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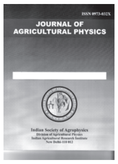
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Research Article

Rain Water Harvesting in Non-arable Land using Staggered Trenching in Semi-arid Climate of Bundelkhand

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ABSTRACT

Almost 80% of Bundelkhand's 18.3 million population lives in rural areas (2011 census), and much of this population is dependent on agriculture for livelihood. The soils of the region are generally shallow having poor fertility. The climatic condition of the region is very harsh. In this view an experiment was conducted at IISWC, Research farm, Datia to assess the performance of staggered contour trenches in augmenting in situ soil moisture on non-arable land. Based on one-day maximum rainfall of two years, 53, 109 and 198 number of trapezoidal staggered contour trenches were constructed at 3-6 m horizontal spacing to retain 30 % (W-2), 50% (W-3) and 80% (W-4) runoff in three micro-watersheds. One micro-watershed (W-1) was kept as control for comparison. Average runoff and soil loss were measured in each micro-watershed. For plantation, Karanj (*Pongamia pinnata*) at 6 × 6 m spacing was selected due to its suitability in the region and being hardy, less browsed by wild animals. A good relationship ($R^2>0.9$) between rainfall and runoff for different watersheds was found. Runoff and soil loss were observed maximum in W-1 (194.9 mm 6.82 t ha^{-1}, respectively) while minimum runoff and soil loss in W-4 (60.9 mm and 1.64 t ha^{-1} respectively) during the monsoon period. 42.72, 38.56, 23.67 and 13.35 % runoff (of total seasonal rainfall 456.2 mm) were generated from W-1, W-2, W-3 and W-4, respectively.

Key words: Bundelkhand, Contour trenching, Non arable land, Rain water harvesting

Introduction

Bundelkhand lies between Indo-Gangetic plain and Vindhya Range and extend over an area of 7.04 Mha. The majority of the population living in the rural area and depend on agriculture for livelihood. Extreme weather conditions, like droughts, erratic rainfall and high temperature add to the uncertainties and seasonal migrations. Poor soil water holding capacity in red soil, harsh weather, low ground water level, erratic rainfall leads miserable condition of agriculture. This adverse situation calls for adoption of in situ soil moisture conservation techniques to develop non arable land.

Soil and water are two basic natural resources for agricultural development. Sustainability of agriculture depends on how judiciously they are used, conserved and developed. Our land resources are limited considering the pressure of food production to feed the large population. Further due to soil erosion, water logging and other deteriorating factors nearly 50% of cultivable land suffers from land degradation at

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various stages (NBSSLUP, 2004). The degraded lands which have reached to severe stage of degradation are not under cultivation. If these lands are not treated immediately they will turn in to waste land and will be unfit for cultivation. Rain water conservation is main activity to check runoff, conserve soil and water and through this conserved water develop perennial vegetative system.

Watershed management is an approach which aims at optimizing use of land, water and vegetation in an area to alleviate drought, prevent soil erosion, improve water availability and finally increase food, fodder, fuel and agriculture production on a sustainable basis (Wang *et al*., 2016). The productivity of the degraded non arable lands is poor due to uncontrolled runoff and soil loss. For sustainable production from these areas, water use efficiency of rain water needs to be enhanced. For this purpose, number of soil working techniques is employed. Rain water that flows as runoff is retained in the area by these techniques. The retained water first saturates the soil profile and excess is drained to reach the ground water to recharge the aquifers. The conserved soil moisture helps in plant establishment and subsequent plant growth.

Contour trench is one of the popular methods employed for rainwater harvesting, can be constructed on hill slopes as well as on degraded and barren waste lands in both high- and low-rainfall areas (Babu and Mishra, 2013). The size and number of trenches depends on soil type, slope and the rainfall amount to be retained in the trenches. However, an optimum option considering size, intensity, cost and performance needs to be identified under various land uses and edaphic and climatic conditions. Keeping the potential of staggered contour trenches for rainwater harvesting, recharge and recycling, a field experiment was conducted at the Research Centre farm to evaluate the performance of Staggered Contour Trench (SCT) layout.

