IMPROVING RAIN WATER PRODUCTIVITY BY MICRO CATCHMENTS WATER HARVESTING (MCWH) SYSTEMS AT NORTHWEST OF IRAN

AMELIORATION DE LA PRODUCTIVITE DE L'EAU DE PLUIE PAR LES SYSTEMES DE LA COLLECTE D'EAU DANS LE MICRO BASSIN (MCWH) AU NORD-OUEST DE L'IRAN

Ali Reza Tavakoli[1] and Theib Oweis[2]

ABSTRACT

*In order to investigate micro catchments water harvesting (MCWH) methods a field experiment was conducted on split split plot factorial design with 5 replications, during 1999-2006 at East Azarbaijan province, Northwest part of Iran. The treatments included two MCWH methods (small basins and semicircular bunds), three catchments sizes (25m^2 (5*5, R=2m); 49m^2 (7*7, R=2.85m) and 81m^2 (9*9, R=3.7m)), three runoff area treatments (Natural, cleared and smoothed, wetting and compacting) and two-infiltration area (Natural, soil mixed with polymer as 1kg/tree). Results of this project at these seasons on comparison with farmer fields (traditional and irrigated) are following: Survival percentage at irrigated farmer fields was about 35-55 % but at this project it was 100%. Polymer was non significant on increased water saving. Although small basin (9*9) + compacted + without polymer treatment was the best results but based on economic aspects, small basin (7*7) + compacted + without polymer treatment can be recommended. At finall year (2006) estimated yield per tree was 3kg and total production was 612 kg.ha^{-1}. At on-farm condition, it is necessary that optimal treatment combines with at least 1-2 times irrigation during summer.*

Key words: *Water Harvesting, Almond, Rain Water Productivity, Evaporation, Dryland, Rain.*

RESUME

Lors des années 1999-2006, une expérimentation a été faite sur le terrain selon la conception graphique du champ divisé avec 5 répétitions dans la province d'Azerbaïdjan oriental au

1 Dryland Agricultural Research Institute (DARI), Kermanshah, Iran, art.tavakoli@gmail.com
2 International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria

*nord-ouest de l'Iran pour étudier les méthodes de la collecte d'eau dans les micros bassins (MCWH). Les traitements comprenaient deux méthodes MCWH (petits bassins et digues semi-circulaires), trois bassins versants de taille (25 m^2 (5 * 5, R = 2m); 49 m^2 (7 * 7, R = 2,85m) et 81 m^2 (9 * 9, R = 3,7 m)), trois traitements dans la zone d'écoulement (naturel, dégagé et lisse, humide et compactage) et deux zone d'infiltration (naturelles, terre mélangée de polymère telle que 1kg/arbre).*

*Suivent les résultats de ce projet par rapport aux champs des agriculteurs (traditionnels et irrigués) : le pourcentage de survie dans les terres irriguées par les agriculteurs est d'environ 35-55%, mais dans ce projet, il est de 100%. L'impact du polymère n'était pas significatif sur l"economie d'eau. Bien que le traitement sur le petit bassin (9 * 9) + le compactage + sans polymère ait donné lieu au meilleur résultat, mais compte tenu des aspects économiques, le traitement sur le petit bassin (7 * 7) + le compactage + sans polymère peut être recommandé. En l'an 2006, le rendement estimé par arbre était de 3 kg et la production totale était de 612 kg.ha^{-1}. Dans les conditions à la parcelle, il est nécessaire de combiner au moins 1-2 irrigations estivales avec les traitements optimaux.*

Mots clés : *Collecte d'eau, amande, productivité de l'eau de pluie, évaporation, zones arides, pluie.*

1. INTRODUCTION

The Middle East and North Africa (MENA region) extends over 17 countries, representing a total land mass of 9.5 million square kilometers, representing 7% of the total world land area (Nasr, 1999). Water harvesting systems supply water for livestock, wildlife, domestic and agricultural users (Frasier et al., 1983 and FAO, 1987). Micro catchments water harvesting is presently practiced in dry tracts in North Africa and West Asia, Australia, India and South America (Prinz, 1994). The problem of water shortage in dry land farming is caused low annual rainfall and unfavorable distribution of rainfall through the year. The scarcity of the rainfall precludes support to dry farming trees and crops. Water harvesting in agriculture is based on the principle of depriving part of the land of its share of rainwater (which is usually small and non-productive) and adding it to the share of another part. This brings the amount of water available to the target area closer to the crop water requirements so that economical agricultural production can be achieved and thus improving the rain water productivity (RWP). Thus water harvesting may be defined as "the process of concentrating precipitation through runoff and storing it for beneficial use" (Oweis and Huchum, 2004). A micro-catchment consists of two elements: the runoff area and the infiltration basin. Micro Catchments Water Harvesting (MCWH) for increasing crop production on dry lands has been the subject of considerable research for the last several decades (Evanari et al., 1971; Sharma, 1986; Rawitz and Hillel, 1974; Ehrler et al., 1978 and FAO, 1987).

