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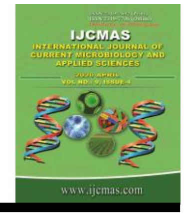

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Rain Water Balance of Finger Millet Cropping System in Alfisols of Bangalore Region, India

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A B S T R A C T

The study on rain water balance of micro catchments under fingermillet cropping system of *alfisols* was carried out at the AICRPDA, GKVK, UAS Bangalore to work out the rain water balance in response to different soil and water conservation measures with varied slopes *viz*., 1.9 %, 2.24 % and 2.1 %. The total rainfall and ET crop during the finger millet cropping period was 604 mm and 250.98 mm respectively. The lowest and the highest runoff were observed in T_1 and T_4 respectively. Also the highest deep percolation was observed in T_1. In general the study reveals a negative water balance for the finger millet crop during the year under study.

Introduction

Contour trench method of land development for soil and water conservation under dryland conditions was chosen in the semi-arid tropic of southern Karnataka. Contour trench fields were constructed manually for the finger millet cultivation. Contour trenches of any shape are the excavated depression across the land slope with the purpose of preventing soil erosion by trapping and absorbing sediments and runoff respectively. Contour trenches will help to collect runoff water and also breaks the continuous slope of the ground and it results in reducing the velocity of runoff water. The reduced velocity of runoff is resulted in better opportunity time for infiltration reflected through reduced runoff and percolate down into the soil profile.

Runoff, soil and nutrients losses are sever in sloppy areas, which can be controlled by putting the continuous contour trenches. In recent years, such contour trench method of land development is recommended to the formers in the Karnataka state .The cross section of the trenches can be of any size and shape like square, rectangle, trapezoidal or triangle. The choice of shape depends on the soil type and prevailing land slope. Square and rectangular shaped trenches are constructed in relatively flat land and minor undulating lands. Whereas in sloppy lands, trapezoidal or triangular trenches are constructed.

Very limited information is available about the rain water conservation in contour trenches under finger millet cropping system. In order to evaluate the contour trenches for rain water conservation in the sloppy areas, investigation was carried out during the year 2019-2020 at the All India Coordinated Research Project on Dry Land Agriculture, UAS, GKVK, Bengaluru with finger millet as a test crop.

The finger millet is the staple food crop in the southern part of the Karnataka state which is cultivated in more than 0.8 million hectares. The study of rain water balance will help in understanding the treatment effect in relation to water balance during the cropping period.

Materials and Methods

Experimental site

The present study was conducted at the All India Coordinated Research Project on Dry Land Agriculture, UAS, GKVK, Bengaluru. Geographically it is located at 12°58' North latitude and 77^0 35' East longitudes with an altitude of 924 meters above MSL. The experimental site comes under Eastern Dry Zone of Karnataka.

The experimental site predominantly consists of sandy loam soil. The annual rainfall of the region is 918.1 mm and more than 70 per cent of the rain received during the *Kharif* season (Manson).

Treatment details

Runoff from the three runoff plots viz; T_1, T_2 and T3was collected in the individual cisterns having the capacity/volume of 9.2 m^2.As part of treatments, the T_1 and T_2 runoff plots are constructed with the trapezoidal shape trench having the cross sectional area of 0.09 m^2across the slope for a distance of 4 m plot width. The T_1 is constructed with the trench at 10 m interval.

There are two trenches constructed in this treatment having the total storage capacity of 73.6 m^3. The T_2 is constructed with the trapezoidal shape trench at 25 m interval. The T_2 is having single trench with the total runoff storage capacity of 36.8 m^3. Hence the runoff in excess of the trench storage capacity can only be collected in the cistern. The T_3 is not having any treatment measures and all the runoff is made to collect in the cistern. The three runoff plots for the treatment $T_{1,}$ T_2 and $T_3$are having an area of 204 m^2.

In addition $T_4$and T_5 are also the two runoff plots having the individual plot with an area of 1184 m^2. $T_4$and$T_5$are constructed with multislot divisors for the collection of runoff. The multi slot divisors are having 15 slots and runoff from one slot is made to pass into the collection cistern.

