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Runoff Estimation and Water Management Options for Coastal Odisha

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Abstract: Coastal areas are always under high stress either due to excess water availability or non-availability of water during summer season. This paper deals with estimation of runoff, which is the major component in hydrologic cycle. Runoff characteristics and the estimation of runoff were analyzed by SCS-Curve Number method with 21 years meteorological rainfall data for Kendrapara district of Odisha. On an average 34 percent of actual rainfall goes as runoff in each year, which is one of the major causes of waterlogged situation in this deltaic region. In this paper a case study was carried out by considering the water availability in creeks and water harvesting structures in different season of the year. Based on runoff from the area, spatial distribution of water availability and water quality in different irrigation sources, water controlling devices like sluice structures was designed to control drainage & check saline water entry into the creeks to improve the land and water productivity of the area.

Keywords: Runoff, Rainfall, Curve Number, SCS-CN method

Water is an important component for living beings. Declining per capita availability of water leads research to focus on different conservation practices. Rainfall is the major form of precipitation through which the water reaches at ground surface. Many research works are going on for the conservation of rainwater. The rainfall conservation practices should be adopted based on the quantification of runoff from the hydrological areas. Runoff is the process of draining or flowing off of precipitation from a catchment area through surface channel. For a given precipitation, the evapotranspiration, initial loss, infiltration and soil moisture storage requirement will have to be first satisfied before the commencement of runoff. When these are satisfied, the excess precipitation moves over land surface (Subramanya, 2008). A fraction of total rainfall that reaches the ground water table called as the effective rainfall. The SCS-CN method is used to calculate effective rainfall which is assessed on small mediterranean catchment. The land use aggregation and land use classification type have significant effect on hydrological modeling and in particular on effective rainfall modeling (Payraudeou, 2003). Runoff measurement is required for estimating the part of rainfall which goes as overflow. The overflowing water can be utilized as ground water recharge and also the runoff water can be stored for the future use. Such estimation is needed for design of engineering structures in the post event appraisal work for evaluation of various land use practices and for assessment of environmental impact of watershed development (Hawkins,1985, 1993).By retarding the flow of runoff water soil erosion can be minimized and conserved runoff water can be reused by irrigation as well as it can be helpful for fish farming. Runoff in volume basis is estimated by using different empirical formula for a closed catchment.United States Department of Agriculture (USDA) Soil Conservation Services (SCS) of USA in 1969 developed SCS-CN method is a simple predictable and stable conceptual method for estimation of direct runoff depth based on storm rainfall depth. It is dependent upon only one parameter, CN (Curve Number) which is determined by Hydrological Soil-cover Complex which depends upon land use cover, land treatment or practice, hydrologic condition and hydrological soil group. In this paper, standard SCS-Curve Number method was used for computation of runoff depth for a coastal irrigated area of Odisha.

MATERIAL AND METHODS

The study was conducted in Kendrapara district of Odisha. The study area is having of 640 ha cropping land. The area receives an average annual rainfall of 1507mm. The area is dominated by clayey soil, which restricts the downward entry of water and creates waterlogging situation during monsoon season. According to the soil property it is in hydrological soil group C, having low infiltration rate when thoroughly wetted and a low rate of water transmission

(Ritzema, 1996). Major cropping system adopted in the study area is Rice-Green gram/pulses-fallow throughout the year i.e. June to September (*kharif*), November to February (*rabi*) and March to May (summer) respectively. Monthly rainfall data for the period of 1994 to 2014 was considered for estimation of effective rainfall by using the FAO CROPWAT model. Runoff was computed by using SCS curve number method. Curve number method being used for measuring the depth of runoff from rainfall depth developed by Soil Conservation Service (SCS, 1964; 1972). The initial accumulation of rainfall represents interception, depression storage and infiltration before the start of runoff which is called as initial abstraction. After the runoff started additional runoff started in form of infiltration is called as actual retention. With increase in rainfall actual retention also increases up to the maximum value: potential maximum retention. Curve Number method mathematically is the ratio of actual retention to potential maximum retention equal to the ration of actual runoff to potential maximum runoff.

$$\frac{F}{S} = \frac{Q}{P - I_a}$$

Where, F = actual retention, mm; S = potential maximum retention, mm; Q = accumulated runoff depth, mm; P = accumulated rainfall depth, mm; I_a = initial abstraction, mm