Precipitation in the drier environments is low compared to crop needs. It is unfavorably distributed over the crop-growing season and often comes with high intensity. As a result, rainfall in this environment cannot support economical dryland farming. In the Mediterranean areas, rain usually comes in sporadic, unpredictable storms and is mostly lost in evaporation and runoff, leaving frequent dry periods during the crop growing season. The overall result is that most of the rainwater in the drier environments is lost with no benefits and/or productivity (Oweis et al., 1999).

Capturing rainwater and using it efficiently is crucial for any integrated development. Water harvesting is an ancient concept with a wealth of indigenous knowledge available. Indigenous systems such as *jessour* and *meskat* in Tunisia, *tabia* in Libya, *cisterns* in north Egypt, *hafaer* in Jordan, Syria and Sudan and many other techniques are still in use (Oweis et al., 1999 and 2001). Traditional techniques of water harvesting have been reported from many regions of Sub Saharan Africa (Reij et al. 1988).

Experience with rainwater harvesting in WANA includes Micro-catchments and Macro-catchments systems. Micro-catchments are those in which surface runoff is collected from a small catchment area and applied to an adjacent agricultural area, where it is stored in the root zone and used directly by plants. The target area may be planted with trees, bushes, or with annual crops. The farmer has control, within his farm, over both the catchments and the target areas. All the components of the system are constructed inside the farm boundaries. This is an advantage from the point of view of maintenance and management, but because of the loss of productive land it is only practiced in the drier environments, where cropping is most risky and farmers are willing to allocate part of their farm to be used as a catchment (Oweis and Huchum, 2004).

In this system the surface runoff is collected from a contributing area over a flow distance of less than 100 m and stored for consumptive use in an adjective infiltration basin. In experiments, the micro catchments sizes varied from roughly 0.5 m^2 to 1000m^2 for trees, shrubs and row crops. Average annual rainfall varied from 100mm to 650mm (Boers and Ben-Asher, 1982; FAO, 1987; Oweis et al., 1998 & 2001). Since runoff amounts are uncertain, crop water requirements are best met when a crop is selected that makes best use of long term water storage in the soil profile. This favors the selection of deep rooted, perennial and drought resistance crops, preferably trees. Numerous water-harvesting projects have failed because the technology used proved to be unsuitable for the specific conditions of the site (Siegert, 1994). Water harvesting, defined as the collection of runoff and its use for the irrigation of crops, pastures and trees, and for livestock consumption (Prinz, 1994 and Finkel and Finkel, 1986). It comprises six different forms, primarily defined by the ratio between collecting and receiving area: (1) Roof Top Water Harvesting, (2) Water Harvesting for Animal Consumption, (3) Inter-Row Water Harvesting, (4) Micro catchments Water Harvesting, (5) Medium-sized catchments Water Harvesting and (6) Large Catchments Water Harvesting (Prinz, 1994). Water harvesting is applied in arid and semi-arid regions where rainfall is either not sufficient to sustain a good crop and pasture growth or where, due to the erratic nature of precipitation, the risk of crop failure is very high. The intermittent character of rainfall and runoff and the ephemeral nature of floodwater flow require some kind of storage. There might be some kind of interim storage in tanks, cisterns or reservoirs or soil itself serves as a reservoir for a certain period of time (Finkel and Finkel 1986). Water harvesting is based on the utilization of surface runoff; therefore it requires runoff producing and runoff receiving areas. In most cases, with the exception of floodwater harvesting from far away catchments, water harvesting utilizes the rainfall from the same location or region. Water harvesting projects are generally local and small-scale projects (Prinz, 1994). The goals of water harvesting are: Restoring the productivity of land, which suffers from inadequate rainfall, increasing yields of rained farming, minimizing the risk in drought prone areas, combating desertification by tree cultivation and supplying drinking water for animals. In regions with an annual precipitation between 100 and 700 mm, low cost water harvesting might provide an interesting alternative if irrigation water from other sources is not readily available or too costly (Prinz, 1994). The most important parameters to be taken into consideration in practicing water harvesting are therefore: rainfall distribution, rainfall intensity, runoff characteristics of the catchments, water storage capacity of soils, cisterns or reservoirs, the agricultural crops, available technologies and socio-economic conditions (Tauer and Prinz 1992). Runoff from the Micro catchments in arid and semi arid regions depends upon rainfall characteristics (amount, intensity and distribution), Micro catchments characteristics (size, slop, length and antecedent moisture conditions) and water spreading properties of the soil.

