

# Rainfall-Runoff Estimation Using SCS-CN and GIS Approach in the Kuakhai Watershed of the Mahanadi Basin of Bhubaneswar Odisha

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## **Abstract:**

**R**ainfall and runoff are significant constitute the source of water for recharge of ground water in the watershed. Rainfall is a major the primary source of recharge into the ground water. Other, substantial sources of recharge include seepage from tank, canals, streams and functional irrigation. Evaluation of water availability by understanding of rainfall and runoff is essential. Hydrometeorological and hydrological data are an important role in the assessment of source water accessibility for planning and design of source water accessibility for planning and design of artificial recharge structures. The surface water resources are available in the watershed from runoff from rivers, streams and in surface water bodies. The total area of study is about 453.5km<sup>2</sup>, of which fall in kuakhai river basin so considered for runoff model assessment in a watershed is a precondition for the design of artificial recharge structures, reservoir and soil erosion control. Surface water resource planning and management is an important and critical issue in the hard rock regions. Runoff in a watershed affected by geomorphological factors, particularly, land use change affects the runoff volume and runoff rate significantly. In the present case study assumed to estimate the surface runoff from a catchment but one of the Curve Number methods is mostly used. The SCS-CN method is useful for calculation volume of runoff from the land surface meets in the river or streams. The proposed construction of artificial recharge structures can be thought of in the given study area. The output is useful for the watershed development and planning of water resources effectively.

Rainfall and runoff are important components contributing significantly to the hydrological cycle, design of hydrological structures and morphology of the drainage system. Estimation of the same is carried out to determine and forecast its effects. Estimation of direct rainfall-runoff is always efficient but is not possible for most of the location in desired time. Use of remote sensing and GIS technology can be useful to overcome the problem in conventional methods for estimating runoff. In this paper, modified Soil Conservation System (SCS) CN method is used for runoff estimation that considers parameter like slope, vegetation cover, area of watershed.

**Keywords:** *Rainfall Runoff estimation, Arc GIS, SCS-CN Mathode, Kuakhai River, Remote sensing*

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## **I. INTRODUCTION**

A watershed is that contributes runoff water to a common point. It is a natural physiographic of interrelated parts and functions. There are many methods offered for rainfall runoff modeling. Soil conservation services and curve Number (SCS-CN) technique is one of the primogenital and simplest method for rainfall runoff modeling. Runoff is one of the most important hydrologic variables used in most of the water resources applications. Its occurrence and quantity are dependent on the characteristics of rainfall event, i.e. the intensity, duration and distribution. Apart from these rainfall characteristics, there are number of catchment specific factors,

which have a direct effect on the occurrence and volume of runoff. This includes soil type, vegetation cover, slope and catchment type. SCS-CN provides an empirical relationship for estimating initial abstraction and runoff as a function of soil type and land-use. Curve Number (CN) is an index developed by the Natural Resource Conservation Service (NRCS), to represent the potential for storm water runoff within a drainage area. The CN for a drainage basin is estimated using a combination of land use, soil, and antecedent soil moisture condition (AMC). There are four hydrologic soil groups: A, B, C and D. Group A have high in-filtration rates and group D have low infiltration rates. The Soil Conservation Service Curve Number (SCS-CN) method is widely used for predicting direct runoff volume for a given rainfall event.

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## **I.I RAINFALL ANALYSIS**

Rainfall is the major component of the hydrologic cycle and is the primary source of runoff. Rainfall is essentially required to fulfill various demands including agriculture, hydropower, industries, environment and ecology. It is implicit that the rainfall is a natural phenomenon occurring due to atmospheric and oceanic circulation (local convection, frontal or orographic pattern) and has large variability at different spatial and temporal scales. However, this input is subjected to uncertainty and stochastic errors. Worldwide many attempts have been made to model and predict rainfall behavior using various empirical, statistical, numerical and deterministic techniques. These data are usually collected using rain gauges, and therefore they are point precipitation data. However, the application of a single rain gauge as precipitation input carries lots of uncertainties regarding estimation of runoff. This creates a lot of problem for the discharge prediction, especially if the rain gauge is located outside the basin. As a result, some utilities such as hydrological modeling need rainfall data that are spatially continuous. The quality of such result is therefore estimated by the quality of the continuous spatial rainfall. Various spatial interpolation techniques to obtain representative rainfall over the entire basin or sub-basins have also been used in the past.

