



International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 6 Number 11 (November-2018)

Journal homepage: <http://www.ijcrar.com>



doi: <https://doi.org/10.20546/ijcrar.2018.611.005>

Impact of Land Configurations on Runoff and Soil Loss under Rainfed Conditions

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Abstract

Rainfed agriculture to great extent depends on water saving technologies. Efficient rainwater management is crucial to rainfed agriculture. Soil and water conservation measures are basic resources essential for survival of human kind on earth. In fact every kind of farm activity is connected with land and prosperity of nation depends on quality of its and resources. Water is most limiting natural resources in semi-arid region. In most of the areas only water available is rain water. Due to inadequate and uneven distribution of rainfall during growth span of crop, it becomes essential to supply water to plant by adopting *In situ* soil conservation measures for increasing water use efficiency. In order to study the *in situ* soil and water conservation measures for cotton and the impact of soil and water conservation measures in terms of increase in soil moisture content, biometric observations, moisture use and production efficiency, reduction in runoff, soil and nutrient losses, three land configurations were studied for soil-water management, viz Cultivation along the slope with opening of tide furrow (T₁), Contour cultivation with opening of alternate furrow (T₂) and Contour cultivation with opening of ridges and furrows (T₃). The present investigation revealed that the treatment T₃ was more prominent and favourably influenced the crop growth, soil moisture, moisture use and production efficiency, cost benefit ratio due to the drastic change in the runoff hydrograph characteristics and reduction in runoff, soil loss and nutrient losses, followed by treatment T₂ over the treatment T₁. In the context of above results, it is concluded that the *In situ* soil and water conservation measures is the need of day in rainfed agriculture for the management of erratic and vagarious rainfall under the changing climatic conditions. To study the rainfall characteristics like duration, intensity classification, frequency distribution of rainy days, kinetic energy of rainstorms and erosion index, it revealed that out of 47 rainy days, 41 rainy days were commenced with rainfall intensity <25 mmhr⁻¹ and 6 rainy days were commenced with 25-50 mmhr⁻¹ rainfall intensity.

Article Info

Accepted: 18 October 2018
Available Online: 20 November 2018

Keywords

Land configurations,
Runoff and soil loss,
Rainfed conditions.

Introduction

Rainfed agriculture is the livelihood vocation of the marginal or subsistence farmers and increasingly seen as better alternative to irrigated agriculture as a result of its environmental friendliness and sustainability over long period. Improving productivity and stability of production of rainfed areas will be crucial in meeting the

needs of the increasing population. India ranks first among the dryland agricultural countries in terms of both extent and value of produce. Out of every three hectares of cultivated land in India, nearly two hectares are under rainfed agriculture. Out of about 143 million hectares (Mha) of cultivated area in India, dryland accounts for 91.0Mha (64%) and in the foreseeable future also nearly 60% of our population will continue to depend on rainfed

agriculture. Rainfed areas are not a homogenous region and vary in terms of soil type, rainfall, cropping pattern, literacy, land and labour productivity. Therefore rainfed areas are highly diverse, ranging from resource-rich areas with good agricultural potential to resource-poor areas with a much restricted potential. Some resource-rich rainfed areas potentially are highly productive and have experience of adoption of improved technologies. The temperature requirement of cotton varies from 15°C to 43°C depending up to stage of the crop. The early variety AKA-7 (Year of release - 1998) is improved G. arboretum L. variety having white flower, good boll opening, no shedding, leaf with 5 bulging narrow lobes without accessories and it takes 140–150 days to mature as against 210 days in late varieties with comparatively less incidence of pink bollworm. This variety was adopted in shallow soil in my research work at spacing 60 × 15cm. India is marked by three distinct cotton growing regions for three major varieties of cotton.

Objectives

1. To Determine Impact of various land configurations on runoff and soil loss.
2. To study the rainfall characteristics like duration, intensity classification, frequency-distribution of rainy day, kinetic energy of rain storm and erosion index.

This chapter illustrates the materials utilized and the methodology adopted in conducting the research project entitled “Impact of land configurations on runoff, soil loss and productivity of cotton under rainfed conditions”. This experiment was conducted during the Kharif season 2012-13 at Model Watershed of Agro-ecology and Environment Centre (AEEC), Dr. P D K V, Akola.

