EXPERIMENTAL INVESTIGATION OF WATER HARVESTING TECHNIQUES (AL-HASA VALLEY IN JORDAN)

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ABSTRACT

Water harvesting techniques of inducing or reducing runoff are numerous, but their proper usages are site specific. Therefore, experimental investigations are prerequisites for any adaptation of these techniques. This paper analyzed the results of three groups of runoff inducing techniques, from simple land clearing, smoothing, and compaction, to four land treatments by salt and salt water, to surface covering by several types of asphaltic treatments or plastic sheets. The results of runoff coefficient ranged from 15.22% for cleared, not smoothed not compacted plot to 87% for asphaltic concrete covering. Regarding the runoff reduction techniques this paper analyzed the results of four combinations of ploughing depths and directions. The results of runoff coefficients ranged from zero for ploughing perpendicular to the slope to 3.52% for shallow ploughing paralles to the slope. The two major types of harvesting were combined here not for contrasting purposes only, but mainly because runoff and run-on areas have to be side by side in agricultural harvesting projects. The results for both types encouraged field implementation in the valley and other similar arid and semi-arid zones.

Keywords: Water, Harvesting, Ground surface treatments, Soil profile Treatments, and Inducing and Reducing runoff.

INTRODUCTION

Water harvesting could be distinguished from other water management practices in many ways. Collecting, using or storing rain water are to be done in localized areas to reduce losses by seepage and evaporation due to water transportation in other water conservation practices. Many water harvesting techniques have been used to improve the productivity of grazing and to increase yields of rainfed farming. Also, they could be used to supply drinking water for animals and to minimize drought hazards [1-3].

The water harvesting system as presented by Frasier *et al.*[4] has two main components : the runoff area (the harvesting area) where induced runoff is to be collected; and the run-on area, where the water is concentrated or stored after being collected from the other area.

Since any proposed harvesting system must be adopted to local conditions to define the ratio of runoff to run-on area, scientific experimenting in real conditions is a prerequisite for wide range usage. Exploring the characteristics and the performances of the run -off and run-on areas needed field experimentation [5, 6].

This paper discusses the results of four groups of harvesting techniques used in Al-Hasa Valley in Jordan (LAT. N 30° 55', LONG. E 35° 47', ELEV. 485 m). Three groups for runoff harvesting and one group for run-on harvesting scheme. In agricultural projects in arid and semi - arid regions, runoff and run-on plots are combined to enhance the amount of harvested water on the intended receiving plots.

This field experiment was not intended to find the proper ratio between runoff and run-on land for successful rainfed agriculture. It was rather intended to experiment with several types of runoff and run-on harvesting techniques. The efficiency of these techniques is site specific. It depends on weather characteristics, ground surface covering, slope, and soil type.

The harvesting techniques of this experiment were grouped in the following scheme. Group-1 investigated the natural conditions in C1, and three types of minimum surface treatments of surface clearing, smoothing, and compaction. Group-2 investigated the harvesting efficiency and durability of using salt and salt water on the surface or in the top ten centimeters of the soil profile. Group-3 investigated the harvesting efficiency and durability of using three types of asphaltic covering and one type of plastic sheets. On the other hand, group-4 was intended to investigate the proper land treatment to prevent runoff by shallow or deep ploughing along or perpendicular to the land slope (see notation).

The ground surface covering and the soil characteristics were examined. The soil was silty clay with low sand content. The bulk densities of normal, compacted, and ploughed soil were investigated for the upper 30 cm (Table 1).

The main work of this experiment was collecting the harvested water from each plot for every rainfall occurrence. The occurrence was defined to be a single day even if the rain happened in minutes or in several days. Measurements were taken every morning. During heavy rain storms more than one measurement of collected rain were taken in 24 hrs, but the record presented the total 24 hours harvested rain.

The runoff coefficients are indicators of the technique efficiency, Runoff coefficient equal collected runoff divided by total incoming rainfall [7]. They were analyzed for each group by finding their means, ranges, standard deviations, the coefficient of variances, skewnesses and the kurtosises. Also all the harvesting techniques were correlated, with the natural conditions, with each other inside the group, and with each other across groups. These correlations explored the interrelationships between the harvesting techniques.

Since these harvesting techniques were to be used through time, the experiment investigated the time dependence of runoff coefficient by trend curves for each harvesting technique. Trend curves were either increasing, decreasing or stable throughout the season which gave indications of the time performance of the harvesting techniques and their durability. Asphaltic concrete was the best runoff harvesting technique and ploughing perpendicular to the slope was the best runoff harvesting technique regardless of ploughing depth.

Table 1 Soil Composition

	Textural Separate Percentage		
Depth cm	Sand	Silt	clay
0-10	8	55	37
10-20	12	53	35
20-30	12	50	38

NOTATION OF WATER HARVESTING TECHNIQUES

Group 1

C1: Not cleared, not smoothed, not compacted ground surface.

C2: Cleared, not smoothed, not compacted ground surface.

C3: Cleared, smoothed, not compacted ground surface.

C4: Cleared, smoothed, compacted ground surface.