## **I.II RUNOFF ANALYSIS**

Further, rainfall generated runoff is very important in various activities of water resources development and management, such as: flood control and its management, irrigation scheduling, design of irrigation and drainage works, design of hydraulic structures, hydro-power generation, and so on. The method of transformation of rainfall to runoff is highly complex, dynamic, nonlinear, and exhibits temporal and spatial variability. It is further affected by many parameters and often inter-related physical factors. It is a common experience that for a given amount of rainfall on a watershed, the event produces a high or low runoff depending on (besides other parameters): the small or large time interval/duration, with the infiltration and evaporation losses depending significantly on how long the water remains in the watershed.

Determining a robust relationship between rainfall and runoff for a watershed has been one of the most important problems for hydrologists, engineers, and agriculturists. Many approaches are being used to estimate runoff, in which the soil conservation service curve number (SCS-CN) method (SCS 1956) converts rainfall to surface runoff (or rainfall-excess) using a CN derived from watershed characteristics and 5-days antecedent rainfall is one. Being conceptual, the runoff curve number method is simple, and this is at the root of its

popularity. The curve number method is an infiltration loss model; where infiltration is the most important loss for short term storm analysis, although it may also account for interception and surface storage losses through its initial abstraction feature, which are usually of secondary importance.

### **I.III REMOTE SENSING and GIS**

Remote Sensing and GIS techniques are being increasingly used for planning, development and management of natural resources. GIS technology helps in integrating various data sets and spatial analysis for decision making. Data acquired through remote sensing satellite can help us in mapping land and other resources in spatial and temporal domain. These technologies presently being used for solving watershed related problems like watershed planning, development and management, aim to harness all natural resources for sustainable development. Thus Remote Sensing and GIS together provide information base for efficient management of water resources.

## **II. LITERATURE REVIEW**

Assessment, simulation and prediction of rainfall and corresponding runoff are essential for stakeholders and policy makers to plan or adopt the required policies. There are various techniques available in the literature to assess, simulate and predict hydrological variables. However, the selection of these techniques normally depends on the objectives of the study, availability of required input data, the quality of available models and some pre- defined assumptions. To facilitate an adequate level of accuracy, the developer has to be responsive to the characteristics of different methods, and determine if a particular method is appropriate for the undertaken situation before embarking its usage in real application. As a result, the choice of a model is one of the important factors that will influence the forecasting accuracy. In the following sections literature review on the application of various hydrological and SCS-CN models for rainfall and runoff assessment, simulation and prediction has been summarized.

Mishra et al. (2013) derived the design CN-values for Banjar, Manot, Burhner, and Shakkar catchments of Narmada River. The study employed 10 years daily rainfall–runoff data, frequency-based design CNs of different rain durations and for 2, 5, 10, 25, 50, 100, and 200 years return periods were derived for normal, dry, and wet weather conditions, representing 50%, 10%, and 90% probability of exceedance, respectively. The design runoff values derived from design storm and design CN-values were found quite close to the conventionally derived design runoff for a given rain duration. It was observed that for a given duration, as the wetness level (wet through dry) decreases, the CN value decreases, and for a given AMC, as the duration increases, the CN value decreases, and vice versa. Further, for a given wetness condition and duration the CN value increases as the return period increases. They concluded that the study will be very helpful for hydrologist.