Morphological study of watershed

Location of Watershed

The agriculture watershed of Agro-ecology and Environment Centre is located at Central Research Station of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Akola is located at an altitude of 307.4m above mean sea level. Watershed map is shown in (Plate3.1). The slope of watershed approximately 5%, average slope is 1.6%. Soil type contributing to the field is clay, sandy, sandy loam, pasture land. The various types of crops are taken in field like custard apple, lemon orchard, mango, jajube, some other plantations are also found. The total area consists of 8 Farm Ponds. The entire area of the Agro ecology and Environment Centre

farm was treated with various land treatments and utilized under plantation of MPTS, Agro-horticulture, Silviculture systems and experimental monitoring plots.

Climate

Agro-ecologically the watershed area lies in sub region (Eastern Maharashtra Plateau, hot, moist, semi-arid with shallow soils, low to medium available water holding capacity). The climate is semi dried monsoonic characterized by three distinct seasons viz, summer with hot and dry weather from March to May; monsoon, warm and rain from June to October and winter, dry mild from November to February. The mean monthly temperature of Akola is 20.5°C to 30.5°C with recorded minimum and maximum temperature of 12°C to 45°C, in the month of December and May respectively. Akola district falls in assured rainfall zone of Maharashtra having an average annual rainfall of 750mm. (Anonymous, 2013). Total watershed area was about 32.5 hectare having average slope 1.6%, two sub watersheds and six micro watersheds. The slope of most of the fields ranges from 0.5 to 2.5%. The soil analysis details of the experimental plots are given in respective experiments. The average height of the model watershed is about 14 to 15m.

Rainfall characteristics

Recording type rain gauge was installed in the observatory located at the Agro-ecology and Environment Centre and data pertaining to rainfall and rainfall intensity classification on the basis of depth of rainfall for the year 2012-2013. South West monsoon had commenced in this area from 22 meteorological weeks, which were useful for seed bed preparation, however the adequate rains received in 28 meteorological weeks were useful for sowing. The rainfall during the season was about 656.8mm with 47 Rainy days (<25 mmday⁻¹), mainly during the month of June, July, August, and September. Out of total rainfall 656.8 mm (i.e.100 %) rainfall was received during the month of June to September.

Rainfall Erosive Index(R)

The rainfall erosive factor(R) in the universal soil loss equation is the number of rainfall erosion index unit EI₃₀ for a particular location.

The method suggested by Wischmeir (1959) was used for estimating the erosion index values of each storm. The EI₃₀ is expressed as,

$$EI_{30} = \frac{\{K.E. \times I_{30}\}}{100}$$

Where,

EI_{30} = Erosion index

K.E. = kinetic energy of storm $mtha^{-1}cm^{-1}$

I_{30} = maximum 30 min rainfall intensity of the storm $cmhr^{-1}$

For computing the Kinetic Energy for the storm, the equation proposed by Weishmeir (1969) in metric unit was used

$$K.E. = 210.3 + 89 \log_{10} I$$

Where,

K.E. = Kinetic energy $mtha^{-1}cm^{-1}$

I = Rainfall intensity in $cmhr^{-1}$

Maximum rainfall (P) and Storm intensity (I)

Month wise daily rainfall was recorded with recording type rain gauges which were installed in the observatory located at the Agro-ecology and Environment centre (AEEC). Maximum precipitation (P) for particular time period, such as 5,10,15,30 and 60 minutes for each rainfall event was observed and noted as P_5 , P_{10} , P_{15} , P_{30} and P_{60} in terms of cm.

Storm intensity (I) $cmhr^{-1}$ was determined for particular date of each rainfall event for particular month and time period such as 5,10,15,30 and 60 minutes (Anonymous, 2013).

Experimental details

Location	:	AEEC, Dr.P.D.K.V. Akola
Crop	:	Cotton (<i>Gossypiumarborium</i>)
Variety	:	AKA-7
Land slope	:	Main-1.6 percent Lateral-0.7 percent
Soil type	:	Shallow soil (20cm-depth)
Monitoring device	:	'H' flume with SLR(Daily type)
i)Date of Sowing	:	03 July,2012
ii) Date of harvesting	:	1 st picking 6 th November 2012 2 nd picking 30 th November 2012
iii)Duration	:	151 (days)

Details about the treatment T_1 , T_2 and T_3 were shown in following Table 1.

