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Controlling Flood and Runoff on Steep SlopesUsing Crescent Catchment Systems:a Case Studyon Alborz Southern Hillside, DarabadRegion, Iran

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ABSTRACT

One of the most important functions of watershed management is increasing the amount of permeation and soil moisture and decreasing surface running water together with maintaining water and soil at basin level. Therefore, in the present research 4 types of treatment A0, A1, A2, A3 were applied which were respectively named witness, treatment, treatment of arched pool system, system treatment with culture and system treatment of modified (TerraCottem).Then,using split-plot design in time, the effect of treatments and mutual relation between them wasdetermined . the amount of damp in soil in A1 comparing witness has become 1.5 times as much and in the treatment A2, 2 times as much and in the treatment A3 has become 2.5 times as much. Statistical analysis of the amount of damp in treatments shows a very significant difference.(Pr<0/0001).Also the amount of damp shows significant differenceat different times. the average running water among treatments didn't show significant difference. (Pr=0/8628) . But in these experiments, the time showed a very significant difference . (pr<0/0001).Therefore, we can determine appropriate amount of runoff by implementing crescent banquette, and store the moisture in the soil for a long time using superabsorbent .

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INTRODUCTION

While rain water catchment systems have been used for various purposes to provide water and utilize rain water from small surface areas of roofs and courtyard homes to the large surface areas of watershed around the world from ancient times, in the recent decade, technology and knowledge of rain water catchment areas has been revived and taken into consideration in parts which face severe problems of water supply and loss of atmospheric flow.

Hudson [7], Pacey and Cullis [8] have consideredthe innovation and use ofrain water catchment systems in the form of grooves constructed on the contour lines by excavating (Banquette) and creating short wallson contour line by pebbles collected from ground surface andthe platform configuration of slope hillsides with the aim of harvesting and obtaining rain water for storing moisture in the soil profile to supply water for plants in many countries such as Ethiopia, Algeria, Morocco, Tunisia, Brazil and Mexico are considered to belong to previous periods.This type of rain water catchment system is called small-scale or Micro-catchment system.It is mainly nameddue to restricted catchments between grooves and platforms and low volume of water storagein the tank which is somehow considered a man-made artificial catchment.These systems typically have small catchments (rain watercollector) and water obtained from them is stored in the pit or grooveconstructed at the catchment downstreamandit gradually penetratesin the soil profile (figures.1and.2).

In addition to controlling runoff, crescent water catchment systems or in other word, runnel systems can also store moisture in soil for irrigating planted saplings. Runoff is harvested for different objectives in various

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countries. Rainwater and runoff harvesting, centralizing and then utilizing them appropriately are done to irrigate one year crops, trees and pastures, domestic and livestock consumptions.

In this region, due to the steep slope and adjacency of thearea to Tehran, the main objective is to control runoff, collect water for cultivating plants and control floods resulted from runoff. Principles of runoff harvesting are based on harvestingthem from small basins and using them in the same area.To collectrunoff in micro-catchments, the sourceof supplying runoff is the slope of hillsides.

MATERIALS AND METHODS

1-2 Characteristics of the Site of Performing the Plan:
Map 1- The geographical location of the area under study:

The present study wasconductedin Darabad, Tehran andin 40% slope to investigate the placement of the plants. Characteristics ofthe region where the planwas performed,are as follows:Height above sea level is 2210m; the direction of the slope is toward west and the slope is 40%; in basin, the average rainfall is 790mm and considering that the study is done at the downstream of the region and in the lower elevation and given the relationship between rainfall –elevation,in the desired elevation, the rainfall rate is about 495mm and about 40% of falls is snow.The maximum rainfall is in February and Marchand minimum fall is in August. During a year, maximum temperature median, minimum temperature median and temperature median are 15 °C, 4 °C and 9 °C, respectively. The value of evaporation and potential transpiration is about 600 mm. The desired designis in components of the mountain area's unit with overhanging rock to 10% andfrom shallow soil to moderate deep soil and in hillsides with the plant species of Arjan, Badamche and Tangras.The texture of the soil is sandy-gravel loam with low to moderate alkalinity.