Mishra and Kansal (2014) suggested a simple approach for derivation of the design CN for different durations, AMCs, and return periods. In this study design CNs were derived by employing the long-term daily rainfall-runoff data of three hydro-meteorologically different watersheds, viz. Ramganga watershed in Uttarakhand (India), Maithon watershed in Jharkhand (India), and Rapti watershed in Mid-Western Region (Nepal) and tested their validity using the design runoff computed from observed data conventionally. The study revealed that for a given duration, as AMC level (AMC III through AMC I) decreases CN decreases and, for a given AMC, as duration increases, CN decreases, and vice versa. It was noticed that for a given AMC and return period, CN decreases as rain duration increases, and vice versa, furthermore, for a given AMC and duration, CN increases as return period increases. Further the study observed that for a given duration and return period, CN increases as AMC level increases from AMC I to AMC III. The results were found reasonable for return periods up to 10-year, 50-year, and 50-year for Maithan, Ramganga and Rapti watersheds, respectively.

## **III. STUDY AREA**

The Kuakhai watershed is a part of the Mahanadi sub basin in the Daya river, Kushabhadra river and Bhargabi river, located in the center part of the khordha district. The Kuakhai river flows in Bhubaneswar block and joins in the river Daya and Bhargabi through a structural fault. The river originates from the Mahanadi river on the north side of the study area. The streams from dendritic to subdendritic drainage pattern in the study region (**Fig.1**) and feeds several small reservoirs and percolation tanks.



Fig 1- Kuakhai river

The study area is bounded by north latitude  $20^{\circ} 25' 00''$  to  $22^{\circ} 25' 00''$  and east longitudes  $85^{\circ} 45' 00''$  to  $85^{\circ} 55' 00''$  falls in the Bhubaneswar of Khordha district in Odisha and covered by survey of India toposheet no.73 H/11, 73 H/12, and 73 H/15, 73 H/16 with scale of 1:50,000. The Average annual rainfall of the area is about 113.85 mm. The mean maximum and minimum temperatures recorded in the area are  $43^{\circ} \text{C}$  and  $26^{\circ} \text{C}$ . location of study area of the watershed is shown in fig. 2 while also a satellite image fig.4 and LISS-III image of the watershed are shown below it. The total area of the watershed as computed using Arc GIS is  $453.5 \text{ Km}^2$ . Towards the north-west of the catchment is a small local hilly area which is mostly covered with scrubs and forest with uneven or gentle slope contributes mostly for the surface runoff. Further towards south lies some small developed villages and towns with surfaced roads and people are mostly involved in agriculture activities. The east-ern part has mostly been covered with built up land due to un-even topography of the surface contrary to which the south-west part of the watershed has good ground water potential and even surface land due to which cultivation and livestock practices are being carried out. Almost 90% of the soil is of mixed gray (Inceptisols) type.

The catchment is situated at an elevation of 457 m from the mean sea level. It is situated at about 19.4 km from the Bhubaneswar city in Odisha state. The catchment is further classified in 3 mini watersheds. There are 173 revenue villages and two other municipalities spread over 393.57 square kilometres (151.96 sq mi). The area under the jurisdiction of the Bhubaneswar Municipal Corporation covers 135 square kilometres (52 sq mi).