Group 2

S1: Surface application of salt water (dead sea water) 0.01 m^3/m^2.

S2: Surface Spreading of salt 2kg/m^2..

S3: Mixing Salt water in 10 cm layer with compaction.(Dead Sea Water) 0.05 m^3/m^2.

S4: Mixing Salt in 10 cm layer with compaction (5 kg/m^2.).

Group 3

AMC: Asphaltic Surface Covering with MC asphalt after compaction 1L/m^2.

ARC: Asphaltic Surface Covering with RC (sealing coat)~2cm thickness of asphalt with aggregates after compaction.

ACO: Asphaltic Concrete-Hot mixture 5 cm layer with compacting the soil below and the asphaltic layer

PL: Plastic Sheet (Black color, 1 mm thickness.) after clearing and smoothing ground surface

Group 4

P1: Surface Ploughing (~15cm) Perpendicular to plot slope.

P2: Deep Ploughing (~30cm) Perpendicular to the slope.

P3: Shallow Ploughing (~15cm) along the slope.

P4: Deep Ploughing (~30cm) along the slope.

METHODS

Design of the Experiment

The studied area was subdivided into four groups. Each group had four plots. Each plot was 2 m wide and 25 m long. The average slope of all plots was 2.5 percent.

The first three groups were designed to study several harvesting techniques which induced runoff. They were treated catchment plots to maximize produced water. The fourth group was designed to study the effects of four combinations of ploughing depths and directions to prevent runoff on cultivated, run-on plots. The runoff producing plots and the run-on receiving plots were studied simultaneously for the same rainfall occurrences in the wet season of 1991-1992 in Al-Hasa valley in Jordan, (see Figure 1)

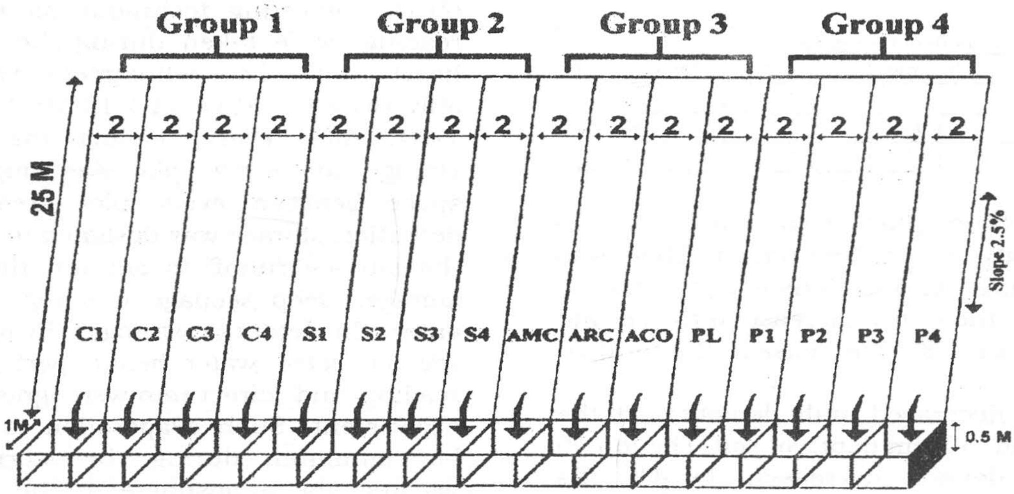

Figure 1 Diagram of water harvesting plots for the used techniques

Ground Surface and Soil Characteristics

The natural ground surface which was represented by C1, was similar to many sloping lands at the feet of mountains surrounding valleys in Jordan. Loose stones were covering 25% of the natural ground, while sporadic natural vegetation was covering 10% of it. The remaining 65% of the soil was bare soil, which was affected by the wind mostly in the extended dry seasons and raindrops in the winter. Partial crusting was observed every year in these areas specially during the time of the experiment.

Soil Composition

The Soil type of the harvesting plots is silty clay with minor sand content. This type of soil has high water retention capacity and high ability to develop surface crusting. The upper 30 cm was analyzed to produce the following textural separate percentages, table 1.

Bulk Densities of Normal, Compacted and Ploughed Soils

Bulk density of soil in each plot was a good indicator of the soil packing and the volume of the interaggregate pores. Compaction increases the packing effects and decreases the volume of the pores. Therefore, compaction decreases the infiltration rate and increases crusting, consequently enhances runoff. Table 2 presents the bulk densities for normal, undisturbed soil, along with, compacted and the ploughed soils of the experiment area for comparison purposes.

Table 2 Bulk densities g/cm^3

Depth cm	Normal	Compacted	Ploughed
0-10	1.02	1.57	0.98
10-20	1.21	1.32	1.08
20-30	1.13	1.15	1.06

Compaction had clear effects on the bulk density of the first ten cm. There was 54% increase of bulk density in the first 10 cm depth, then 9% increase in the second 10 cm, then 1.8% increase in the third 10 cm.

Ploughing decreased bulk density in all the investigated 30 cm depth of soil. The top 10 cm bulk density decreased by 4%, the second by 10%, and the third by 6%. The highest effects of ploughing on soil bulk density appeared in the second 10cm. The apparent crusting could be the reason for not having the highest reduction in soil bulk density in the top 10 cm depth.