Collection and analysis of data required for study

In situ recharge of rain water

In situ recharge of rain water which calls for land treatment in such a fashion that the maximum rain water gets infiltrate in the soil profile and it becomes available to the crop during prolonged monsoon break. This requires efforts of every farmer to go for contour and cultivation across the slope by opening of furrows in alternate or in every crop row.

Rainfall

The daily rainfall for the year 2012-2013 (Shown in Appendix A) was recorded at the Model Watershed of Agro-ecology and Environment Center C. R. S., Dr. P. D. K. V., Akola with the help of automatic recording type rain gauge.

Runoff

The runoff from each plot concentrated at the outlet of runoff plot was measured by H-flume of 0.30m depth installed as a runoff measuring device. The float type automatic stage level recorder was installed at the outlet of each gauging site (shown in plate 3.9).

The runoff chart obtained from Stage Level Recorder gives a continuous record of depth of flow over the flume with respect to time. This stage graph will subsequently process to obtain the runoff rates and Peak rate of runoff volumes which will later use for further analysis.

Installation of Stage Level Recorders

A stage level recorder converts mechanically the vertical movement of a counter weighted float resting on the surface of a liquid into a curvilinear, inked record of the height of the surface of the liquid relative to a datum plane and with respect to time. The time element of this recorder consists of a daily-winding-spring-driven clock supported on a horizontal shaft to which the chart drum is firmly secured horizontally.

The gauge element consists of a float and counter weight graduated float pulley. The movement of the float is transmitted to a cam and with the help of a set of gears; it moves the pen on the chart in the horizontal direction. Installed stage level recorder depicted in Plate 3.9.

Marking and tabulation

The process consist of marking of all the breaks on the hydrograph where the slope changes. The rate of change of flow between two adjacent marks is assumed to be uniform and consequently that segment of the hydrograph is considered to be straight. The number of points will depend on the fluctuations of stages.

The following steps were done for marking and tabulating the runoff charts.

The information on the top of sheet was completed.

1. Marking on hydrograph was provided whenever slope changes
2. The time was noted at each of the points where marking was provided on the stage hydrograph.
3. The corresponding stage of flow was recorded and procedure was repeated till all the points have been tabulated.

Computation of runoff

The information collected was to be further process to get the total runoff volume. The computation was done by following way

1. Time interval obtained by differences in the successive values of the time which were noted from hydrograph.
2. Gauge height should have to convert into discharge rates in $m^3 \text{ sec}^{-1} \times 10^{-3}$ (lps) with the help of appropriate rating table for 0.30m H-flume.
3. The average discharge rates in lps for time interval were obtained by averaging successive discharge rate recorded from rating table of flume.

The average discharge is given by,

$$Q = \frac{q_1 + q_2}{2}$$

Where,

q_1 = initial discharge in, lps

q_2 = discharge after interval of t sec, lps

Q = average discharge, lps

4. The runoff volumes in litter for the time interval will obtained by relationship = Average discharge for the time interval (lps) \times Time interval (min) \times 60

5. Cumulative values of runoff will obtained by adding the runoff values for different time intervals.

6. The runoff depth (mm), peak runoff rate $m^3 \text{ sec}^{-1} \text{ ha}^{-1}$ and percentage surface runoff will obtain as follows.

a) Runoff depth:

Usually runoff is expressed in terms of depth over the producing area. To obtain the depth of runoff; volume of runoff will be divided by area over which it would produced.

b) Peak Runoff rate:

The Peak Runoff rate will obtained by observing the maximum values of runoff rate recorded and will further divided by total area of watershed, to get the peak runoff rate in lps/ha

c) Percentage surface runoff:

By observing the values of rainfall and runoff; runoff occurred as a percentage of rainfall will computed.

$$\text{Percentage surface runoff} = \frac{\text{runoff}}{\text{rainfall}} \times 100$$

Stage hydrograph analysis

Stage hydrograph is graphical representation of instantaneous discharge of field plots plotted with time. After the storm commences, the initial losses like interception and infiltration are met and then the surface flow begins. The stage hydrograph gradually rises and reaches its peak value after a time measured. Thereafter it declines and there was a change of slope at inflection point, i.e. there was inflow of the rains up to this point. By this time the ground water tables were built up by the infiltrating and percolating water, and now the ground water contributes more into the stream flow than the beginning of storm, but thereafter ground water declines and the stage hydrograph again goes on depleting in the curve. If a second storm occurs now, again the stage hydrograph starts rising till it reaches the new peak and then falls and the ground water recession begins (Raghunath, 1999).