Therefore the total runoff can be worked out by multiplying with 15 for the quantity of runoff collected in the respective plot cisterns. Further the treatment details is as fallows,

1. T_1 -Trenches at 10 m interval at slope 1.7%
2. T_2 - Trenches at 25 m interval at slope 1.93 %
3. T_3- Field conditions at slope 1.9%
4. T_4 - Field condition at slope 2.24%
5. T_5- Field condition at slope 2.1%

Hydrological data

To estimate the water balance of the runoff plots, the data on rainfall, runoff, soil moisture, deep percolation and evapotranspiration losses were worked out by following the Mc Gowan and Williams (1980) equation. Rainfall was recorded by an automatic siphon type rain gauge, which is installed at the weather station located adjacent to the experimental plots. Also the data on atmospheric relative humidity, wind speed and pan evaporation (A standard United States Weather Bureau Class A pan) were recorded from the observatory. Penman method was adopted for estimating the reference crop evapotranspiration (Allen *et al.*, 1998.). The details of penman method of estimation of actual evapotranspiration is detailed further as;

$$Et_o = \frac{0.408\Delta(R_n - G) + y\left(\frac{900}{T+273}\right)u_2\,(e_s - e_a)}{\Delta + y\,(1 + 0.34u_2)}$$

Where,
Rn is the net radiation
G the soil heat flux density
T the air temperature
u_2 wind speed
e_s vapour pressure of the air at saturation
e_a actual vapour pressure
y is the psychrometric constant

Bi Weekly per cent soil moisture was worked out gravimetrically on oven dry basis for the soil depth of 15 cm, 30 cm and 45 cm. The percent soil moisture was converted to depth of water in mm by following the procedure adopted by Sing *et al.*, (1960). Since the water balance study was carried out on monthly basis, soil moisture in the beginning and at the end of the month was considered to estimate the soil moisture held in the soil. Soil moisture was monitored up to the depth of 45 cm since the test crop is finger millet being shallow rooted.

Rain water balance

The hydrologic water balance equation used for this study was the one used by Mc Gowan and Williams (1980). The equation is explained further,

$$P = R + E + \delta S + U$$

Where,

P = precipitation over the catchment
R = Runoff from the catchment
E =Evapotranspiration losses
δS = Change in soil moisture storage
U = Deep percolation
All the parameters are expressed in mm.

Results and Discussion

Rainfall

Intensity and duration of rainfall is one of the major inputs to produce runoff. The normal rainfall of the region is 918.1 mm. During the year, the total rainfall received was 918.1. Monthly rainfall of 173.4, 186.6, 234 and 10 mm recorded for the month of August, September, October and November respectively. In general there are 8, 6 and 5 runoff causing rainfall events recorded for the month of October, September and August respectively

Reference crop evapotranspiration (ET crop)

The reference crop evapotranspiration for finger millet crop is common for all the treatments and it is accounted as 250.92 mm (Table 2). ET crop worked out to be showing increase trend up to crop grand growth period and declines as it approaches maturity period. ET crop was maximum during the eared development stage (66 to 88th days after sowing).

Runoff

Intensity and duration of rainfall is one of the major inputs to induce runoff. During the experimental period, the treatment T_1 resulted in lowest runoff (151.09 mm) from among the treatment. This may be due to the treatment effect of closer trenches at10m interval which is resulted in breaking of the continuous slopes reducing the runoff and conserving the rain water in the field itself. The $T_1$is having the trench with the total capacity of 73.6 m^3.

In contrast the highest runoff was observed in T_4 (230.42mm) having the highest field slope of 2.40 %. The reason for higher amount of runoff may be attributed to the higher slopes. Similar trend was also observed in other treatments. The treatment T_2 is having the trenches at 25m interval with the total trench volume of 36.8 m^3 and the treatment T_3 has no treatment measures.

