EVALUATION OF EFFICIENCY OF THREE DIFFERENT RAINFALL WATER HARVESTING SYSTEMS FOR RAIN-FED HORTICULTURE IN KERMANSHAH, IRAN

EVALUAION DE L'EFFICIENCE DE TROIS DIFFERETNS SYSTEMES DE COLLECTE DES EAUX DE PLUIE POUR L'HORTICULTURE PLUVIALE A KERMANSHSH, IRAN

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ABSTRACT

*Iran has many arid and semi-arid regions and consequently, deficiency of water for crop plantation, especially in the rain-fed areas. The rainwater harvesting can be used for water storage and crop use in the rain-fed areas. Besides, it reduces runoff coefficient, soil erosion and flash flood hazards. This research was carried out for comparing the efficiency of three rainwater harvesting systems. For this purpose, three experimental rainfall harvesting systems were designed with a lozenge shape (1.7*1.7 m in diameter) and three replications were established with three treatment including compacted soil with pug mulch, plastic mulch with stone pavement and virgin soil surface (testing plot). The run-off volume and sediment yield were measured using a water storage tank (100 litters) which was placed in the lower section of each plot. Collected water and sediment yield were measured after each single storm. Statistical analysis was carried out for efficiency of these water-harvesting systems using SPSS (version 11.0). Results indicated a significant relationship ($\alpha<0.01$) between rainfall amount and collected water volume in all water harvesting systems. The plastic mulch with stone pavement indicated the highest efficiency of rainfall harvesting (92% of each single rain was stored). So, the system is suggested for this region with distributed precipitation during drought periods for rain-fed cropping.*

Key words: *Harvesting Efficiency; Rainfall Harvesting; Rain-fed Cropping; Runoff Coefficient; Sediment Yield.*

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RESUME ET CONCLUSIONS

*L'Iran est caractérisé par les régions arides et semi-arides et par conséquent, manque d'eau pour la plantation des cultures, en particulier dans les zones d'agriculture pluviale. L'eau de pluie peut être utilisée pour le stockage de l'eau et de plantes cultivées dans les zones d'agriculture pluviale. En outre, il contribue à la réduction du coefficient de ruissellement et par la suite réduisant l'érosion des sols et les risques de crue soudaine. Cette recherche a été effectuée pour comparer l'efficacité de trois systèmes de récupération d'eau résultant de l'humidité du sol et l'érosion des sols accrue atténués par la réduction en run-off de ruissellement et à l'échelle de la parcelle. A cet effet, trois des précipitations expérimentale des systèmes de collecte ont été conçus avec une forme en losange (1,7 * 1,7 m de diamètre) et trois répétitions ont été établis avec trois traitements, y compris le sol compacté avec un paillis de roquet, paillis de plastique avec revêtement en pierre et la surface du sol vierge (parcelle d'essai). Le volume de ruissellement et la production de sédiments ont été mesurés en utilisant un réservoir d'eau (100 litres) qui a été placé dans la partie inférieure de chaque parcelle. Eau collectée et la production de sédiments ont été mesurées après chaque tempête unique. Enfin, l'analyse statistique a été réalisée pour l'efficacité de ces systèmes de récupération de l'eau à l'aide du logiciel SPSS (version 11.0). Les résultats ont montré une relation significative (α <0,01) entre la quantité des précipitations et le volume d'eau prélevés dans tous les systèmes de collecte d'eau. Le paillis de plastique avec revêtement en pierre a indiqué la plus grande efficacité de la récolte des précipitations (92% de chaque pluie seul a été conservé). Ainsi, le système est proposé pour cette région avec des précipitations distribués au cours de périodes de sécheresse pour les cultures pluviales. Sur la base de ces résultats, les précipitations en saison de sécheresse est inférieure à 1 mm pour chaque événement pluvieux unique.*

***Mots clés :** Efficience agricole, collecte des eaux de pluie; culture pluviale; coefficient d'écoulement; production de sédiments.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

Farmers were accustomed to rainfall water harvesting for agriculture and domestic use, especially in the Mesopotamia areas, where water has always been in short supply. It is believed that in the old times farmers in the arid and semi-arid regions had used overland flows and surface water as sources for supplemental irrigation (Evenori/Mashash, 1975). In ancient times, surface water was harvested for agricultural use where river water had not been plenty, especially in the sub-desert areas such as Saudi Arabia, North Africa and Mexico (Evenori/Mashash 1997).