Toposheet of the study area



study area with boundary

Fig.2 BASE MAP Of study area

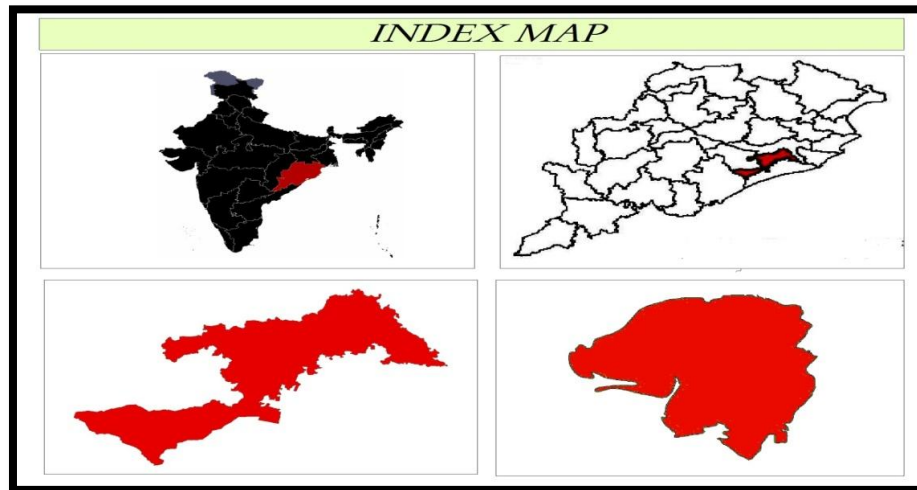


Fig. 3 Location of study area

### A. Water Resources

Kuakhai is mainly rain fed river and the water availability undergoes large seasonal fluctuations. The National Commission for Integrated Water Resources Development estimated the basin-wise average annual flow in Indian River systems as 1953 km<sup>3</sup>, out of which average annual flow of Mahanadi river basin is 36.88 km<sup>3</sup> /year. Utilizable water resource is the quantum of withdrawal water from its place of natural occurrence. The utilizable annual surface water of the country is 690 km<sup>3</sup>, out of which 19.99 km<sup>3</sup> /year is the utilizable flow of kuakhai river basin, utilized for drinking and irrigation purposes. Total replenishable groundwater resource of the country is assessed as 431.89%. After allotting 15% of this quantity for drinking, and 6 km<sup>3</sup> for industrial purposes, the remaining can be utilized for irrigation purposes. Thus, the available groundwater resource for irrigation is 361 km<sup>3</sup>, of which utilizable quantity (90%) is 325 km<sup>3</sup> (Kumar et al., 2005). Total replenishable ground water resources of Kuakhai river basin is 8.46 km<sup>3</sup>/year, out of which 2.47 km<sup>3</sup>/year ground water has provision for domestic, industrial and other uses, so 6.99 km<sup>3</sup>/year ground water is made available for irrigation. Therefore net draft of ground water resources of the basin is 0.97 km<sup>3</sup> /year. Balance ground water potential of the basin is 13.02 km<sup>3</sup> /year and level of ground water development (%) per year is 6.95 km<sup>3</sup>.

### B. Rainfall

Rainfall is dominated by the summer monsoon (June through September) with an average annual rainfall in the basin is 1293.2 mm. During the remainder of the year, rainfall is extremely low, rarely exceeding 30 mm per month. The spatial variation in rainfall is moderate in the basin. Average annual rainfall in the most upstream part of the basin is about 1000 mm, increasing toward the central basin part (1300 mm) and further in the most downstream coastal belt of the basin (1700 mm) (Asokan et al,2010).

Table-1 Rainfall Data for Monsoon period (in mm)

| Month/year | june  | july  | August | Sept  | TOTAL  |
|------------|-------|-------|--------|-------|--------|
| 2000       | 380.2 | 540.0 | 316.0  | 115.0 | 1351.2 |
| 2001       | 240.0 | 416.0 | 635.0  | 343.0 | 1634   |
| 2002       | 240.0 | 416.0 | 635.0  | 343.0 | 1634   |
| 2003       | 397.0 | 630.0 | 840.0  | 328.0 | 2195   |
| 2004       | 124.0 | 273.0 | 300.3  | 244.7 | 942    |
| 2005       | 130.0 | 296.0 | 166.0  | 585.0 | 1177   |
| 2006       | 240.0 | 416.0 | 635.0  | 343.0 | 1634   |
| 2007       | 180.0 | 194.0 | 422.0  | 581.5 | 1377.5 |
| 2008       | 333.0 | 219.5 | 310.0  | 488.0 | 1350.5 |
| 2009       | 75.0  | 455.5 | 440.0  | 226.0 | 1196.5 |
| 2010       | 227.0 | 217.0 | 316.5  | 313.0 | 1073.5 |

|         |       |       |       |       |         |
|---------|-------|-------|-------|-------|---------|
| 2011    | 242.0 | 351.0 | 378.5 | 296.0 | 1267.5  |
| 2012    | 146.0 | 455.5 | 273.0 | 154.0 | 1082.5  |
| 2013    | 255.0 | 241.0 | 163.0 | 266.0 | 925     |
| 2014    | 98.0  | 482.0 | 242.0 | 440.0 | 1262    |
| 2015    | 75.0  | 252.0 | 284.0 | 135.0 | 746     |
| 2016    | 236.6 | 314.0 | 294.9 | 289.7 | 1135.2  |
| TOTAL   |       |       |       |       | 21983.4 |
| Average |       |       |       |       | 1293.2  |