The intensity of rainfall is inversely proportional to its duration of occurrence and directly proportional to return period. The relationship between rainfall and peak runoff was represented by many empirical formulae. The rational formula (Frevert *et al.*, 1955), which is one of the representatives of such formulae, is in use for estimating runoff to be expected from small drainage areas. The rational formula requires rainfall intensity for duration equal to the time of concentration and for particular recurrence interval. A specimen example for

computation of runoff from stage level chart is presented in Appendix B.

Estimation of soil loss

The soil samples from the runoff were collected during the season. The soil loss estimation from the runoff was made by adopting the following procedure:

1. After each storm the runoff samples were collected manually.
2. Stirred 100ml of runoff water each from individual sample were taken into aluminum box.
3. The weight of dry soil from 100ml runoff water was determined by weighing.
4. The soil loss in total runoff volume was expressed in tha^{-1} . A specimen example for determination of soil loss from runoff sample is presented in Appendix D

Determination of soil moisture

One of the important objectives of present investigation is to analyze treatment wise soil moisture enhancement in experimental field. Observations were taken with minimum 3 to 4 samples at various depths such as 15cm, 30cm, 45cm and 60cm depth at different growing stages of Cotton after 30 days interval from the date of sowing. The percentage moisture will be calculated on oven dry basis. The percentage moisture observed by using formula, (A. M. Michael, 2008)

$$\text{Moisture content(\%)} = \frac{W_1 - W_2}{W_2} \times 100$$

Where,

W_1 = Weight of wet sample (gm)

W_2 = Weight of dry sample (gm)

(a) Stage hydrograph

Runoff hydrograph was obtained from stage hydrograph by converting the ordinates of stage hydrograph i.e. discharge (cm) into the discharge rate (m^3/sec) by using rating tables of 0.30m H-flume (shown in Appendix C)

Rainfall and season

Recording type rain gauge was installed in the observatory located at the Agro-ecology and Environment Centre and data pertaining to rainfall on the basis of depth of rainfall for the year 2012-2013 (as

shown in Appendix A) and frequency distribution of rainy days were incorporated in Table 2.

The data in Table 2 revealed that out of 47 days of rainfall, 41 rainy days were commenced with rainfall $< 25\text{mmhr}^{-1}$ rainfall intensity and 6 rainy days were commenced with rainfall $25\text{--}50\text{mmhr}^{-1}$ rainfall intensity.

Rainfall Erosive Index (R)

Maximum rainfall (P) was determined by analysis of rainfall charts obtained from recording type rain gauges installed at the Agro-ecology and Environment Centre (AEEC). Likewise P and I were determined for each rainfall event occurred in particular month. Rainfall intensity was calculated (shown in Appendix J) and incorporated in table 3(a). Earlier this rainfall intensity was used for determining erosion index (E_i).

Table 3(a) revealed that the rainfall intensity for 5 minute duration is maximum i.e. 6.0 cmhr^{-1} in a month of June. It was noticed that rainfall intensity for 60 minute duration is lower i.e. 0.2cmhr^{-1} .

Daily rainfall and rainfall intensity

Rainfall intensity for the duration of 8hr 38min and 16.7mm of total rainfall was received with $10\text{--}20\text{mmhr}^{-1}$ rainfall intensity for the duration of 55 min. Likewise 8.5mm for 20 min under $20\text{--}30\text{mmh}^{-1}$ rainfall intensity, 8.9mm for 15min under $40\text{--}50\text{mmh}^{-1}$ rainfall intensity, 4.5mm for 5 min under $50\text{--}60\text{mmh}^{-1}$ rainfall intensity in month of June 2012(Shown in Appendix J).

Data in Table 3(b) revealed that the rainfall erosive index (EI_5) for 5 minute duration is maximum during the month of July (671.86) and minimum for month of June (110.3). The rainfall erosive index EI_{10} maximum (i.e. 503.90) for the month of July while minimum (i.e. 73.43) for the month of August. Similarly erosion index for 15, 30 and 60 minutes i.e. EI_{15} , EI_{30} and EI_{60} are maximum in month of July while minimum in month of August.