Almond is an important and ancient crop in northwest of Iran (East Azarbaijan province). Objectives of this study were to determine the optimal design parameters for micro catchments for almond, taking into account (a) rainfall, runoff and runoff area relationships, (b) growth, yield and fruit characteristics of almond, (c) long term runoff behavior of the micro catchments, and determine runoff percentages and threshold runoff values for different water harvesting treatments.

2. MATERIALS AND METHODS

Soil: The soil at research area was shallow, sandy and poor for agricultural activity, and in order to increasing water holding capacity, the soils of infiltration areas changed by surface soil. Relevant properties were : PH, 7.6; EC, 1.11 ds/m; Extractable K, 370 ppm; Extractable P, 15.2 ppm; Zn, 1.1 ppm; Mn, 3.94 ppm; and Fe, 2.22 ppm; and Total N, O.C. and T.N.V., were 0.049, 0.49 and 9.8 %, respectively; and amounts of sand, silt and clay, were 500, 430 and 70 gr/kg, respectively.

Precipitation: Total annual precipitation is directly influenced by the land topography and elevation, especially by the great mountain ranges. Research site is a semi-cold region having a 10-year average annual precipitation of 208 mm, mostly falling as snow.

Although total annual precipitation is highly effective in determining the success of dry-farming, distribution of rainfall throughout the year is also of great importance. The average annual rainfall varies between 160 and 250 mm in project location and there are not any rainfalls for 5-7 months from May to October. The total precipitation amounts in research site during the 1999 - 2005 crop seasons were 163.3, 176.4, 217.6, 176.8, 245 and 249.4 mm, respectively (Table 1).

Table 1. Amounts of precipitation, evaporation and air temperature

Crop season	Prec. mm	Evap. mm	Tmax-abs °C	Tmin-abs °C	Pmax mm/day
1999-2000	163.3	2310	-13.6	40.8	18.3
2000-01	176.4	2269	-11.8	36.2	17
2001-02	217.6	2072	-10.4	32.8	20
2002-03	176.8	2094	-12.6	38.2	18
2003-04	245	2089	-12	35.4	42
2004-05	249.4	2254	-14	35.6	27

Treatment. A study during the 1999-2006 on farmer field was conducted on split – split – factorial plot design (RCBD) for five replications. The treatments included two Micro – catchments – water – harvesting methods (Fig. 1): small basins and semicircular bunds (main plots), three catchments sizes: (25m^2 (5*5, R=2m); 49m^2 (7*7, R=2.85m) and 81m^2 (9*9, R=3.7m, (sub plots), three runoff area treatments: Natural, cleared and smoothed, wetting and compacting combined (factorial) with two-infiltration area: Natural, soil mixed with polymer as 1 kg/tree.

Micro catchments water harvesting provides potential solution to water availability. Based on soil and leaves analysis (Table 2 and 3), the fertilizer were applied for all trees in two part of infiltration areas. The fertilizers were including: Ferrous Sulphate, Amonium Sulphate, Zinc Sulphate, Boric Acid and Compost (Table 4).

Table 2. Results of soil analysis

S.P	E.C	P.H	T.N.V	O.C	P	K	Fe	Mn	Zn	Cu
%	ds/m	-	%	%	ppm	ppm	ppm	%	%	%
34	1.11	7.6	9.8	0.49	15.2	370	2.22	3.94	1.1	1.48

Table 3. Results of leaves analysis

N	Ca	P	Mg	K	Fe	Mn	Zn	Cu	B
%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
2.37	2.06	0.21	0.372	1.78	172	80	16	15	5.3

Table 4. Amounts of fertilizer for each tree

Ferrous Sulphate	Ammonium Sulphate	Zinc Sulphate	Boric Acid	Compost
400g	1kg	350g	200g	5kg

3. RESULTS AND DISCUSSION

Results of this experiment in comparison with farmer fields (under traditional management and irrigated) showed that the tree survival percentage at irrigated farmer fields MCWH treatments were about 35-55% and 100%, respectively. Tables 5-9 show that the effects of different treatments on total brunch length, maximum brunch length and percentage increase of Stem diameter. Polymer not only had non significant effect on water holding content, it had negative effects on total brunch length, maximum brunch length and percentage increase of Stem diameter (Tables 8-9). Maximum brunch length of growth at farmer-irrigated condition was about 10-30 cm but at this project it was 10-73 cm. Total brunch length of growth at this project at first year reached 15.5 m.