Though the T_2 is having higher land slope of 1.93% than T_3 with 1.90 %, the runoff collected was lower. This is mainly due to the treatment effect of trench provided at 25 m interval having the trench capacity 36.80m^3. Therefore the reduced trend of the runoff was in the order of $T_1<T_2<T_3<T_5<T_4$. The Findings are in conformity with the observation of Asokha *et al.*, (1995.) They reported that the higher slopes results in an increased runoff. The results are presented in the table 1.

Micro catchment water balance

Monthly water balance accounted in the different treatments reveals that there was direct correlation between runoff and slope. The higher runoff was observed with an increased slope (Table 3). The runoff was maximum in the treatment T_4having 2.24 percent slope and it was minimum in the $T_1$with 1.7 percent slopes. The results are in conformity with the findings of Asokha *et al.*, (1995) and Rama Sastri (1975).

Further the higher deep percolation generally observed in all the treatments during the October 2019. Generally the observation of runoff and deep percolation exhibited the inverse relationship. The treatments observed the higher amount of runoff resulted in lower amount of deep percolation. The highest deep percolation of 107.75 mm was observed during October 2019 for the T_1 which is having slope of 1.7 % slope. The lowest deep percolation of 2.95 mm was observed during September 2019 for T_4 having the highest slope of 2.24 %.

Seasonal water balance during the finger millet cropping period for the treatments T_1, T_2, T_3, T_4 and T_5were worked out for the total rainfall of 604 mm (Table 4). The total seasonal water balance for different component accounted as 662.59 mm in T_1 (R, E, δS and U) against the seasonal rainfall of 604 mm. This implies a negative water balance of 58.45 mm.

There is a need for better rain water management from the point of crop growth and productivity. The treatment T_1 with trenches at 10 m interval targeted to harvest the rainwater of 73.6 m^3. Also the T_2 has got the trenching at 25 m interval with 36.8 m^3water harvesting capacity.

Therefore the total water balance among the five different treatments during the cropping period better reflected for T_1 followed by T_2. The treatments T_3, $T_4$and T_5 do not have the conservation measures reflected in lower deep percolation. Also the treatments T_3, $T_5$and T_4 are having higher slopes from each other and the seasonal rain water balance reflected accordingly.

Table.1 Rainfall and runoff under different treatments for finger millet cropping system at the GKVK campus during 2019

Date	Rainfall (mm)	T_1	T_2	T_3	T_4	T_5
15-08-2019	24.6	9.92	10.82	11.72	13.30	12.32
18-08-2019	14.2	1.80	2.25	4.50	6.96	5.3571
19-08-2019	23.4	4.50	4.96	6.31	10.07	10.71
20-08-2019	35.4	12.17	12.62	14.43	15.58	14.12
21-08-2019	14.8	4.50	2.70	4.50	5.85	5.15
30-08-2019	24	10.82	12.62	10.82	12.56	11.02
19-09-2019	71.2	43.29	43.74	44.64	47.05	46.86
23-09-2019	28.4	8.11	5.41	12.17	15.09	14.81
24-09-2019	26.4	1.8	3.60	4.50	5.88	5.32
25-09-2019	20.4	4.5	4.96	6.31	9.86	8.736
26-09-2019	7.6	0	0	2.70	3.8	3.34
02-10-2019	26.2	2.25	2.70	3.60	6.08	5.82
03-10-2019	12.4	1.35	1.35	2.25	3.12	2.97
04-10-2019	17.2	2.7	2.70	4.50	6.66	5.85
05-10-2019	16.6	1.8	3.15	4.50	5.79	5.07
09-10-2019	35.2	12.17	12.62	14.43	16.03	15.35
10-10-2019	28.8	18.03	18.94	24.35	26.15	25.84
22-10-2019	33.4	5.41	5.86	8.11	10.78	10.12
28-10-2019	33.2	5.86	4.96	7.21	9.81	9.07
Total	493.4	150.98	156.03	191.66	230.432	217.83

Table.2 Estimated actual evapotranspiration for the finger millet crop during 2019