By simplifying

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \text{for} P > 0.2S$$

Potential maximum retention S has been converted to Curve Number. This relationship is

$$CN = \frac{25400}{254 + S}$$

Curve number is decided relating to land use cover, land treatment or practice, hydrologic condition and hydrological soil group. These parameters together called as Hydrological Soil-cover Complex. The CN value varies from 0 to 100.This runoff estimation procedure was followed for study area. The soil type of the area was found to be clay soil with low infiltration rate which comes under Hydrological soil group C. Other parameters for deciding CN are land use and land cover for which the land use pattern was classified into three growing seasons as mentioned above. As per the field survey, it was observed that farmers grow paddy and legumes or pulses in *kharif* and *rabi* season respectively. Mostly fallow lands were observed during summer season due to non-availability of required amount of water. Generally, conventional straight row method is being adopted by the farmers. The curve number (CN) values were decided based on this field condition (Table1).

RESULTS AND DISCUSSION

Rainfall data of 21 years (1994 to 2014) showed that average annual rainfall and runoff of Kendrapara is 1507mm and 510mm respectively (Table 1) with 59 numbers of rainy days. The highest annual rainfall of 2832 mm occurred during the year 2003 with highest runoff of 1239mm (Fig. 1). The lowest rainfall of 582 mm occurred during the year 2000 with lowest runoff of 78 mm. It showed the positive correlation between the rainfall and runoff. Similarly highest monthly average rainfall was recorded during the month July, August, September and October with 300mm, 411mm, 237mm and 238mm respectively. The highest runoff was also recorded for same months with 101, 152, 66 and 93mm respectively. On an average 72.7 per cent of the annual rainfall is received during monsoon season. Pre and post monsoon rainfall contributed only 7.2 and 19.0 per cent of the total annual rainfall in the study area. Rest 0.9 per cent rainfall occurred during winter season (Table 2). It also showed that pre monsoon rainfall contributed maximum rainfall (89.1%) as effective rainfall followed by monsoon and winter rainfall. Monthly rainfall/runoff analysis was shown in Table 3. July month receives highest average rainfall of 410.9 mm (27.3% of annual rainfall) and runoff of 152 mm (29.7 % of annual runoff). December receives lowest average rainfall (3.3 mm) and no runoff. Maximum rainfall and runoff occurred in August with 894.9 and 416.0 mm respectively (Table 4).

In this analysis, CN method with basic parameters like hydrologic soil group, land use, land cover and condition of soil were considered. From the field survey, it was observed that rice-pulses (green gram)-fallow is the common cropping

Table 1. CN values for study area soil condition relating to different crop growing seasons

Crop growing season	Land use	Treatment/ Practices	Hydrological condition	Hydrological soil group	CN value	*S*
Monsoon *kharif* (June- September)	Paddy	Straight row	Good	C	83	52.02
Post-monsoon *rabi* (October-February)	Legumes	Straight row	Good	C	81	59.58
Pre-monsoon summer (March-May)	Fallow	Straight row	Good	C	91	25.12

pattern in the study area. The cultivation practices adopted by the farmers are conventional straight row cropping system for rice and green gram. During the summer season mostly the land remains fallow. The water availability status showed that the area received excess amount of water only during the monsoon periods i.e. July to October, whereas rest all the season, there is deficit rainfall which could not fulfill the crop water requirement (Fig. 2). Monthly rainfall, runoff and PET status (Table 5) showed that 72 per cent of annual rainfall occurred in monsoon season. Nearly 68 per cent of annual runoff occurred in this season only where the potential ET is only 33 per cent of annual PET. Hence additional storage structures could tap the excess rainfall during monsoon season, which could be utilized in post monsoon and summer season. But, the area is located very close to sea and waterlogging is the common problem in most of the deltaic region of the State.