Material and Methods

Location

Field experiments were conducted at the ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Datia. Four denuded micro-watershed with various shape and size having slope ranging from 1 to 3 percent are selected. These micro-watersheds are situated at 25°42′ N latitude and 78°26′ E longitude at an altitude of 214 m above msl. The detail characteristics of the micro-watersheds are given in the Table 1. Further, soils of all four micro-watersheds were observed slightly alkaline in reaction with pH 7.8-7.9, but free from excessive salinity hazard having EC < 1 dSm^{-1}. The fertility status of soils was poor in organic carbon (0.26-0.32 %), medium in P (9.1-11.2 kg ha^{-1}) and K (157-190 kg ha^{-1}). The average annual rainfall at the Centre is 810 mm and it comes under the Central Plateau and Hills agro-climatic zone.

Design and construction of trenches

One-day maximum rainfall (mm) of two years return period was computed using Gumbel extreme value distribution (Gumbel, 2012) from 20 years (1995 to 2014) rainfall data of the research Centre for designing the contour trenches. One-day maximum rainfall (mm) of two years return period was 91 mm (Fig. 1). The

Table 1. Characteristics of the four micro-watersheds

Parameter	Micro-watershed			
	W-1	W-2	W-3	W-4
Area (ha)	0.70	0.23	0.27	0.40
Shape	Semi-circular	Elongated	Rectangular	Elongated
Soil type	Loamy sand	Loamy sand	Loamy sand	Loamy sand
Land use	Fallow	Fallow	Fallow	Fallow
Slope (%)	1.0	1.5	2.0	3.0

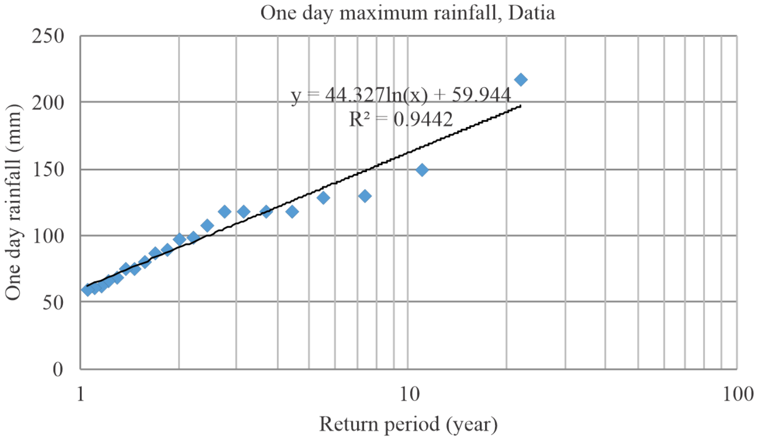


Fig. 1. One day maximum rainfall derived from 20 years rainfall data (1995-2014) of Datia

trench design and density was estimated using the DSS software (Kurothe *et al*., 2014). Accordingly, a number of 53, 109 and 198 contour trenches of volume 0.77, 0.64 and 1.02 m^3, respectively were constructed to retain 30 (W-2), 50 (W-3) and 80% (W-4) of surface runoff, respectively. One micro-watershed (W-1) was kept as control for comparison.

The layout of staggered trenches with trapezoidal cross section derived from the DSS in different micro-watersheds are given in Fig. 2. The DSS is an integrated assembly of models, data, interpretive routines and other relevant information which efficiently processes input data, runs the model and displays the result in an easy to interpret format (George *et al*., 2002, Rao and Rajput, 2009). Trenching was carried during winter so that the site was ready for planting during the first monsoon.

Plantation, runoff and soil loss calculation

Karang (*Pongamia pinnata*) was planted on the trenches in the three micro-watershed at 6×6 m spacing, considering its suitability in the region. To measure the runoff, 0.61 m H-Flume structure was constructed at the downstream outlet of each micro-watershed. Daily runoff was calculated from the runoff hydrograph recorded by automatic water stage level recorder installed on stilling wells, which were constructed near the H-Flume structure. The representative runoff sample was collected in 1L capacity bottle from the silt collecting tank after thorough stirring at 8.30 AM. The silt was allowed to settle down in the sample runoff and after draining the excess water, the soil was kept in an oven and the dry weight was determined. The soil loss was estimated in proportion to total runoff occurred in a particular rainfall event. Combining all individual events data, annual runoff and soil loss were worked out and converted to unit area. For analysis the data, rainfall data of Centre's meteorological observatory was used which is adjacent to the experimental site.