(Data collected from IMD BHUBANESWAR)

### **C. Temperature**

Temperature variation of the basin is from 7°C to 45.5°C (CWC, 2009). Summer temperatures are around 29°C and winter temperatures of 21°C. In winter the mean daily minimum temperature varies from 4°C to 12°C. In summer the mean daily maximum temperature varies from 42°C to 45.5°C (Dadhwal et al., 2010). December is the coldest month with the mean minimum temperature ranging from 10°C to 13.7°C. May is the hottest month in this region where the mean maximum temperature ranges from 38°C over the hills to 43°C in the plains. As compared to eastern portion and delta area, western portions record the lowest and highest temperatures during winter and summer respectively. The diurnal range of temperatures during July-August is of the order of 5°C to 6°C and the same during winter is up to a maximum order of 14°C to 16°C

### **D. Relative Humidity**

The highest relative humidity in the basin varies between 68% and 87% and occurs during July/August. The lowest relative humidity occurs during April/May and varies between 9% and 45%. The average highest relative humidity in the basin is 82% and the average lowest relative humidity is 31.6%.

### **E. Evaporation and Evapo-transpiration**

Monthly Evaporation of the basin ranges from 40 mm in winter to 360 mm in summer (CWC, 2009). However, the average daily pan evaporation of the basin varies from 2.4 to 14.6 mm (Tiwari et al, 2012). The Indian Meteorological Department has reported that the basin has a high rate of yearly evapo-transpiration varying from 1520 mm in the east to 1740 mm in the west.

### **F. Physiography and Soil**

Based on the physiographic set up, the district may be broadly divided in to four natural divisions such as (a) Coastal sand dune (b) Alluvial plain, (c) Lateritic upland and (d) Hilly terrain.

The dunes having limited width occur along the Chilika coast discontinuously. These deposits are fluvio aeoline in origin and are of longitudinal type.

Alluvial plain is the most potential hydrogeomorphic unit. It occurs as narrow strip along Chilika coast in the south east & along the courses of major rivers. The Alluvial plain in the northeast is a part of Mahanadi delta system.

The lateritic upland constitutes the major parts of the district. This forms an undulating terrain covered with lateritic capping over Gondwana sand stone and Precambrian rocks.

The hilly terrain is prominent in southwestern and western part. The area is underlain by Precambrian hard rocks and major part of this terrain is capped by laterities and lateritic gravels. The subunits in this terrain are (a) shallow buried pediplain (b) Moderately buried pediment (c) pediments (d) intermontane valley (e) residual hills (f) structural hills etc.

There are three types of soil generally found in the district

- 1) Alfisols
- 2) Ultisols
- 3) Entisols

**1. Alfisols:** The deltaic alluvial soil in the eastern part of the district and the red loamy soils in the northwestern part of the district come under this class. It consists of a wide range of soils including mixed red and black soils,

red earth, red loamy soils, red sandy soils, red gravelly soils and other alluvial soils. The red soils are light textured, usually devoid of lime concretions deficient in nitrogen, phosphate & organic matter. The PH of the soil varies from 6.5 to 7.3. These soils are suitable for cultivation of paddy and other crops.

**2. Ultisols:** These include laterite & lateritic soil, red and yellow soils of the northern and north central part of the district. They are characterized by low contents of Nitrogen, Phosphate, Potassium & Organic matter. The PH of the soils ranges from 4.5 to 6.0. Due to granular nature of these soils cultivation is possible immediately after heavy rains without the danger of any unsatisfactory physical state.