2-2 Methodolog:

1- Constructing catchment systems or crescent Banquettebased on the desired plan and map.
2- Measuring the rate of soil moisture from zero to 30 cm depth usingTDR psychrometer.
3- Measuring the rate of the runoff resulted from falling after each falling at the level of each system using scale.
4- Recording the rate of moisture and runoff in the related tables and statistical analysis of the obtained data.
5- In this study, to determinethe effects of catchment systems, 4 treatments have been applied as following:

A0- the control treatment was located next to other treatments and at the same slope and direction andits area, length and width were 100 square meters, 20 and 5 meters, respectively.

A1-The treatment of the crescent catchment system (as illustrated,with a 3m diameter and other following characteristics) is considered according to theclimatic and soil conditions, the distance of crescents are considered 6 meters from each other; in another words, the center of distance of crescents is 6 in 6 from each other. These crescents are exactly constructed on contour lines using camera.

A2-The treatment of the system with cultivation (cultivating Arjan seed in a hole with diameter of 5 in 5cmor one year old Oras with the elevationof 10cm).The region soil hasA horizon located on C horizon in 10 to 30 cm thickness.

A3- The system treatment with soil modifier (Terra Cottem) to place plants after digging the hole in which 100 grams of Terra Cottem is mixed with soil and then the plant is planted after the mixture is put in the hole.

This plan has 4 treatments and 3 repetitions.Properties of the studied soil include: Soil with light sandy loam texture having 30%gravel and alkaline with low fertility. The whole performing plan area is 432 square meters.

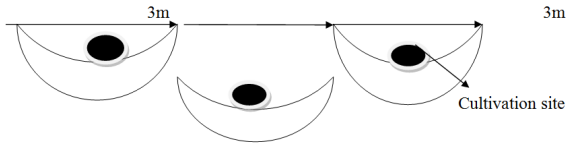

Fig. 1: the placement order of crescent systems:

Each arrow indicates a distance of 3 meters.The depth of each crescent is 20 to 40cm. Also, systems in which cultivationis not doneare constructed without hole.

Results:

Semicircular or crescent bandsare considered as the most important and practicalkind of small rain water catchment systems and micro- catchments.Given the steep slope i.e. slope between 40 to 60%, in the studied region,gutter- shape semicircular systems with drilling system in soil are used to obtain the best runoff and to

prevent breaking down of the systems due to runoff.In the following, a sample of the guttersystem implemented in the study regionhas been presented.

Harvesting rainwateras runoff in cold to relatively cold seasons, slope lands and the rapid movement of water due to hydraulic slopeand out of reach root, light texture containinggravel will cause rapidsinkof moisture from the profile of planting seedling, therefore, the special measures should be considered in this context.Riprap on the back of the system has been used to keep moisture in soil.To measure the rate of the obtained runoff in each system, the method of determining runoff elevation in system was obtainedfrom multiplying the system surface by the elevation using scale and estimating volume.Thus, after falling and at a given time, the rate of runoff resulted from falling was acquired in all repetitionsand treatments.To determine the runoff percentage obtained from falling, high surfaces of each system have been completely specified and by estimating therunoff rate obtained in each system and afterfalling, the runoff percentage has been calculated for each falling occurredand then the results were provided in related tables.There have been two other notes about themeasuring ofthe runoff resulted from falling in theregion.

Due to the lack of traffic in the regioneither as walking or driving or using a car,the first issue was the lack of measurementin three months of winter i.e. from January to Marchand the second issue was two cases of falling in the area as snowthatit is tried to use the runoff resulted from the snow stored in the system compared with the control group.

Figure 2- A sample of crescent systems with the mark created from runoff.

Figure 3- The crescent system with the storage and maintenance of snow compared with regions around that all snow has been melted and become out of reach.

In table 1- CDs, for atmospheric precipitations occurred in the region, the number, volume and percentage of the runoff resulted from falling from October 2011 to 2012 is presented. As it is observed, the maximal falling occurred in March and its minimal amountoccurred in August.

Table 1: the number, volume and percentage of the runoff resulted from falling.