Rainfall Occurrences During the Experiment Season

The experimental plots received rainfall from 12-10-1991 until 22-3-1992. It was one wet season extended for 162 days with 46 rainfall days (occurrences). For Academic purposes storms of several days were subdivided into several single day occurrences. There were 12 storms of 2 days or more. The longest storm duration was 6 days.

The minimum daily rainfall used in the calculation to find the runoff coefficient was 1 mm. per day. The maximum daily rainfall occurrence was 26 mm per day on 25-2-1992. The measurements were taken every 24 hrs at 8 o'clock in the morning.

Harvested Water Collection

At the lower end of each plot water was allowed to accumulate in a separate detention storage (Figure 1). The allocated detention size for each plot was (2mX1mX0.5m), which equaled 1 m^3

Most of the time for all plots the daily harvested water volume was far below 1 m^3 except for (ACO). To avoid any error due to expecting runoff more than 1 m^3/day over (ACO) harvesting technique, more than one reading were taken during the 24 hrs of heavy rain. This adjustment was needed only twice for (ACO) on 1-12-1991 and 25-2-1992. After every reading the detention storage for every plot was emptied. The space between every plot area and its detention storage was designed to allow only the surface runoff to get into the readable storage. Deep seepage was not allowed to enter the detention storages. Evaporation of the collected water before performing the reading and direct rain were ignored in this experiment. Such evaporation is known to be minimum during the storm period, because the atmosphere in the vicinity is expected to be saturated or close to saturation [5]. Besides that, evaporation and direct rain offset partialy each other effects.

DISCUSSION

Descriptive Statistics of Runoff Coefficient

The mean of runoff coefficient for each harvesting technique was the main concern of technique effectiveness evaluation. But range, standard deviation, skewness and kurtosis would allow for deeper insight of the harvesting processes in each technique. They are presented in Table 3 for comparison purposes in each harvesting group and between groups. Correlations between runoff coefficient for harvesting techniques are presented in Table 4 for the same comparison purposes.

Group - 1

Group 1 with minimum ground surface treatment had the lowest runoff coefficient of all runoff producing techniques. It ranged from 12.28% for C1, the natural conditions to 22.46% for C4, the cleared, smoothed, and compacted ground surface. Since the ground surface did not need extensive clearling, the addition to runoff coefficient by clearing was only 2.84% in C2. Also, since the initial crusting made some smoothing, the addition to runoff coefficient by smoothing was only 2.02% in C3. On the other hand compaction in C4 increased the runoff coefficient by (5.22%) which is larger than the sum of the effects of clearing and smoothing, because of compaction effects on infiltration characteristics. Moreover, compaction reduced depression storages.

The range and standard deviation for each were comparable, but skewness and kurtosis were not comparable between the techniques. subgroups C1 had the highest negative skewness, then came C2. Since all group-1 had negative skewness; so the longer tails of the actual distributions were to the left where the median and the mean were pulled from the mode. The kurtosis of group-1 were all positive with C1 the highest then came C2. So the peakedness of group-1 specially C1 and C2 indicated that the number of harvesting cases near the mean is greater than the expected number in normal distribution.

Table 3 Descriptive Statistics of Runoff Coefficient

	Range	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
(C1)	.1500	.1228	.0239	-3.4900	.3501	15.8644	.6876
(C2)	.1000	.1522	.0197	-1.5112	.3501	3.3514	.6876
(C3)	.0900	.1724	.0209	-.7608	.3501	.2256	.6876
(C4)	.1100	.2246	.0259	-.7079	.3501	.1357	.6876
(S1)	.2400	.3483	.0590	-.8727	.3501	.1403	.6876
(S2)	.1800	.2863	.0517	-.6873	.3501	-.5704	.6876
(S3)	.3100	.4763	.0915	-1.1650	.3501	.1610	.6876
(S4)	.2800	.3987	.0772	-.7929	.3501	-.4874	.6876
(AMC)	.3200	.6068	.0789	-.6055	.3501	-.0949	.6876
(ARC)	.2600	.7426	.0681	-.9013	.3501	-.0148	.6876
(ACO)	.2700	.8700	.0678	-1.1535	.3501	.4344	.6876
(PL)	.5900	.7057	.1503	-1.4979	.3501	1.1644	.6876
(P1)	.0000	.0000	.0000	.000	.000	.000	.000
(P2)	.0000	.0000	.0000	.000	.000	.000	.000
(P3)	.0700	.0352	.0233	-.7377	.3501	-1.1352	.6876
(P4)	.0400	.0100	.0148	1.0410	.3501	-.5017	.6876