Hence detail study in one of the representative area of the coastal ecosystem was identified for the detail study. The area was surrounded by the network of creeks, which very common in most of the coastal areas. From the preliminary study, it was observed that in study locations (Sunity) of 3800 ha of area, there is presence of 65 numbers of water bodies and a network of 19 numbers of creeks within the length of

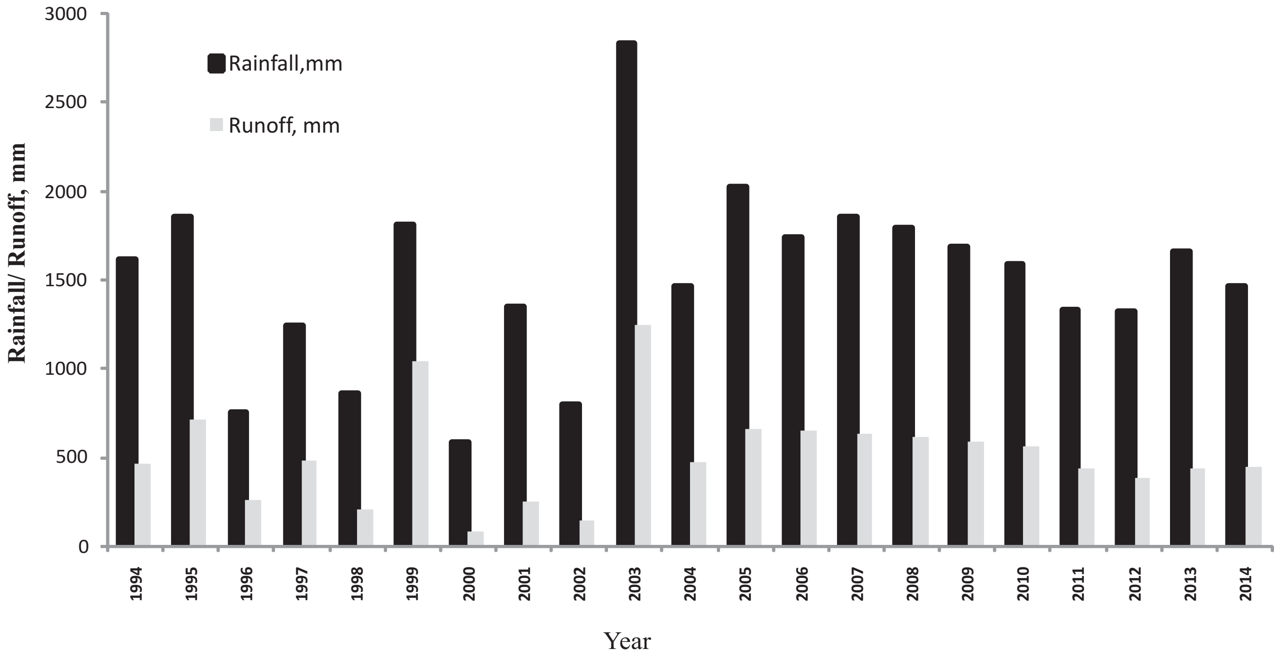

Fig. 1. Annual rainfall, runoff of Kendrapara

Table 2. Rainfall/runoff analysis of Kendrapara

	Minimum rainfall, mm	Maximum rainfall, mm	Average rainfall, mm	Standard Deviation, mm	Coefficient of variation
Rainfall	582.3	2831.8	1507.1	491.5	0.3
Runoff	77.5	1238.7	510.5	267.2	0.5

Table 3. Rainfall, effective rainfall distribution in Kendrapara district

Seasons	Average rainfall (mm)	Percentage of total rainfall	Average effective rainfall, mm	Effective rainfall (% of rainfall)
Pre-monsoon (March-May)	109.4	7.2	97.0	89.1
Monsoon (June-September)	1096.1	72.7	909.7	82.8
Post-monsoon (October-December)	287.3	19.0	146.4	50.6
Winter (January-February)	13.8	0.9	11.5	82.3

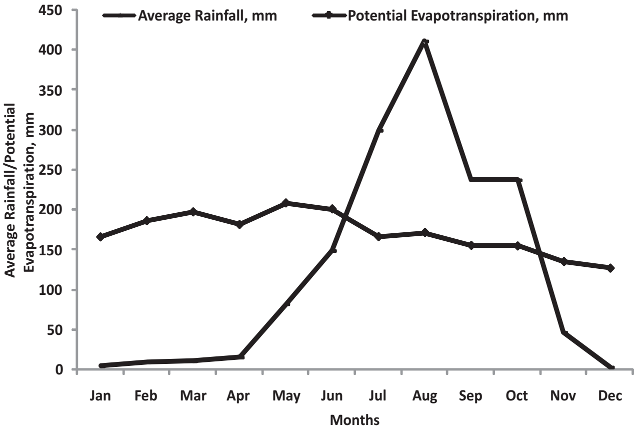

Fig. 2. Water availability status of Kendrapara

0.43 to 23 km. Statistics showed that the area of the water bodies varied within 823-3568 m^2 with average area of $1800m^2$ and 900-1300 m^2 water harvesting structures were quite common in this area.