Month	Runoff percentage	Falling volume mm	The number of falls
October	10	8	1
November	30	27	3
December	32	45	3
January	---	55	4
February	---	58	4
March	---	72	5
April	35	75	6
May	37	43	4
June	33	22	1
July	18	7	2
August	0	4	2
September	10	10	1
Year	22/8	426	36

Based on thepluviometer data installed in the region, the rate of whole falling was about 426 mm and 22.8% has been converted to runoff.In other words, 97 mm of the falling has been converted to runoff. In 2009,Roghani *et al* attempted to study various parametersaffecting the design of systems, the evaporationrate from the system surfaces and stored runoff amount in eight places of Iranand they concluded that using these systems, alarge amount of runoffcan be obtained. Other results include controlling flood on hillsides and increased moisture in soil.

3-1-Measuring the Soil Moisture and Data Analysis:

After each falling, soil moisture was measured using TDR calibration. The mentioned devicecan measure the amount of soil moisture from the saturation point at pressure rate of-25.In 2009, Ghodrati could raise soil moisturein level of dry cultivating olive usingrainwater catchment systems.

Experiment data is collected from four treatments of **(A_0‘A_1‘A_2‘A_3)** at seven times and in three replications using split-plot design in time, the effect of treatments and mutual relation between them is determined in the form of completely randomized design and randomized complete block design at different times.In this test, at theprobability level of 1%, both treatments and time have very significant differences. But an interactionhas not beenobserved between these two factors i.e. factors have been independently operated.The table of variance analysis of the testhas been shown in the following:

Table 2: grouping mean treatments.

Means with the same letter are not significantly different			
Duncan Grouping	**Mean**	**N**	**treat**
A	11.6381	21	3
B	9.0667	21	2
B	8.4810	21	1
C	4.7381	21	0

Table 3: Statistical Analysis Of Data.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treat	3	510.7114286	170.2371429	156.57	<.0001
treat*rep	6	4.2635714	0.7105952	0.65	0.6870
time	6	83.4095238	13.9015873	12.79	<.0001
time*treat	18	29.4285714	1.6349206	1.50	0.1458
time*rep	12	2.9519048	0.2459921	0.23	0.9958

Table 4: grouping different mean times.

Means with the same letter are not significantly different.				
Duncan Grouping		Mean	N	Time
	A	9.6500	12	3
	A	9.6000	12	4
	A	9.2417	12	2
	B	8.2917	12	5
	B	8.2333	12	1
C	B	7.5250	12	6
C		6.8250	12	7

The data in the table showsthat according to themoisture mean the maximal moisture was inMarch, April and December and all of them are in the same group and then, May and November; and the minimal mean was related to July.

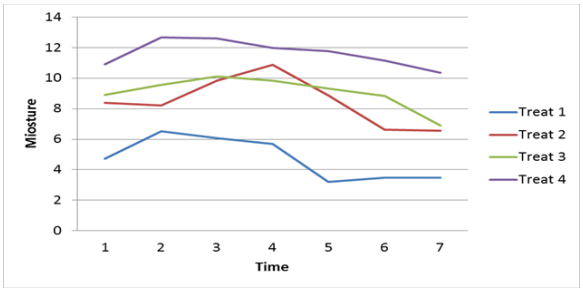

Fig. 4: Comparing moisture in various treatments at different times.

3-2- RUNOFF:

since the control was a region next to the performing plan andthe region also had a slope, no runoff was measured in the control region. However,after each falling, the runoff amount was measured on the other three treatments.As it was observed, there is a huge difference between the amounts of water in systemsandin other words, the constructedcatchment systems have earned the resulted runoff in the same amount.The statistical analysis of runoff data has been presentedin(table5).

Data related to the second test (runoff) includes 3 treatments (A1, A2, and A3) (Since there is no data in the control group,its analysis was ignored). This testwas also performed as the plotsplit in time, so that we can study the effect of its treatment, harvesting and interaction.