Table 4 Correlations of Runoff Coefficient for Harvesting Techniques

(C1)	1.000															
(C2)	.913	1.000														
(C3)	.814	.929	1.000													
(C4)	.779	.863	.929	1.000												
(S1)	.539	.624	.552	.532	1.000											
(S2)	.637	.776	.723	.701	.900	1.000										
(S3)	.642	.749	.735	.734	.847	.856	1.000									
(S4)	.634	.746	.769	.781	.694	.736	.929	1.000								
(AMC)	.478	.599	.530	.461	.875	.873	.793	.651	1.000							
(ARC)	.506	.653	.618	.547	.841	.865	.838	.744	.968	1.000						
(ACO)	.706	.816	.799	.752	.775	.849	.900	.880	.812	.882	1.000					
(PL)	.498	.644	.626	.617	.850	.850	.858	.799	.832	.822	.766	1.000				
(P1)	000	000	000	000	000	000	000	000	000	000	000	000	000			
(P2)	000	000	000	000	000	000	000	000	000	000	000	000	000	000		
(P3)	.584	.743	.756	.797	.607	.786	.849	.853	.644	.715	.806	.708	000	000	1.000	
(P4)	.327	.444	.476	.495	.523	.551	.546	.527	.522	.531	.593	.482	000	000	.518	1.000
	(C1)	(C2)	(C3)	(C4)	(S1)	(S2)	(S3)	(S4)	(AMC)	(ARC)	(ACO)	(PL)	(P1)	(P2)	(P3)	(P4)

Group-2

Wet salt at soil surface or in soil profile holds particles together and limit soil infiltration characteristics. Group-2 with salt and Salt water treatment of ground surface or soil profile, had higher runoff coefficient than group-1, it ranged from 28.68% for S2, surface spreading of salt to 47.63% for S3 mixing salt water in ten cm of soil profile. It was apparent from the averages of runoff coefficients that using saltwater was better than using salt. Also, using the soil profile was better than using the ground surface.

The ranges and standard deviations of S1 and S2 were lower than S3 and S4. It was understandable because the first two were surface treatments with limited variability and the second two were soil profile treatments. Skewness was negative for all with S3 the largest in absolute sense. S1 and S3 had positive kurtosis while, S2 and S4 had negative kurtosis. This result meant that salt water treatment made runoff coefficients closer to the mean than the normal distribution. On the other hand, salt treatment pulled runoff coefficients away from the mean of the expected normal distribution.

Group-3

Asphaltic group with plastic sheet had the highest runoff coefficients of all groups. The highest of all was ACO then came ARC. Most of runoff coefficients of this group were above 0.7, expect for AMC which was 0.6068.Having ACO first then ARC, then AMC was average. In the other hand, PL the plastic sheet, was expected to have lower runoff coefficient because of the developed depressions in the course of the flow, but runoff coefficient of PL was not far from the average. The runoff coefficient numbers reflected the physical performance of each harvesting technique. The AMC covering started cracking early in the season. Also peeling up started in November. In the other hand ARC was stronger. It had less cracks and less peelings until March. But its surface depression storage was larger than AMC, because of the relatively rough surface, due to the used aggregates. PL started to develop wrinkles and folds which enhanced these subgroups depression storage, therefore lowered its runoff coefficient. All had negative skewness with the tail to the left. ACO and PL had the largest skewness, and had positive kurtosis, while AMC and ARC had lower skewness and negative kurtosis. So AMC and ARC were flatter than normal distribution, which was flatter than ACO and PL.

Group-4

Group-4 techniques were actually intended to test methods of preventing runoff in run-on plots instead of runoff plots in the other techniques. Ploughing perpendicular to the slope either shallow or deep, prevent runoff. Ploughing along the slope reduced runoff but did not prevent it. Doubling the depth of Ploughing does not decrease runoff coefficient to the half but rather to less than a third. Doubling the depth of ploughing increased the ponding effects which withhold runoff water. Shallow ploughing increased the exposed area by 15.5% while deep ploughing increased it by 42.4 percent.

Even though the range of P3 was double its mean and the range of P4 was four times the mean, the standard deviations were comparable. P3 was skewed to the left and P4 was skewed to the right, but both had negative Kurtosis with distributions flatter than the normal distribution. P3 was Platter than P4.It seemed that peakedness increased with increasing runoff coefficient.

The Coefficient of Variance (C.V.) analysis

The Coefficient of Variance is defined to be the standard deviation divided by the mean (S/X), to normalize the numerical value of the standard deviation. Therefore, the ranking of (S) is different from the ranking of (C.V.). Table 5 presents C.V. of all the harvesting techniques (H.T.)

Table 5 Coefficient of variance of the different harvesting techniques

H.T	P4	P3	P1	C1	S4	S3	S2	S1	ARC	C2	C3	C4	ACO	AMC
C.V	.148	.662	.213	.195	.194	.192	.181	.169	.130	.129	.121	.115	.092	.078

The highest variability indicated by (CV) was for P4 then P3 plots. PL came third due to the surface wrinkles of the plastic sheets. C1 represented the natural conditions with no ground surface modification, it had C.V =.195. PL and group-2 were the closest to the natural conditions (C1), with C.V varying from (.213) for PL to (.169) for S1, with S4 and S3 very close to the natural conditions (C1).