In order to study the hydraulics of water harvesting structures, depth-capacity curve of two water harvesting structures were plotted. It showed that out of 52 standard weeks, the water harvesting structures remains dried within 14 to 28^{th} week i.e. during summer season. These structures could be utilized to store the runoff water during monsoon period, which could be utilized during non-monsoon season to meet the crop water demand. Hence appropriate locations should be identified based on the land use land pattern of the

Table 4. Monthly rainfall and runoff analysis

Month	Minimum, mm		Maximum, mm		Average, mm		% contribution to annual, %		Standard Deviation, mm		Coefficient of variation	
	R	RO	R	RO	R	RO	R	RO	R	RO	R	RO
January	0.0	0.0	37.3	1.0	4.2	0.0	0.3	0.0	8.6	0.2	2.1	Nil
February	0.0	0.0	108.6	42.0	9.6	2.0	0.6	0.4	24.1	8.9	2.4	4.4
March	0.0	0.0	93.5	52.0	10.8	4.0	0.7	0.8	21.3	11.3	1.9	2.8
April	0.0	0.0	128.4	98.0	16.3	7.0	1.1	1.5	31.9	22.5	2.0	3.2
May	0.0	0.0	513.2	350	82.3	38.0	5.5	7.5	110.2	77.2	1.3	2.0
June	42.7	0.0	355.8	99.0	148.6	32.0	9.9	6.3	93.3	28.8	0.6	0.9
July	40.1	0.0	717.5	380	299.5	101	19.9	19.7	163.9	98.5	0.5	1.0
August	75.6	3.0	894.9	416	410.9	152	27.3	29.7	204.9	120	0.5	0.8
September	30.0	0.0	500.0	287	237.0	66.0	15.7	12.9	141.1	67.4	0.6	1.0
October	15.0	0.0	760.3	262	238.0	93.0	15.8	18.3	231.2	136	1.0	1.5
November	0.0	0.0	218.4	86.0	46.0	15.0	3.1	2.9	72.1	26.9	1.6	1.8
December	0.0	0.0	38.0	4.0	3.3	0.0	0.2	0.0	8.8	0.8	2.9	Nil

Table 5. Season wise rainfall/runoff analysis

Season	Minimum (mm)		Maximum (mm)		Average (mm)		Contribution to annual (%)		Standard deviation		Coefficient of variation	
	R	RO	R	RO	R	RO	R	RO	R	RO	R	RO
Pre-monsoon	36.0	0.9	513.0	349.8	109.4	49.9	7.3	9.8	103.4	76.4	0.9	1.5
Monsoon	462	71.4	2130	963.1	1096	350.3	72.7	68.6	411.7	211.9	0.4	0.6
Post-monsoon	15.0	0.0	760.0	567.1	284	108.0	18.8	21.2	230.9	134.0	0.8	1.2
Winter	0.0	0.0	109.0	41.8	17.1	2.3	1.1	0.5	25.5	8.9	1.5	3.9

R= Rainfall, RO=Runoff

Table 6. Monthly rainfall, runoff and PET status of the Kendrapara

Month	January	February	March	April	May	June	July	August	September	October	November	December
Average rainfall, mm	4.2	9.6	10.8	16.3	82.3	148.6	299.5	410.9	237.0	238.0	46.0	3.3
Average runoff, mm	0.1	2.1	4.1	7.4	38.4	32.0	100.8	151.6	66.0	93.3	14.7	0.2
Potential ET, mm	166.0	186.1	197.1	181.4	208.2	200.8	166.3	171.5	155.5	154.8	135.4	127.2

area to store the runoff water before flowing to the sea. This will facilitate to increase the crop coverage during post and summer season by increasing overall productivity of the area.

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