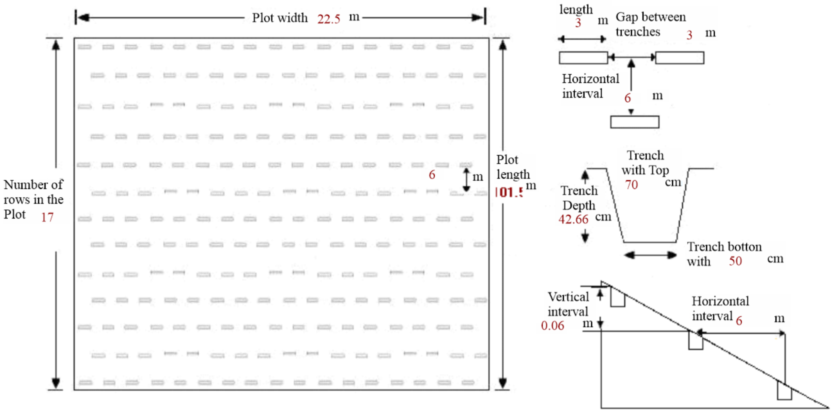
Data analysis

There was 15 runoff producing rainfall storms during the monsoon period. All the runoff charts were analyzed manually and data were exported in the MS Excel. All the analysis of data was carried out using MS excel.

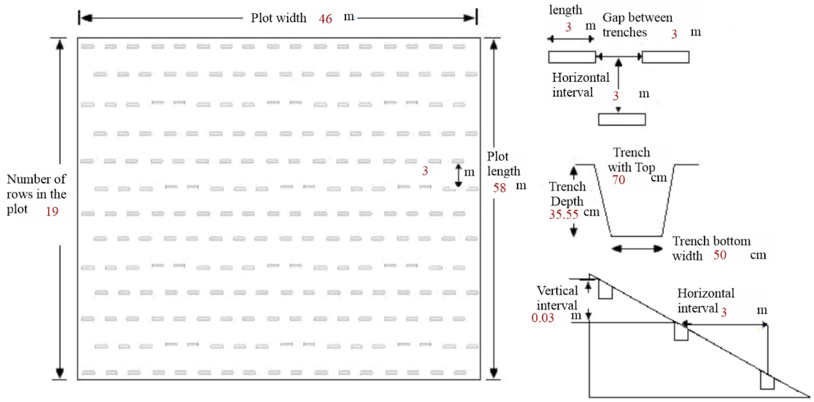
Results and Discussion

During the monsoon season 2015, there was 15 runoff producing rainfall events. Event wise rainfall and runoff under different micro-watersheds is depicted in Fig. 3. Rainfall-runoff relationships for different micro-watershed were developed (Fig. 4) and found a very high coefficient of determination ($R^2 > 0.90$). The relationship of runoff of control watershed with other watershed is also developed and showed a good relationship.

(a) W-2



(b) W-3



(c) W-4

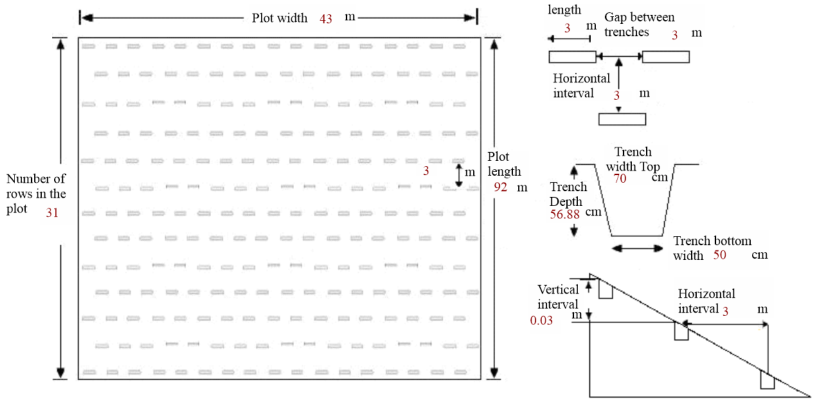


Fig. 2. The layout of staggered trenches with trapezoidal cross section for (a) W-2, (b) W-3 and (c) W-3 micro-watersheds

