25 mm). A total of 215 m^3 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 1651 kg/ha for irrigated plots (Table 3).

The second trial for supplementary irrigation 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 (of the total 420 mm crop water requirement) was produced from by rainfall. A number of 3 supplementary irrigations were carried out at critical crop growing stages with total volume of 310 m^3 (5th, 24th and 31st of May, 2007 in booting stage, milky and doughy stages of grain filling period, respectively) with corresponding irrigation applications of 35, 55 and 60 mm. It means that around 58% of the required excess water was met by the 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 1394 kg/ha in the irrigated areas: Table 3). Such a production growth is certainly encouraging since it is higher than the normal wheat production in the neighboring area and more importantly because dryland wheat cultivation is very competitive farming in arid and semi arid region of the country.

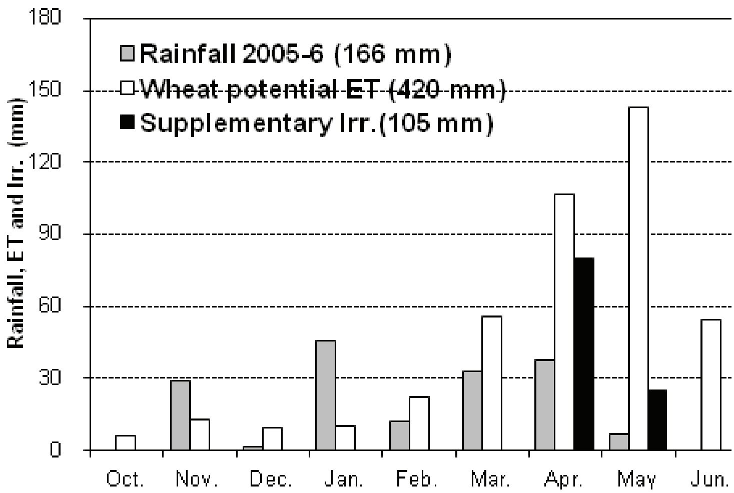

Figure (3): Rain, ET and Irr. height (2005-6)

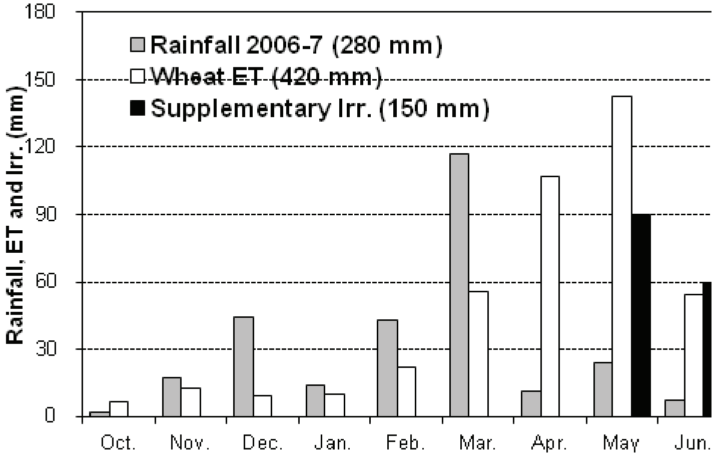

Figure (4): Rain, ET and Irr. height (2006-7)

Table 3. Response of grain yield to supplementary irrigation

Year	Dryland (Control) (kg/ha)	Supplementary Irr. (kg/ha)	Response (%)
2005-6	975	1651	70
2006-7	744	1394	87

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.

4. CONCLUSIONS

Water shortage and consequent decrease of food production has seriously endangered the food security of the 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. Crop's required water in excess of natural rain, would be harvested from neighboring area and preserved for the following dry period or before the next rain occurs. This practice is better than the conventional dryland farming due to its capability to increase crop productivity, which could have not otherwise been possible. Present research was one of the first systematic attempt 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 N-E of Iran.

Following the installation of project's components, 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 on how to face two important dryland problems of the rainfall shortage and the mismatch of rainy season with crop water requirement. It is in agreement with other's results in that if the minimum water required for critical time of crop growing period can be met from harvested water from the preceding rainfalls, the grain yield can be increased considerably. The research outcomes give hope to many local farmers who cannot compensate their expenses following the traditional dryland farming.

REFERENCES

Cluff, C. B. (1980). Surface storage for water-harvesting agrisystems. In *Rainfall collection for agriculture in arid and semiarid regions*, Univ. of Arizona, Tucson.

Farshi, A.A. (1997). *Estimation of water requirement for the main agricultural products*, Soil and Water Institute, Ministry of Agriculture, Iran.

Laura, R., (2004). Water farms: a review of the physical aspects of water harvesting and runoff enhancement in rural landscapes. *CSIRO Land and Water*, Canberra ACT, Technical Report 04/6.

Oweis, J., Hachum, T. A. and Kijne, J. (1999). Water harvesting and supplementary irrigation for improved water use efficiency in dry areas. *SWIM Paper 7. International Water Management Institute*, Colombo, Sri Lanka.

Qiang, Z., Yuanhong, L. and Manjin, C. (2006). Effect of low-rate irrigation with rainwater harvesting system on the dry farming. *The 2nd International RWHM Workshop*, Beijing.

Short, R. and Lantzke, N. (2006). *Increasing runoff from roaded catchments by chemical application*. Department of Agriculture and Food, Western Australia, Project Number: RT 03/20-4.