The coefficients of variance of C2, C3, and C4 were lower than the natural conditions due to the surface clearing, smoothing, and compaction. As expected, the lowest of all were ACO and AMC because their modifications of the ground surface were substantial, specially the ACO. Even though, AMC deteriorated faster than ACO but the surface smoothness in both was comparable before the deterioration of AMC.

Time Dependence of Runoff Coefficient

Runoff coefficient performance through time for each harvesting technique was explored through the linear curve fitting. Each harvesting technique had its own trend and its own variability around that trend [8].

The natural ground surface conditions was represtend by C1 with no clearing, no smoothing, and no compaction. The observed variability in Figure 2 was low except for the beginning and the end of the season. At the beginning there was no previous rainfall which increased the wetting water requirements, then decreased the runoff amounts. At the end of the season the rainfall intensity decreased which allowed for more infiltration and evaporation, therefore decreased runoff. There was a slight increasing trend due to crusting effects. The cleared ground surface C2 plot showed similar characteristics with C1 plot in the trending direction and the variability pattern, even though the crusting effects of C2 were more than C1 (Figure 3).

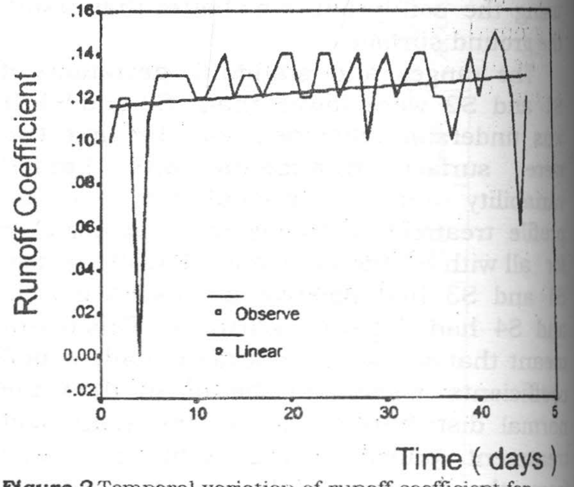

Figure 2 Temporal variation of runoff coefficient for subgroup C1

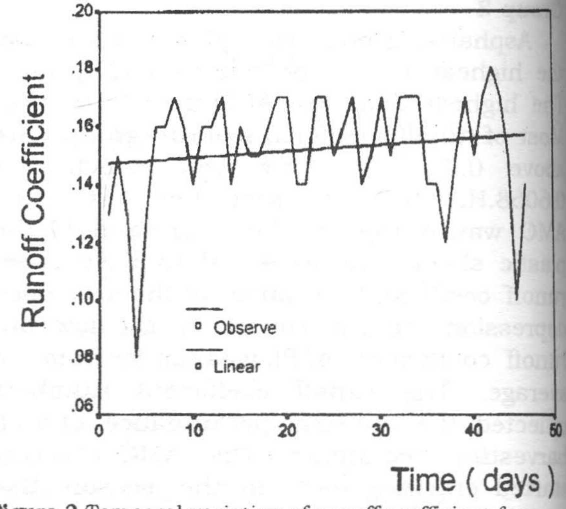

Figure 3 Temporal variation of runoff coefficient for subgroup C2

C3 and C4 had very clear increasing trend and observed variability. Numerically the trend of C4 is three times the trend of C3. Field observations showed that crusting of compacted surfaces was clearer than smoothed surfaces. The curve fittings of C3 and C4 were clarifying this fact (Figures 4 and 5).

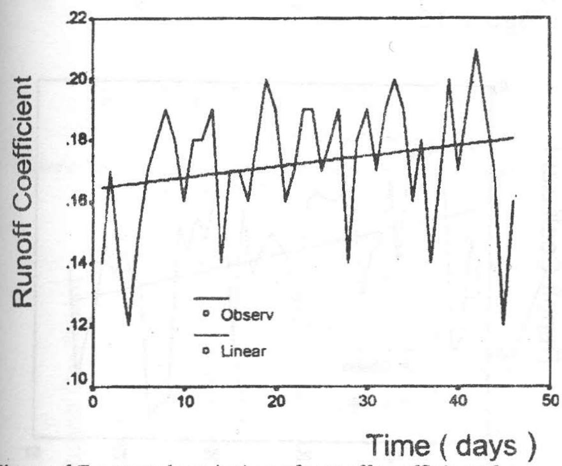

Figure 4 Temporal variation of runoff coefficient for subgroup C3

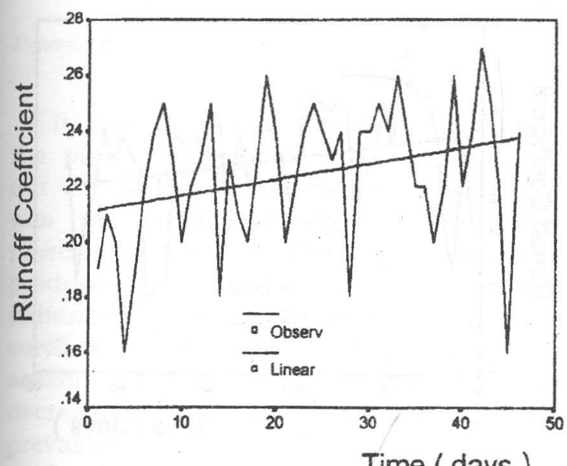

Figure 5 Temporal variation of runoff coefficient for subgroup C4

In the salt treatment group (S1, S2, S3 and S4), it was found that the surface application of salt and salt water had different trend results from the soil profile application. S1 and S2 had decreasing trends in runoff coefficient due to salt leaching effects. The decreasing trend Of S1 is more than S2 because part of the spread salt had been desolved by the rain water to get into the soil profile and increase crusting in S2 case, (Figures 6 and 7).