Period	ET Crop (mm)	No. of days	crop duration (days)
01-08-19 to 11-08-19	11.98	11	11
12-08-19 to 22-08-19	12.99	11	22
23-08-19 to 02-09-19	15.38	11	33
03-09-19 to 13-09-19	19.97	11	44
14-09-19 to 24-09-19	27.78	11	55
25-09-19 to 05-10-19	32.07	11	66
06-10-19 to 16-10-19	33.18	11	77
17-10-19 to 27-10-19	31.24	11	88
28-10-19 to 07-11-19	27.25	11	99
08-11-19 to 18-11-19	20.09	11	110
08-11-19 to 18-11-19	20.09	11	110
19-11-19 to 29-11-19	16.07	11	122
30-11-19 to 31-11-19	2.92	2	124
Total	**250.92**	**124**	**124**

Table.3 Monthly Rain water balance under finger millet crop at the GKVK campus during 2019

Treatments	Months mm	Rainfall mm	Runoff Mm	Evapo-traspiration (ET) Mm	Change in soil moisture storage (δS) Mm	Deep percolation (U) mm
T_1	August	173.4	43.75	37.36	49.12	43.17
	September	186.6	57.73	68.39	43.81	16.68
	October	234	49.61	89.62	-12.98	107.75
	November	10	0.00	55.62	8.21	-
T_2	August	173.4	46	37.36	46.46	43.57
	September	186.6	57.72	68.38	41.15	19.33
	October	234	52.31	89.61	-15.66	107.73
	November	10	0	55.61	6.90	-
T_3	August	173.4	52.31	37.36	35.90	47.81
	September	186.6	70.35	68.38	40.04	7.811
	October	234	69	89.61	-19.02	94.41
	November	10	0	55.61	7.01	-
T_4	August	173.4	64.32	37.36	31.37	40.34
	September	186.6	81.68	68.38	33.56	2.95
	October	234	84.42	89.61	-21.24	81.20
	November	10	0	55.61	5.51	-
T_5	August	173.4	58.68	37.36	33.12	44.23
	September	186.6	79.06	68.38	35.84	3.30
	October	234	80.89	89.61	-20.24	83.73
	November	10	0	55.61	6.85	-

Table.4 Seasonal rain water balance under finger millet crop at GKVK campus during 2019

Treatments	Total seasonal Rainfall (mm)	Runoff (mm)	Evapotranspiration (ET) (mm)	Change in soil moisture storage (S) (mm)	Deep percolation (mm)
T_1	604	151.07	250.98	92.95	170.64
T_2		156.03	250.98	87.61	167.6
T_3		191.66	250.98	75.95	150.03
T_4		230.43	250.98	64.93	124.5
T_5		218.63	250.98	68.96	131.27

The highest runoff with lowest deep percolation was observed in $T_4$and the lowest runoff of $T_1$is attributed to be treatments with trenches at 10 m intervals. The highest runoff observed in $T_4$is attributed to the runoff plots having no conservation measures.

The intensity and duration of rainfall had much influence on the runoff. The trenches at 10 m closer interval helped to retain the moisture in the field reducing the runoff, whereas with the same amount of rainfall, higher runoff was observed for the T_4 plot having the slope of 2.4 percent. On the contrary lower amount of rainfall with very low intensity had not produced runoff in lower slopes plots.

Also the control measures play an important role in reducing runoff and helps in deep percolation. Accordingly, treatment T_1 is having trenches at 10 m interval resulted in more conservation of rain water which helps in increased deep percolation. The treatments $T_{3,}$ T_4 and T_5 did not have any conservation measures and resulted in higher runoff.

Monthly water balance of treatments with different slope indicated that there was lower runoff reflected through highest deep percolation observed in $T_1$with 1.7 % slope. The treatments $T_{1,}$ $T_2$and T_3having the landslope of 1.7, 1.93 and 1.90 % respectively yielded the lower quantity of runoff compare to $T_4$and $T_{5.}$

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