Furthermore, supplement irrigation through harvested flood water is more common in the semi-arid region. For instance, native farmers in the northwest of United States and Mexico had diverted the surface run-off in their agricultural areas (Crithley, 1987). Nowadays, however, the surface water, floods and run-off are more important sources for supplemental irrigation in the arid and semi-arid regions due to increasing demand for water as well as expensive investment for other water sources such as extraction of ground water. Beside these traditional benefits, rainfall water and overland flows are considered for remediation of natural resources and agricultural lands (Hoogmoed & Stroosnijder, 1984). They are feasible and economic sources for perennial plant cultivation on the hill slopes and upper catchments. These areas are dominated by overland and subsurface flow flows. Thus, runoff collection can alleviate water deficiency in soil layers, especially in the plant root system (1985 Hoover).

Rainfall water harvesting is multifunctional system which not only enhances available water for crops, it also contributes to flood control and soil conservation. In addition, it is simple and eco-friendly in the rural areas, especially for smallholders at the upper lands. For instance, a simple layer of crop residue as the filter layer on the surface soil can result in recharging the soil with adequate moisture (1975 Gardner; Fairbourn, 1975). The objectives of this research were (i) to construct different run-off harvesting systems at the plot scale; and (ii) to compare the contribution of these systems for run-off collection.

2. MATERIALS AND METHODS

2.1 Study Area

This study was conducted in a rangeland in the Kabodeh-Olia village, located about 10 km southeast of Kermanshah, in the semi-arid region of Iran. It lies between 34° 15' 32" N latitude and 47° 05' 51" E longitude at 1500 m amsl. The topographic features of the site include a northern aspect with 25% slope. Soil depth is shallow (about 30 cm) and heavy texture with gravelly surface. The mean annual precipitation is 470 mm. The climate, topography, soil and land-use of this site are typical of similar mountainous areas, especially those which are being converted to orchard by local inhabitants.

2.2 Site Establishment

The Kabodeh-Olia site was established with cooperation of local inhabitants, especially their leaders. The site area was 6400 m^2 (80m × 80m) and was enclosed with a wire fence (1.8 m high) for protecting from intruders. Waterway was constructed for letting run-off and overland flows into the site.

2.3 Establishment of Rain gage

A rain gage (data logger system) was established on the nearest house roof for recording rainfall. The results were taken every two months and analyzed using relevant software.

2.4 Designing the Plots and their Water Storages

Figure 1 shows the 3 different rhombus shaped plots (170 cm in dimensions) designed for runoff harvesting. One set of 3 plots had compacted surface covered with straw mulch, another set of 3 plots was covered with plastic sheet overlain by rubble, and the third set was control plot (virgin soil surface). The area of each plot was 4 m^2. Runoff from each plot was collected in its storage tank, which was constructed below the lowest point (Fig. 2). The plots were separated from the surrounding area by means of wood sleepers (1.7m × 0.14m × 0.01m), as shown in the illustrations in Figures 3 to 7. The runoff volumes were converted into equivalent depth for estimating runoff coefficient. The plots were separated from one another by 3 m among the replicates and 1 m within the replicates.

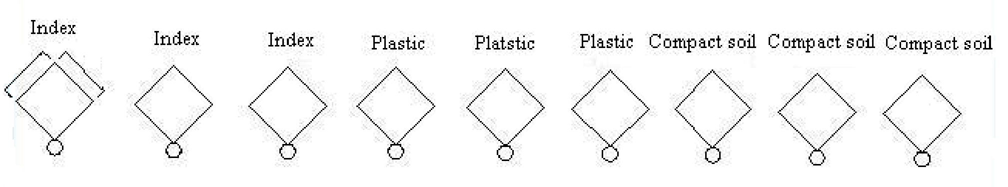

Fig. 1: Designation of different plots with their repetitions (Désignation des différentes parcelles avec leurs répétitions)