Runoff and soil loss data analysis showed that the maximum runoff and soil loss were observed in W-1 (194.9 mm 6.82 t ha^{-1}, respectively) while minimum in W-4 (60.9 mm and 1.64 t ha^{-1}, respectively) (Table 2). Runoff and soil loss from the W-4 micro-watershed was very low as most of the runoff was harvested in the SCT dugouts and soil settled. The construction of SCT at different intensity reduced the surface runoff by 9.7-68.8% and soil loss by 51-76% compared to the control. The land cover and low intensity of rainfall during the monsoon have significant

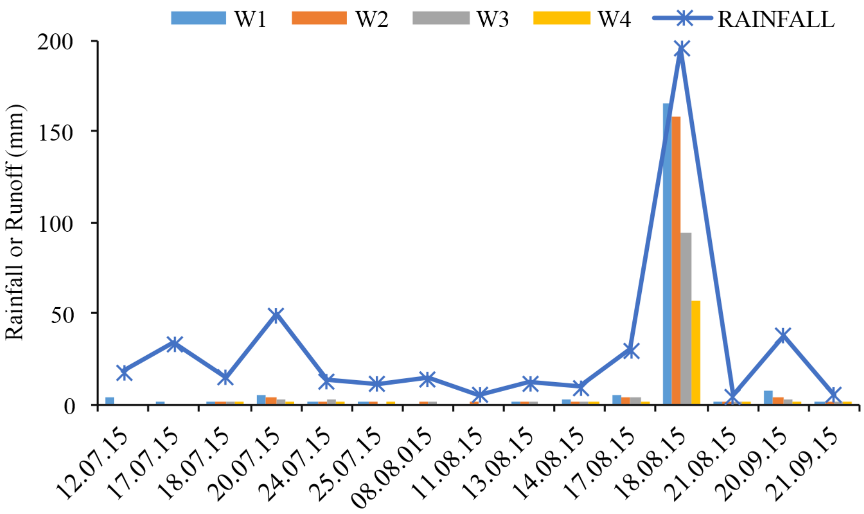


Fig. 3. Event wise rainfall and runoff recorded in different micro-watersheds during 2015

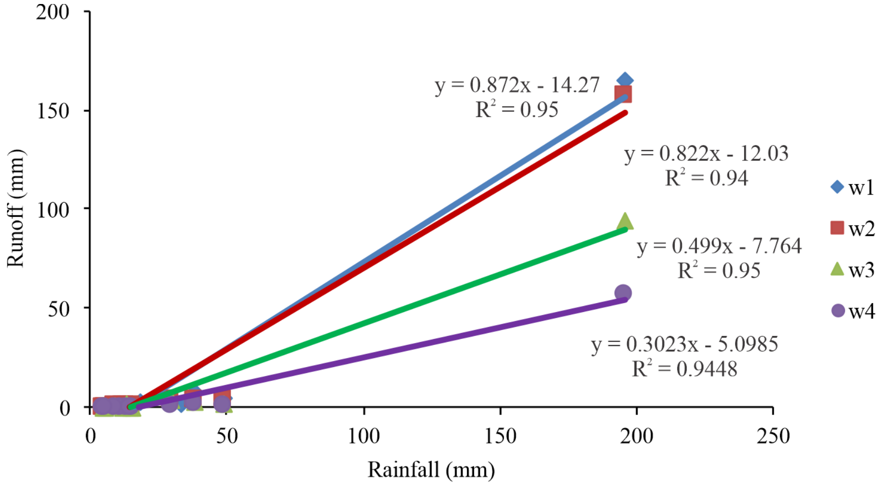


Fig. 4. Rainfall- runoff relationship of different micro-catchments for the year 2015