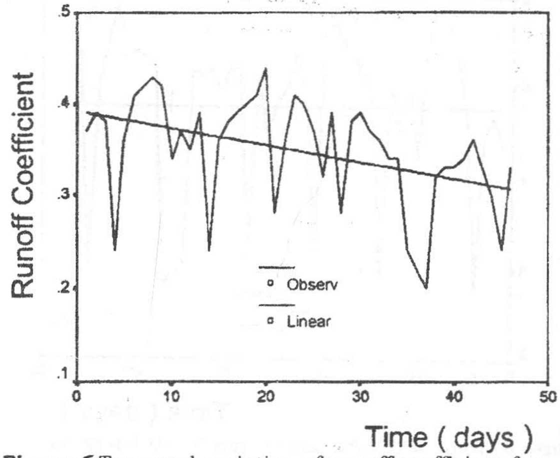

Figure 6 Temporal variation of runoff coefficient for subgroup S1

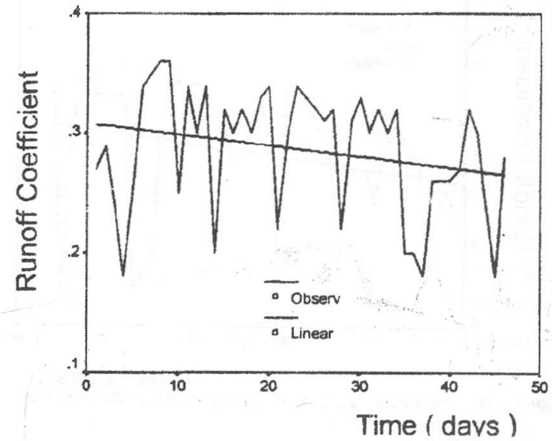

Figure 7 Temporal variation of runoff coefficient for subgroup S2

The profile application of salt water was distinctly different from the application of pure salt. S3 had an approximately horizontal trend with minimum time dependence or salt leaching. In the other hand, S4 with salt mixed in the upper ten cm of soil profile, had a clear increasing trend. (Figures 8 and 9). The effects of salt leaching were offset by the effects of rainwater disolving the applied salt and combining it with the soil structure. This process increased the soil surface ability to prevent infiltration and enhance runoff.

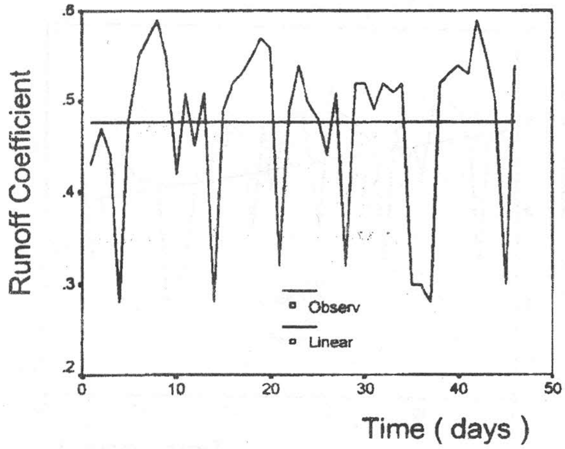

Figure 8 Temporal variation of runoff coefficient for subgroup S3

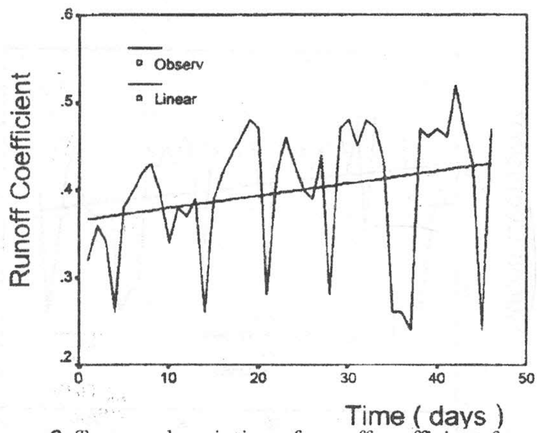

Figure 9 Temporal variation of runoff coefficient for subgroup (S4)

In the asphaltic group (AMC, ARC and ACO), there was great variability in the trends, (Figures 10, 11 and 12).AMC as expected had the fastest decreasing trend. It was observed that the AMC covering was deteriorating faster than the others which decreased the runoff coefficient through the season. ARC had less deterioration, and the decreasing trend of runoff was half that of AMC. In the other hand, the ACO had a slight increase in runoff coefficient trend.

