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Designing of small water harvesting structures based on rainfall-runoff relationship for Dharashiv district of Maharashtra

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Abstract
The standardization of rainwater harvesting structures (farm pond) in India takes into account the unique climatic conditions, agricultural practices, and socio-economic factors prevalent in different districts. This process involves the development of guidelines and recommendations based on scientific research, practical experiences, and lessons learned from successful implementations. In conclusion, the standardization of small water harvesting structures for districts under changing climate in India is a critical approach to address the water management challenges in agriculture. The rainfall data was collected from the Agro-meteorological station. Runoff was estimated using SCS curve number method considering the all parameters like soil type, vegetation etc. The rainfall runoff relationship was worked out for further planning of small water harvesting structures like farm ponds. Rainfall and runoff are significant constitute the sources of water for recharge of ground water in the watershed. Estimation of runoff in a watershed is very important to manage the water resources efficiently. The runoff potential for Dharashiv station was found to be 20.07%, indicating a good scope for rainwater harvesting and thereby, many more rainwater harvesting structures can be constructed based on site specific conditions. A relation between rainfall and runoff for Dharashiv station was worked out as Y = 0.423X – 140.4 (R^2 value -0.808). The derived linear rainfall-runoff relation may be used to determine the runoff associated with any rainfall that takes place in the region. The link between rainfall and runoff will be helpful in determining the possibility for collecting rainwater and reusing it to increase the yield of different types of crops that get rain. Farm pond sizes of storage capacity of 351cum 741 cum and 939 cum are standardized for catchment area of 1 ha, 2 ha and 3 ha respectively for Dharashiv station under changing climatic condition. Based on storage capacity, the square shaped farm ponds of sizes 15 x 15 m, 20 x 20 m and 22 x 22 m (top dimensions) with depth of 3 m and side slope of 1.5:1 (Trapezoidal shape) are suggested.

Keywords: Curve number, farm pond, micro-catchment, rainfall, runoff

Introduction
Runoff is one of the important hydrologic variables used in most of the water resource planning. Rainfall duration, intensity and aerial distribution influence the rate and volume of runoff. Catchment characteristics such as slope, shape and size, cover of soil and duration of rainfall have a direct effect on the peak flow and volume of runoff from any area (Chandler and Walker, 1998) [4]. Estimation of runoff for designing of any water harvesting structure is very important. Therefore, rainwater harvesting and its storage is an important issue in this region. The harvested water with suitable rainwater harvesting structure can be utilized for sustainable crop production.
By considering rainfall patterns, soil characteristics, cropping patterns, and socio-economic factors, this standardization process aims to optimize water resource utilization, enhance resilience to climate change, and promote sustainable agricultural practices. The guidelines and recommendations developed through scientific research and practical experiences support farmers in implementing appropriate farm pond sizes, ensuring the long-term sustainability of agricultural systems in the face of a changing climate.

Dharashiv district falls within the central part of the Marathwada region. This region is characterized by a semi-arid climate with hot and dry summers and a moderate monsoon season. The average annual rainfall in these districts ranges from 600 to 800 millimeters (24 to 31 inches). The soil types found in this region are predominantly black soil (vertisols) and medium to deep black soil (vertisols) with moderate to high fertility.

The socio-economic factors of the districts, including the economic feasibility and affordability for farmers, are crucial in determining the standardized farm pond sizes. The cost of construction, operation, and maintenance of farm ponds must be balanced with the potential benefits and returns for farmers. By considering the economic viability and local financial constraints, the standardization process ensures that small rainwater harvesting structures (farm pond) sizes are practical and achievable for farmers across different socio-economic backgrounds.

Materials and Methods

For estimation of runoff potential, the daily rainfall data for Dharashiv district for the period of 2011-2021 have been collected from Meteorological Observatory, All India Coordinated Research Project on Agro-Meteorology, VNMKV, Parbhani. The daily runoff for the each runoff producing rainfall event was estimated using SCS curve number method. The rainfall and runoff data was analyzed and grouped in as fortnightly manner.

The SCS curve number techniques is based on recharge capacity of the watershed. The recharge capacity was determined by antecedent moisture condition and by physical characteristics of the watershed. Antecedent moisture condition (AMC) was used as an index of watershed wetness (Ponce and Hawkins 1996) [7]. Hydrological Soil Group (HSG) plays an important role in runoff production from a particular land surface of watershed. For the study area, the hydrological soil group was considered as "D'. The selection of curve numbers is based on various hydrologic soil cover, land use, treatment or cultivation practices, hydrological condition of the area and hydrological soil group. The standard sets of equations for estimation of runoff potential from black soil region were used using SCS curve number technique. Considering the available maps of land use/ land cover and hydrological soil group, the area of each class of land was worked out. Assigning the suitable curve numbers for respective land use and HSG to each area, the weighted curve number was determined and used in estimation of runoff potential. Amutha and Porchelvan (2009) [1], Bansode and Patil (2014) [2], Bhura *et al.* (2015) [3] and Mishra *et al.* (2005) [6] used SCS curve number method for runoff estimation. Similar technique was used in this study for estimation of runoff potential.

Based on the runoff potential from the standard catchment area, the fortnightly runoff volume was estimated and considering the pan evaporation and seepage rate from the soil strata, the cumulative runoff potential to be harvested in the farm pond was estimated. Accordingly, the sizes of small rainwater harvesting structures (farm ponds) as per catchment area were worked out.

Results and Discussion

Estimation of cure numbers

CN values were estimated based on hydrologic soil group, average slope of land and land use pattern of the area for Dharashiv district of Marathwada region. The weighted values of curve numbers for three AMC condition were calculated as per USDA SCS-CN method. The hydrologic soil group for the region was observed as 'D' with slope range of 0.5 to 3.0%. The weighted curve numbers were calculated as 71, 85 and 94 for AMC-I, AMC-II and AMC-III respectively.