Table 2. Runoff and soil loss in different micro watersheds during year 2015

Micro-watershed	Runoff (mm)	Runoff (%)	Soil loss (t ha^{-1})	% reduction as compared to control (W-1)	
				Runoff	Soil loss
W-1	194.9	42.7	6.82	-	-
W-2	175.9	38.6	3.34	9.7	51.0
W-3	108.0	23.7	2.98	44.6	56.3
W-4	60.9	13.3	1.64	68.8	76.0

Rainfall during the monsoon: 456.2 mm

impact on the runoff and soil loss. The result was in accordance with the finding of Madhu *et al.* (2011) and Manivannan and Sikka (2013) who have reported SCT in combination with vegetative barrier are more effective in controlling runoff and soil loss. Although the during the whole monsoon season received low intensity rainfall except an extraordinary rainfall of 195.6 mm on 18th August which generated high amount of runoff and soil loss in all micro-watersheds. The runoff was seen to be collected in trenches in the month of August and remained available for about 15 days.

The survival of Karang (*Pongamia pinnata*) plantation was almost 100% and plant growth was also satisfactory in all micro-watersheds but around 70% and 90% plants were browsed by the wild animals in W-3 and W-4, respectively. To observe the effect of moisture conservation on plant growth, plant height and collar diameter of randomly selected 15 plants of each micro-watershed were recorded. The analysis of data showed that the maximum plant height and collar diameter (104 cm and 1.5 cm, respectively) was observed in W-2 micro-watershed and that of minimum (83 cm and 1.2 cm) in W-3 micro-watershed. The first year of plant growth data was inconclusive.

Conclusion

The trapezoidal shape of staggered contour trenches of 0.64-1.02 m^3 volume spaced at 3 to 6 m horizontal interval are very much effective in harvesting the rainwater which led to uniform in-situ soil moisture in the non-arable land of Bundelkhand. This augmented in situ soil moisture also helped in the establishment of karaj plantation. Construction of trapezoidal SCT may be the suitable soil moisture conservation measures of Bundelkhand region to develop the degraded sloppy land under rain-fed condition for establishment of plantation and vegetation. However, more experimentation is required to quantify the impact on plant growth parameters.

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References

Babu, R.R. and Mishra, P. 2013. Innovative design and layout of Staggered Contour Trenches (SCTs) leads to higher survival of plantation and reclamation of wastelands. *Journal of Soil and Water Conservation* **12**: 10-16.

George, B.A., Reddy, B.R.S., Raghuvanshi, N.S. and Wallender, W.W. 2002. Decision support system for estimating reference evapotranspiration. *Journal of Irrigation and Drainage Engineering* **128**: 1-10.

Gumbel, E.J. 2012. *Statistics of extremes*. Courier Corporation.

Kurothe, R.S., Vishwakarma, A.K., Sena, D.R., Kumar, G., Rao, B.K. and. Pande, V.C. 2014. Decision support system for contour trenching. *Indian Journal of Soil Conservation* **42**: 143-153.

Madhu, M., Raghunath, B., Tripathi, K.P., Sam, M.J., Chandran, B., Mohanraj, R. and Haldorai, B. 2011. Vegetative barrier with contour staggered trenches for resource conservation in new tea plantations of the Nilgiris. *Indian Journal of Soil Conservation* **39**: 33-36.

Manivannan, S. and Sikka, A.K. 2013. Hydrological impact of bioengineering conservation measures on cashew plantations in lateritic soils of Konkan region. *Journal of Agricultural Engineering* **50**: 57-65.

National Bureau of Soil Survey & Land Use Planning (NBSS&LUP). 2004. Soil Map (1:1 Million Scale); NBSS&LUP: Nagpur, India.

Rao, B.K. and Rajput, T.B.S. 2009. Decision support system for efficient water management in canal command areas. *Current Science* **97**: 90-98.

Wang, G., Mang, S., Cai, H., Liu, S., Zhang, Z., Wang, L. and Innes, J.L. 2016. Integrated watershed management: evolution, development and emerging trends. *Journal of Forestry Research* **27**: 967-994.

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