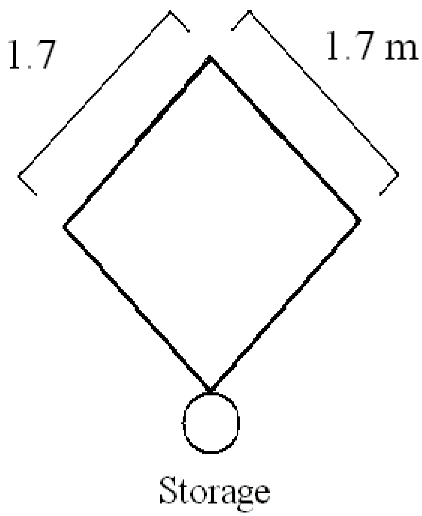

Fig. 2: A schematic shape of water harvesting system with its thank (Une forme schématique du système de récupération de l'eau avec ses remercie)

Tables 1 and 2 show the relationship between the rainfall and runoff generated by the three rain water harvesting systems (Natural cover, Compact soil with straw mulch and Plastic with rubble cover).

Table 1: Harvested runoff in storage tanks in the different plots(Récolté de ruissellement à travers les réservoirs de stockage dans les différentes parcelles)

No	Rainfall (mm)	Collected Run-off though tanks (cm)								
		Natural covers Repetition			Compact soil with straw Repetition			Plastic with stone cover Repetition		
		1	2	3	1	2	3	1	2	3
1	6.8	2	1.5	1.8	5	4	5	10	10	11
2	18.6	9	8	9	18	29	20	30	28	28
3	7.6	2	2	1.5	4	3	3	10	9	8
4	3.4	0.2	0.2	0.2	0.5	0.5	0.5	4	3.5	5
5	0.8	0	0	0	0	0	0	0	0	0
6	2	0	0	0	0.3	0.5	0.7	2.5	2	3
7	3.2	0	0	0	0.2	0.5	0.5	5	4	4
8	22	10	11	10	26	27	26	34	35	36
9	1.5	0.5	0.25	0.5	1	1	1	2	2	2.5
10	16	7	8	8	16	17	18	25	26	27
11	21.8	12	13	12	23	24	25	30	32	35
12	13.6	3	4	4	15	14	15	22	20	18
13	11.5	2	3	4	13	13	14	20	18	17
14	38.3	22	22	22	50	50	50	50	50	50
15	17.4	4	4	5	14	15	14	29	24	22
16	9.1	1	2	2	11	10	12	15	14	15
17	29.7	8	9	8	29.5	30.5	33	50	50	50
18	15.5	4	5	4	10	10	11	26	25	26
19	38.9	24	25	25	50	50	50	50	50	50
20	26.2	8	7	8	17	19	20	42	40	45
21	15.3	3	2	2	12	9	10	24	25	26
22	18	5	4	5	12	10	10	30	29	30
23	6.2	1	0	0	5	2	2	10	9	10
24	29	11	12	11	23	25	30	50	50	50

2.5 Harvested Runoff

Harvested runoff of each rainfall storm is shown in Table 2. The relationship between rainfall and runoff depth was statistically analyzed using SPSS software. As shown in Table 3, the runoff depth was significantly correlated with rainfall for all treatments. In the compacted soil with straw mulch this correlation was strong ($p < 0.01$; $R^2 = 0.949$) and equation (1) shows simple regression between rainfall (Y) and runoff depth (X):

$$Y = 3.81 + 1.367X \quad (1)$$

The relationship between rainfall and runoff for natural cover was also significant ($p < 0.01$; $R^2 = 0.921$). The regression equation for this treatment was:

$$Y= -1.511+0.315X \quad (2)$$

Runoff was also significantly correlated with rainfall for plastic mulch with rubble cover ($P<0.01$; $R^2 = 0.995$). The Eq. 2 shows the regression of runoff and rainfall for plastic mulch treatment:

$$Y= -0.752 + 0.957 X \quad (3)$$

In (1), (2) and (3), Y and X are in millimeter.