Runoff

Data in table 4(a) revealed that there were more reduction in runoff (97.06 per cent) in treatment T_3 over treatment T_1 followed by treatment T_2 (86.67%). Maximum runoff losses were found in control plot t (T_1), along the slope cultivation with opening of tied ridges

and treatment T₃ was more effective in reducing runoff losses. It has least runoff about 0.90mm.

The observations of surface runoff for different runoff producing storms were recorded and presented in table 4(a).

Table.1 Treatment details

Sr.No.	Treatment	Description of treatment	Size(m x m)	Area(ha)
1	T ₁	Along the slope cultivation with opening of tied furrow	129.37 × 30.92	0.40
2	T ₂	Contour cultivation with opening of alternate furrows	126.90 × 28.00	0.35
3	T ₃	Contour cultivation with opening of ridges and furrow	124.49 × 28.00	0.34

Table.2 Frequency distribution of rainy days during the year 2012-13 (Anonymous, 2013)

Month	Rainfall (mm)	Daily rainfall(mm)					Rainy days
		<25	25-50	50-75	75-100	>100	
Jun	95.9	5	1	-	-	-	6
July	283.2	13	4	-	-	-	17
August	108.1	13	-	-	-	-	13
September	138.1	09	1	-	-	-	10
Seasonal total	625.3	41	6				47
October	31.5	02					02
January	29.4	02					02
February	2.5	01					01
Total		46					52

Table.3(a) Maximum rainfall (mm) and rainfall intensity (cmhr⁻¹) for the selected time duration, June 2012. (Anonymous, 2013)

Date	Total rainfall, (mm)	5 minute		10 minute		15 minute		30 minute		60 minute	
		P ₅	I ₅	P ₁₀	I ₁₀	P ₁₅	I ₁₅	P ₃₀	I ₃₀	P ₆₀	I ₆₀
11/6/2012	3.1	1.5	1.8	2.0	1.2	2.0	0.8	2.5	0.5	2.7	0.27
16/6/2012	10.9	3.2	3.84	3.5	2.1	5.5	2.2	8.0	1.6	8.0	0.8
17/6/2012	4.0	1.0	1.2	1.0	0.6	1.5	0.6	1.5	0.3	2.0	0.2
18/6/2012	44.5	4.5	5.4	4.5	2.7	5.0	2.0	7.5	1.5	11.0	1.1
19/6/2012	17.2	2.0	2.4	3.0	1.8	4.5	1.8	5.0	1.0	5.5	0.55
30/6/2012	16.2	5.0	6.0	7.0	4.2	8.0	3.2	12.0	2.4	13.5	1.35
	95.9										

Table.3(b) Month wise erosion index (EI) of rainfall for selected time duration during the year 2012-13
(Anonymous, 2013)

Month	Rainfall Mm	Total KE (metric unit)	EI ₅	EI ₁₀	EI ₁₅	EI ₃₀	EI ₆₀
June	95.9	1038.88	110.3	77.21	58.82	44.12	24.81
July	276.2	5598.89	671.86	503.90	425.51	246.31	139.97
August	105.9	2039.53	146.87	73.43	53.03	36.71	20.39
Sept	134.9	2819.59	338.35	372.18	183.55	130.52	77.50
Grant total	612.9	12296.39	1267.38	1026.72	721.91	457.66	262.67
Octo.	31.5	755.64	51.0	36.72	30.22	19.94	9.97
Jan	29.8	792.65	40.18	47.55	31.70	22.82	10.31
Total		13844.68					

Table.4(a) Effect of land configurations on surface runoff (mm)

Date	Rainfall causing runoff(mm)	Runoff (mm)		
		T ₁	T ₂	T ₃
02/07/2012	29.60	18.96	4.09	0.90
07/07/2012	38.50	0.38		
04/09/2012	45.40	11.36	-	-
Total	113.5	30.70	4.09	0.90
Reduction over T ₁	-	-	86.67	97.06

Table.4(b) Effect of land configurations on surface runoff (%)