Although small basin with (9*9) and runoff area compacted and without polymer gave better results in survival, growth and productivity of almond (Tables 5-7), the 49 meter runoff area treatment (small basin or semicircular bound) with compaction and without polymer, can be recommended based on economic analysis. total brunch length, maximum brunch length and percentage increase of Stem diameter increased under 81 square meter runoff area treatment, but land productivity of this treatment is lower than 49 square meter runoff area treatment, because there are 204 and 123 trees per ha. The optimal treatment was 49 square meter runoff area treatment which cleared, smoothed and compacted and without polymer can be recommended. Under this condition, using animal manure, evaporation controls (Fig. 1) and soil changing is necessary for improving soil water contents on infiltration area.

Threshold runoff were measured 2.5-3.5, 3.5-4.5 and 4.5-5.5 mm for natural, cleared and smoothed, clearing, wetting and compacting conditions, respectively. During the 2006 season, the fruit yield is estimated to 3 kg/tree, totaling 612 kg/ha for the recommended treatment. At on – farm condition, its necessary optimal treatment combines with at least 1-2 times irrigation during summer.

Sepaskhah and Foooladmand (2004), Sharma (1986), Prinz (1994), Finkel and Finkel (1986), Boers and Ben-Asher (1982), FAO (1987) Oweis et al. (1998 & 2001) and Frasier et al.(1983) reported substantial increase in production different crops and trees. The relationship between rainfall and runoff has been observed over a period of 7 years on sandy loam soils of the Indian Arid Zone. Fifteen micro catchments areas (MC) were studied; these were formed by combinations of three slopes (0.5, 5 and 10%) and five lengths (5.12, 7.0, 8.5, 10.75 and 14.5 m) with corresponding areas of 252, 324, 360, 396 and 432 m^2. These MC's can produce 13.3–45.4% runoff depending upon their morphological characteristics. Over the 7-year period, threshold rainfall reduced by half and runoff efficiency doubled due to the formation of a less pervious soil crust over the MC surface; it became denser each year (Sharma, 1986).

The micro catchments area according to the amount of annual rainfall with 90% probability of occurrence was estimated to be 21 m^2, but with lower probability of occurrence (higher value of annual rainfall), micro catchments area decreased. Meanwhile, with decreasing micro catchments area, although the yield of each tree decreases, but the number of trees in a unit area (ha) increases. Therefore, the total yield in unit area (ha) will increase. So, using smaller micro catchments area is more appropriate. Therefore, due to the spacing of 3m×3 m for grape plantation in Bajgah area, the best micro catchments area is 9 m^2. (Sepaskhah and Foooladmand, 2004)

Table 5. Effects of runoff area treatment on almond trees

Runoff area treatment	Total brunch length	Maximum brunch length	% increase of Stem diameter
Natural	327.3	43.6	47
cleared and smoothed	431.3	44.3	47.7
wetting and compacting	480	47.2	46.8

Table 6. Effects of runoff area pattern and size on almond trees

Runoff area size	Total brunch length	Maximum brunch length	% increase of Stem diameter
Small basin & 25 m^2	329.4	43	39
Small basin & 49 m^2	475.8	45.9	55.2
Small basin & 81m^2	600.2	51.4	50.2
Semicircular & 25 m^2	287.4	43	42.6
Semicircular & 49 m^2	373.7	43.8	41.8
Semicircular & 81m^2	410.7	42.9	54.3

Table 7. Effects of polymer application on almond trees

Polymer treatment	Total brunch length	Maximum brunch length	% increase of Stem diameter
Natural	432	45.2	48.3
1 kg polymer/tree	393	44.8	46.1

Table 8. Effects of polymer application and runoff area pattern on almond trees

Polymer treatment	Total brunch length	Maximum brunch length	% increase of Stem diameter
Small basin + no polymer	489.7	45.7	43.8
Small basin + polymer	447.2	47.8	52.5
Semicircular bunds + without polymer	374.7	44.6	52.8
Semicircular bunds + with polymer	339.7	41.9	39.7

Table 9. Effects of polymer application and runoff area treatment on almond trees

Polymer treatment	Total brunch length	Maximum brunch length	% increase of Stem diameter
Natural + without polymer	326.9	41.1	39.6
Natural + with polymer	327.7	46.2	54.4
cleared and smoothed+ without polymer	433.9	45.2	54.3
cleared and smoothed+ with polymer	428.7	42.9	41.1
wetting and compacting + without polymer	535.9	48.9	51
wetting and compacting + with polymer	424	45.5	42.7

Fig.1- micro catchment water harvesting patterns, runoff and evaporation control

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