Table 2: Runoff depth produced during a precipitation in three different rain water harvesting systems (Hauteur de ruissellement produites au cours d'une précipitation dans l'eau de pluie trois différents systèmes de récolte)

No	Rainfall (mm)	Average of runoff depth (mm)		
		Natural cover	Compact soil with straw mulch	Plastic with rubble cover
1	6.8	1.02	2.68	5.92
2	18.6	4.98	12.84	16.48
3	7.6	1.05	1.92	5.17
4	3.4	0.11	0.29	2.39
5	0.8	0.00	0.00	0.00
6	2	0.00	0.29	1.44
7	3.2	0.00	0.23	2.49
8	22	5.94	15.13	20.12
9	1.5	0.24	0.57	1.25
10	16	4.41	9.77	14.94
11	21.8	7.09	13.79	18.58
12	13.6	2.11	8.43	11.49
13	11.5	1.72	7.66	10.54
14	38.3	12.64	28.74	47/35
15	17.4	2.49	8.24	14.37
16	9.1	0.96	6.32	8.43
17	29.7	4.79	17.82	29
18	15.5	2.49	5.94	14.75
19	38.9	14.18	28.74	90/35
20	26.2	4.41	10.73	24.33
21	15.3	1.34	5.94	14.37
22	18	2.68	6.13	17.05
23	6.2	0.19	1.72	5.56
24	29	6.51	14.90	28.74
Mean	15.51	3.40	8.99	15.40

Table 3: Simple regression between rainfall intensity and run-off height for water harvesting systems using SPSS

Water harvesting system	R	R_s	R_{Adj}	Standard Error (SE)
Compacted soil with straw mulch	0.949	0.900	0.895	3.2938
Natural cover	0.921	0.848	0.841	1.5173
Plastic mulch with stone pavement	0.995	0.990	0.990	0.8030

Table 4: Regression parameters between rainfall and run-off

Water harvesting system	Model	Non-standard Ratio		Standard Ratio	t	p
		B	(SE)			
Compacted soil with straw mulch	Rainfall	3.910	1.033	0.949	3.786	0.001
	Run-off	1.367	0.100		13.949	0.000
Natural cover	Rainfall	-1.511	0.539	0.921	-2.801	0.010
	Run-off	0.315	0.028		11.078	0.00
Plastic mulch with stone pavement	Rainfall	-0.752	0.327	0.995	-2.302	0.033
	Run-off	0.957	0.022		44.130	0.000

As shown in Table 5, the ANOVA analysis revealed that both plastic cover and compacted soil significantly affect run-off harvesting ($p<0.001$). Mean harvested runoff of plastic cover overlain by rubble was 15.40 mm which contributes to maximum level of run-off harvesting.

Table 5: The ANOVA for soil variables among the three run-off harvesting system (Average rainfall: 15.51 m)*

Variable	Run-off harvesting system			Pr >F
	Plastic	Compacted soil	Natural (Index)	
Runoff(mm)	15.40 (A)	8.99 (AB)	3.40	0.0030

*Means with the same letters within rows are not significantly different (at $p \leq 0.05\%$)

Fig. 3. The experimental plots in the field(Les parcelles expérimentales dans le domaine)

Fig. 4. The compacted soil with straw mulch and its tank (down ward)(Le sol compacté avec paillis et il est le réservoir)

Fig. 5. The natural (virgin) plot(couverture naturelle)

Fig. 6. The plastic with stone plot cover its tank (down ward)(Le plastique avec couvercle en pierre)

Fig. 7. Harvested run-off through plastic with stone plot(Récoltée par le ruissellement en plastique avec une intrigue de pierre)

3. CONCLUSIONS

This research revealed that all three rainfalls harvesting systems significantly contribute to surface runoff collection, while among three deigned systems, plastic mulch with stone pavement was the best method for harvesting run-off with minimum sediment yield and soil erosion hazard. This system can be used for harvesting overland flows in the rain-fed areas, especially for supplement irrigation of planted trees. Furthermore, it is a simple and economic system for inducing to smallholder farmers in the upper catchments.

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