Date	Rainfall causing runoff(mm)	Runoff (%)		
		T ₁	T ₂	T ₃
02/07/2012	29.60	64.05	13.81	3.04
07/07/2012	38.50	0.98	-	-
04/09/2012	45.40	25.02	-	-
Total	113.5	90.05	13.81	3.04
Reduction over T ₁	-	-	84.24	97.12

Table.5 Effect of land configurations on soil loss (tha⁻¹)

Date	Rainfall causing runoff(mm)	Soil loss (tha ⁻¹)		
		T ₁	T ₂	T ₃
02/07/2012	29.60	13.03	2.4	0.54
07/07/2012	38.50	0.18	-	
04/09/2012	45.40	12.78	-	
Total	113.5	25.99	2.4	0.54
Reduction over T ₁	-	-	90.76	97.91

Plate.3.9 H-flume and stage level recorder for measuring runoff and soil loss



During the Kharif season of 2012-13 the total rainfall was 656.8mm and rainfall causing runoff was 113.5mm. During this season three runoff events were recorded in the plot having cultivation in tied ridges (T_1), one runoff event occurred in the treatment plot having contour cultivation with opening of alternate furrows (T_2) and plot having contour cultivation with opening of ridges and furrows (T_3).

From the table 4(a) it was clear that the maximum total surface runoff in the season was 30.70mm in treatment (T_1), while minimum was 0.90mm occurred in treatment T_3 and in month of September there was no runoff due to low rainfall.

It was also clear that in all the storms Contour cultivation with opening of ridges and furrows recorded least runoff followed by contour cultivation with opening of alternate furrows. Thus there was a decreasing trend of surface runoff from treatment T_1 to T_3 . In treatment T_2 there was 84.24 per cent reduction in surface runoff over T_1 , while 97.12 per cent reduction was achieved in treatment T_3 over the treatment T_1 [Table 4(b)].

Soil loss

Soil loss was estimated by frequent sampling during runoff events. Soil loss computed for different treatments are presented in table 5.

From table 5 it was seen that soil loss estimated in treatment T_1 i.e. cultivation in tied ridges was maximum (25.9tha^{-1}), where as in treatment T_2 i.e. contour cultivation with opening of alternate furrows it was minimum (2.4tha^{-1}) as compared to treatment T_1 . On the same day under treatment T_3 i.e. Contour cultivation with opening of ridges and furrows recorded least soil loss as there was minimum runoff as compared to both above

treatment. This was the effect of land configurations. It was observed that in all the storms the soil loss recorded in the treatment T_3 was minimum followed by treatment T_2 and treatment T_1 . A prominent reduction in soil loss was due to the fact that under the system of Contour cultivation with opening of ridges and furrows, velocity of flowing water was reduced by obstruction and soil particles could get longer period to settle on the ground surface. From above discussion related to surface runoff and soil loss reflected the superiority of Contour cultivation with opening of ridges and furrows method of *In situ* soil and water conservation measure.

Summary and Conclusion

The rainfall was commenced on 3rd June 2012. The season was favorable for germination and intercultural operations as there were continuous showers. The last two showers were of 26.0mm on 3rd Oct and 11.5mm on 4th Oct. 2012 and thereafter there was withdrawal of monsoon. From the results following conclusions were made.

1. Contour cultivation with opening of ridges and furrows (T_3) was more effective than Contour cultivation with opening of alternate furrow (T_2) over other treatments (T_1) cultivation with opening of tied ridges in reducing runoff and soil loss.
2. Contour cultivation with opening of ridges and furrows (T_3) reduced the peak discharge rate and cumulative runoff over treatments T_2 and treatment T_1 .
3. From rainfall analysis it was revealed that out of 47 rainy days, 41 rainy days were commenced with rainfall intensity $< 25\text{ mmhr}^{-1}$ and 6 rainy days were commenced with $25\text{-}50\text{ mmhr}^{-1}$ rainfall intensity.

4. The erosive index EI_{30} (246.31) was maximum for a month of July and least for month of August.

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How to cite this article:

Sathe, M.P., A.U. Surwase, Pradip Dalvi and Taley, S.M. 2018. Impact of Land Configurations on Runoff and Soil Loss under Rainfed Conditions. *Int.J.Curr.Res.Aca.Rev.* 6(11), 39-47.

doi: <https://doi.org/10.20546/ijcrar.2018.611.005>