The asphaltic concrete (ACO) was strong enough to withstand any deteriorating effects in that season. The slight increase in runoff coefficient was due to the filling of the tiny microscopic depressions by wet dust which made the ACO surface smoother.

The plastic sheet technique (PL) had a distinct decreasing trend in linear, logarithmic and exponential fittings as see in Figure 13.

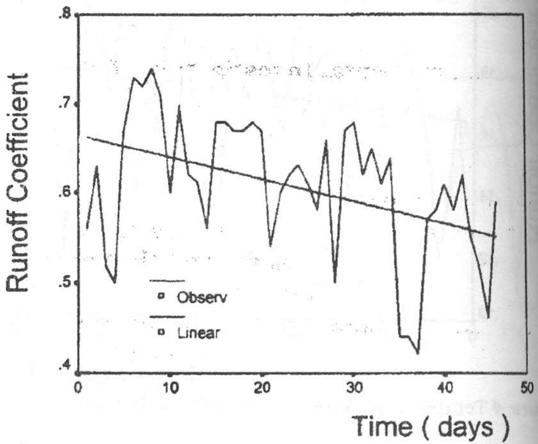

Figure 10 Temporal variation of runoff coefficient for subgroup (AMC)

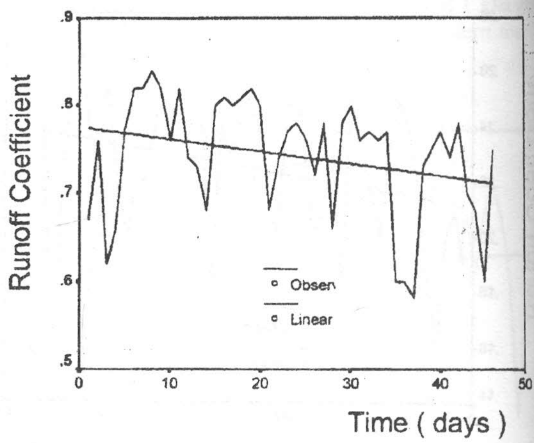

Figure 11 Temporal variation of runoff coefficient for subgroup (ARC)

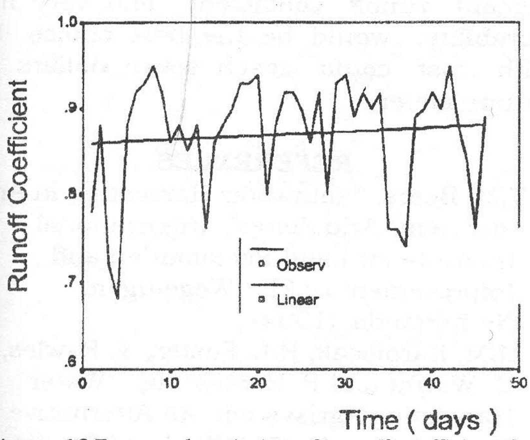

Figure 12 Temporal variation of runoff coefficient for subgroup ACO

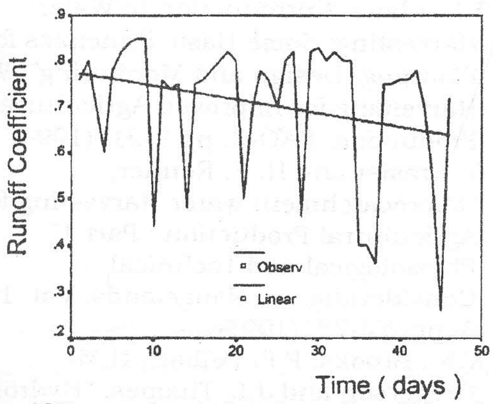

Figure 13 Temporal variation of runoff coefficient for subgroup PL

It was observed that the smoothness of the plastic sheets were decreasing through out the season. The direct reason for that was the solar heating which affects the plastic sheets. The non-smoothness produced depressions of all sizes which enhanced evaporation and reduced runoff coefficient, specially by the end of the season when the rainfall intensities decreased and the warming conditions prevailed.

In the runoff decreasing techniques of group-4, P1 and P2 with perpendicular ploughing had zero runoff. P3 and P4 with ploughing along the slope had two different trends. The shallow ploughing of P3 had increasing runoff trend due to the forming of partial surface crust. In the case of P4 with deep ploughing the runoff coefficient trend remained essentially the same. Deep ploughing made the effects of crusting very minimal, (Figures 14 and 15).