Table 5: Runoff Data Analysis Using Split-Plot In Time Design.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treat	2	2.1667	1.0833	0.15	0.8628
treat*rep	4	85.2778	21.3194	2.91	0.0318
time	11	275644.4444	25058.5859	3425.93	<.0001
time*treat	22	2687.3889	122.1540	16.70	<.0001
time*rep	22	219.8333	9.9924	1.37	0.1861

In the present test, no difference has been observed among three treatments. But the time effect has shown a highly significant difference and a severe interaction effectwas observed between these two factors. Themeanof traits desired at 12 times in the table indicates that there is difference among 12 groups.

The maximal meanhas been related to the time of 2011/4/8as much as 248mm andits minimal has been related to 2011/6/19as much as 100.778mm.

Table 6: Grouping Different Runoff Mean Times Related To Different Treatments Usingdunkan Method.

Means with the same letter are not significantly different.			
Duncan Grouping	Mean	N	Time
A	248.000	9	4
B	242.556	9	5
C	223.111	9	2
D	197.556	9	9
E	190.556	9	6
F	186.778	9	1
G	163.889	9	7
H	150.333	9	8
I	123.889	9	12
J	112.444	9	3
K	104.111	9	10
L	100.778	9	11

Data related to treatments obtained at different times in a completely randomized design were analyzed separately.No significant difference was observed between all mean times, that is, they were exactly grouped into 12 separate groups.

5-Discussion and Conclusion:

In addition to controlling the runoff resulted from falling and flood,using rainwater catchment systemscan also cause storing moisture in soil andcollect considerable amount of runoff in small systems or micro-catchments.According to the obtained results, the amount of soil moisture is about1.5-2 and 2.5 times comparing the control in treatment A1 (system), A2 (system with cultivation) and A3 (system with cultivation and Terra Cottem), respectively.And after the statistical analysis, using the statistical method of split plot, the moisture amount has indicated a very significant difference in treatments (Pr<0.0001)(Table 3). Also,the moisture amount showed a significant difference at(pr<0.0001) at various times so that the maximal and minimal amount ofmoisture mean has been in Marchat 9.65 and in Julyat 6.82, respectively.The meanamount of the runoff obtained among treatmentsdidn't showa significant difference (pr=0.8628). But in the test,the time effect has shown a very significant difference (pr<0.0001).So that the maximal mean of the obtained runoff was related to Marchat 248 mL and its minimal amount was inMayat 100.778and according to table 1, about 23% of

fallingshave converted to runoff (about 97 mm). The amount of obtained runoff is about 970 cubic meters of water for each hectare.In other words, if we have 400 systems with growing plants per hectare micro, 2328 liters of water can be provided for each micro- catchment or system and the plant in it; on the other hand, the runoff amount resulted from falling has completely been obtained and providing a proper principle and design,no flood will happen in the downstream of these lands.Normally,in the area 15 to 20 irrigation intervals are used to irrigateplanted saplings by tractor and worker, and thevolume of each irrigation interval is 20 to 30 liters for each plant. As a whole, during water year, between 300 to 600 liters of water is providedfor every planted sapling.So that only without considering any measures to increase runoff, about 2400 liters of the water is suppliedfor each plant; that is approximately 4 times the volume of maximal suppliedwaterwith highcosts.If the amount of the runoff resulted from falling can be maintained bythe possible specific arrangements, in addition to controlling runoff and flood, many plant species could be tried for cultivation without consideringirrigation costs.

Table 7: The Effect of Time on the Rate of Obtaining Runoff in Various Treatments.

time*treat Effect Sliced by time for runoff					
time	DF	Sum of Squares	Mean Square	F Value	Pr > F
1	2	206.888889	103.444444	14.14	<.0001
2	2	357.555556	178.777778	24.44	<.0001
3	2	106.888889	53.444444	7.31	0.0018
4	2	274.666667	137.333333	18.78	<.0001
5	2	43.555556	21.777778	2.98	0.0613
6	2	620.222222	310.111111	42.40	<.0001
7	2	346.888889	173.444444	23.71	<.0001
8	2	182.000000	91.000000	12.44	<.0001
9	2	193.555556	96.777778	13.23	<.0001
10	2	216.222222	108.111111	14.78	<.0001
11	2	0.888889	0.444444	0.06	0.9411
12	2	140.222222	70.111111	9.59	0.0004

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