Estimation of runoff volume

The daily surface runoff was estimated and thereby, the yearly runoff data for Dharashiv station of Marathwada region is presented in table 1. The average runoff was calculated and also noticed the maximum runoff year.

Table 1: Year-wise rainfall, runoff and % runoff for Dharashiv station

Year	Annual Rainfall, mm	Rainfall, mm	Runoff, mm	% Runoff	Runoff coefficient
2012	400.7	391.7	12	30.63	0.3063
2013	726.2	649.4	100	15.39	0.1539
2014	505.2	442.6	84	18.97	0.1897
2015	477	379.2	31	8.175	0.08175
2016	868	836.1	272	32.53	0.3253
2017	891.2	862.3	283	32.81	0.3281
2018	492.8	411.9	65	15.78	0.1578
2019	688	660.7	52	7.87	0.0787
2020	860.6	827.1	183	22.12	0.2212
2021	1044.3	923.2	245	26.53	0.2653
2022	833	831.8	160	19.23	0.1623
Average	707.9	656	135.18	20.91	0.2063
Maximum	1044.3	932.2	283	32.81	0.3281

Extreme/heavy rainfall events: The data related to extreme / heavy rainfall events for Latur and Dharashiv stations respectively during the year 2011 to 2021 is presented in table 2.

Table 2: Extreme Events-Dharashiv station

Years	June		July		August		September		October	
	Date	Rainfall	Date	Rainfall	Date	Rainfall	Date	Rainfall	Date	Rainfall
2016							23.9.16	53.8		
2017					20.8.17	66.5				
2020									15.10.20	53.7
2021			10.7.21	52.9			5.9.21	50.6		

Rainfall-runoff depth relation

The rainfall-runoff relationship is graphically represented in Fig.1.

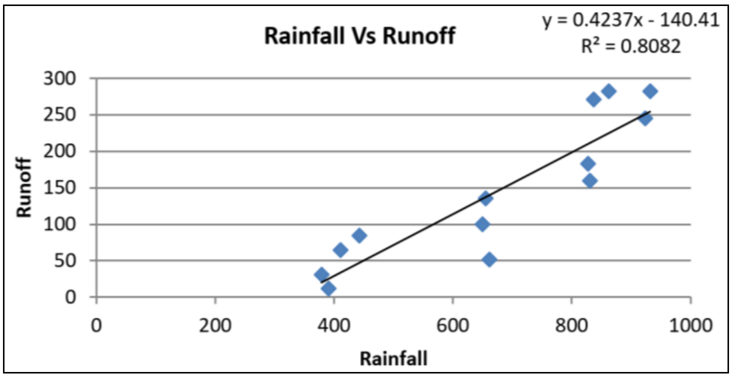

Fig 1: Rainfall-runoff relationship for Dharashiv station of Marathwada region

The relation obtained can be used for finding out runoff corresponding to any rainfall occurring in the area. For the study area, the relation was found to be linear. The relation obtained was Y = 0.423X – 140.4 and the R^2 value was 0.808.

Vinithra and Yeshodha (2013) [9] used rainfall-runoff modelling using SCS-CN method as a case study of Krishnagiri district, Tamilnadu. Satheeshkumar *et al.* (2017) [8] conducted study on rainfall–runoff estimation using SCS–CN and GIS approach in the Pappiredipatti watershed of the Vaniyar sub basin, South India.

Designs of farm pond for various average catchments of Dharashiv station: Farm ponds are designed based on rainfall runoff relationship and expected evaporation and seepage losses during the monsoon season and also according to catchment area of 1 ha, 2 ha and 3 ha based on the average size of land holding of the farmers of the region. Farm ponds are designed related to size of pond and the storage capacity based on expected runoff from the corresponding catchment area.

Based on runoff potential, the farm pond of capacity 417 cum., 651 cum. and 939 cum. were designed for 1 ha, 2 ha and 3 ha catchment area respectively. The details of farm pond sizes, storage capacity, area under protective / supplemental irrigation and area under pond construction is presented in table 3.

Table 3: Farm Pond sizes for Dharashiv station

Catchment Area, ha	Top Size of pond mxm	Bottom Size of pond mxm	Side slope	Depth of farm pond, m	Capacity of farm pond Cum	Area under 2 irrigation of 5 cm depth (ha)	Area irrigated % of catchment area	% Catchment Area under pond construction
1.0	16 x 16	7 x 7	1.5: 1	3	417	0.75	75	2.56
2.0	19 x 19	10 x 10	1.5: 1	3	651	1.2	60	1.80
3.0	22 x 22	13 x 13	1.5: 1	3	939	1.8	60	1.61

The harvested rainwater in farm pond constructed for 1 ha, 2 ha and 3 ha area with storage capacity of 417 cum, 651 cum and 939 cum could provide supplemental irrigation on 0.75 ha, 1.2 ha and 1.8 ha area respectively. Similarly, the area engaged under construction of small rainwater harvesting structure varies from 1.6 to 2.5 percent.

Conclusions

Rainfall-runoff relationship proved to be the most valuable information for designing of small rainwater harvesting structures (farm pond). Following conclusions were drawn from the study.

1. The runoff potential for Dharashiv station of Marathwada region is found to be 20.07%. A linear relationship of rainfall and runoff was observed representing a good scope for rainwater harvesting.
2. Farm pond sizes of storage capacity of 417 cum., 651 cum. and 939 cum. are standardized for catchment area of 1 ha, 2 ha and 3 ha respectively for Latur division of Marathwada region.

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