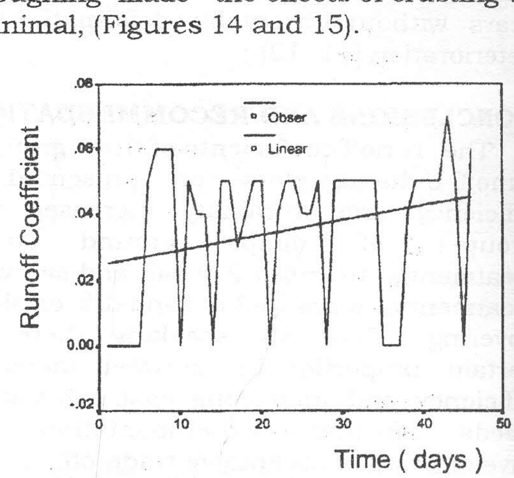

Figure 14 Temporal variation of runoff coefficient for subgroup P3

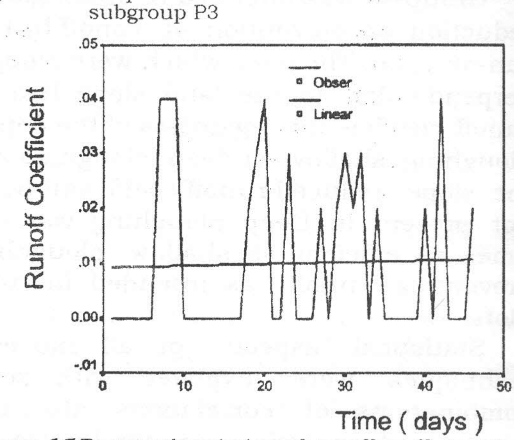

Figure 15 Temporal variation of runoff coefficient for subgroup P4

Studying closely the runoff coefficient trends for each harvesting technique clarified the time effects on each technique. The techniques were intended for long term usage, so the trends through out time were essential factors for decision-making of the proper technique. The basic limitation of this trend analysis was the time limit of one season. Multi-seasonal experimentation would give clearer trend and runoff coefficient results by exploring the effects of the summer solar radiation on all used harvested techniques, specially the asphaltic and the plastic sheets [9-10]

These techniques would respond to summer heat by expediting surface deformations and deteriorations. Roads in the vicinity showed that AMC deformed and deteriorated through summer heating in weeks, ARC in months, and ACO stayed for years without observable deformation and deterioration [11, 12]

CONCLUSIONS AND RECOMMENDATIONS

The runoff coefficients of three groups of runoff inducing plots were presented. The efficiency and durability increased from group-1 of simple ground surface treatments, to group-2 of salt and salt water treatments, to group-3 of asphaltic or plastic covering. Generally speaking there was certain proportionality between increasing efficiency and increasing cost. This aspect needs further experimentation and investigation of acceptable trade-off.

Group-4 was intended to investigate the reduction or prevention of runoff by using run-on plot. The plots which were ploughed perpendicular to the land slope had zero runoff coefficients, regardless of the depth of ploughing shallow or deep. Ploughing along the slope reduced runoff coefficient but did not prevent it. Deep ploughing was three times as efficient as shallow ploughing in preventing runoff as intended in run-on plots.

Statistical aspects of all harvesting techniques were explored with several combinations of correlations. Also, trend curves and analysis gave the indication of time dependence of each harvesting technique to check for the short term durability, since this experiment was performed only for one season. Further experimentation for more than one season is necessary to explore the proper durability for longer times.

This paper was not intended to specify the best harvesting technique but rather to compare them. If minimum cost not maximum efficiency and durability was intended, then surface clearing, smoothing, and compaction would be enough, with one dollar per square meter estimated cost. If moderate cost and efficiency was intended then salt water treatment of the soil profile would be enough, with two dollars per square meter estimated cost. But if maximum efficiency was intended regardless of cost then asphaltic concrete, with 87 percent runoff coefficient and very high durability, would be the best choice, but with cost could reach seven dollars per square meter.

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تحليل تجريبي لتقنيات الحصاد المائي في وادي الحسا -الاردن

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ملخص البحث

تقنيات الحصاد المائي سواء التي تزيد او تقلل الجريان كثيرة ، لكن الاستعمال المناسب لأي منها يعتمد على مكان الاستعمال، لذا فإن البحث التجريبي متطلب سابق لأي تبن لهذه التقنيات ، وهذه الورقة تحلل نتائج ثلاث مجموعات من التقنيات البسيطة التي تقوم على إزالة الشوائب او تسهيل أو دك قطعة الأرض ، الى أربع معالجات للأرض بالملح او بالماء المالح ، وآخرها تقنيات تغطية القطع المدكوكة بثلاثة أنواع من الطبقة الإسفلتية او بالبلاستيك الأسود ، وقد تفاوتت نتائج معامل الجريان من ١٥,٢٢٪ للقطعة المنقاة من الشوائب لكن دون تسهيل او دك الى ٨٧٪ في القطعة المغطاة بطبقة الخلطة الإسفلتية ، كما وحللت هذه الورقة أربعة أنواع من الحراثة اعتماداً على عمقين واتجاهين في الحراثة السطحية او العميقة والموازية او المعامدة لميل القطعة ، وقد ضمت هذه الورقة الطريقتين الرئيسيتين في زيادة او تقليل الجريان ليس للمقارنة فقط ؛ وإنما لأن المساحات المخصصة لزيادة الجريان والمساحات المخصصة لاستقبال الجريان تكون غالباً جنباً الى جنب في أي مشروع حصاد مياه زراعي ، وقد كانت النتائج في كلا النوعين مشجعة على الاستعمال الحقلي في الوادي وفي غيره من الأراضي الجافة وشبه الجافة.