**3. Entisols:** These include the coastal alluvial soils along the Chilika lake and younger alluvial soils in the central part of the district. The texture in general is sandy to loamy and soils in general are deficient in nitrogen, phosphoric acid and humus. These soils are suitable for wide variety of crops including paddy.

### **G. Land use and Land cover**

The Kuakhai River originated as a branch of Kathajodi river of Mahanadi River tributaries, is one of the main river of Odisha flows slowly for 451 km and deposits more silt than any other river in the Indian subcontinent. The basin has a culturable area of about 79,900 km<sup>2</sup> which is about 57% of the basin area and 4% of the total culturable area of the country. Major crops cultivated in the basin are rice and wheat. Except in the coastal plains of Odisha, the basin has an extensive area under forests. The sparse vegetation of the highlands contrasts with the moderately luxuriant vegetation of the river valleys. The coastal plains of Odisha, with a high incidence of rainfall, are predominantly rice growing areas.

As per Land Use Classification for 1999-2000, the reporting area for land utilization is classified into (i) forest area (ii) area not available for cultivation (iii) other uncultivated lands excluding fallow land (iv) fallow land (v) net area sown (vi) total cropped area and (vii) area sown more than once. The land utilization pattern of Kuakhai river basin comprises 150.98% forest area, 10.432% area not available for cultivation, 9.137% area for other uncultivated lands excluding fallow land, 2.75% fallow land and 38.187% net sown area. Besides the total cropped area is 13.08% and the area sown more than once is 6.508%. The major part of the basin is under agriculture land use, where rice and wheat are the predominant crops. The cultivable area of Kuakhai river basin is irrigated by different sources of irrigation such as canal, tank, tube well, other well and by other sources also. The percentage of gross irrigated area by canal, tank, tube well, other well and other sources in Kuakhai river basin are 23.050, 8.463, 12.380, 18.056, 38.048 respectively. The percentage of net irrigated area by canal, tank, tube well, other well and other sources in Kakhai river basin are 5.644, 2.944, 17.905, 60.341, 13.164 respectively (CWC, 2009).

In Odisha, the Hirakud dam with its reservoir, built in 1956 with a gross water storage capacity of 8136 × 10<sup>6</sup> m<sup>3</sup>, is an engineered water storage structure that facilitates different human water uses, including water use for irrigation in the basin. Agricultural areas in the basin are cultivated throughout the year. The cropping seasons are broadly classified into Kharif (rain fed cultivation) and Rabi (irrigated cultivation) seasons. The Kharif season extends from June till November and the Rabi season spans from December till May. Out of the total annual irrigation water demand of 11km<sup>3</sup> in the basin, the Kharif season utilizes 7km<sup>3</sup> and Rabi season demands 4km<sup>3</sup>. Major land use and associated water use changes that have taken place in this basin in the 20th century are related to intense irrigation of agricultural areas (Asokan, 2013).

### **H. Data collectin**

The adopted methodology of the present study is shown in this Fig.5 which shown the flowchart for the model development of runoff. The various steps are involved in the following manner as follows. The land use and land cover map are obtained from satellite image LISS III (ORSAC, BHUBANESWAR), toposheet were collected from survey of India, BHUBANESWAR. Soil types (gray soil, red soil and mud) Texture, structure, from survey of India, Digital Elevation model (DEM) created from GIS Softwear and Rainfall Data collected 2000-2016 from SECHA SADAN BHUBANESWAR. The various steps involved in the following manner as defined the boundary of the watershed and catchment area, for which to find out curve number. After studying satellite image determine the land use and land cover (LU/LC) area of both type of land (Fig.3). Determine the soil types and convert them into Hydrological soil groups like A, B, C & D according to their Infiltration capacity of soil. The Superimpose the land use map on the hydrologic group maps obtained each land use soil group with polygon and finally, find out the area of each polygon then assigned a curve number to each unique

polygon, based on standard SCS curve number. The curve number for each drainage basin of area weighting calculated from the land use soil group polygons within the drainage basin boundaries (Kudoli and Oak 2015)

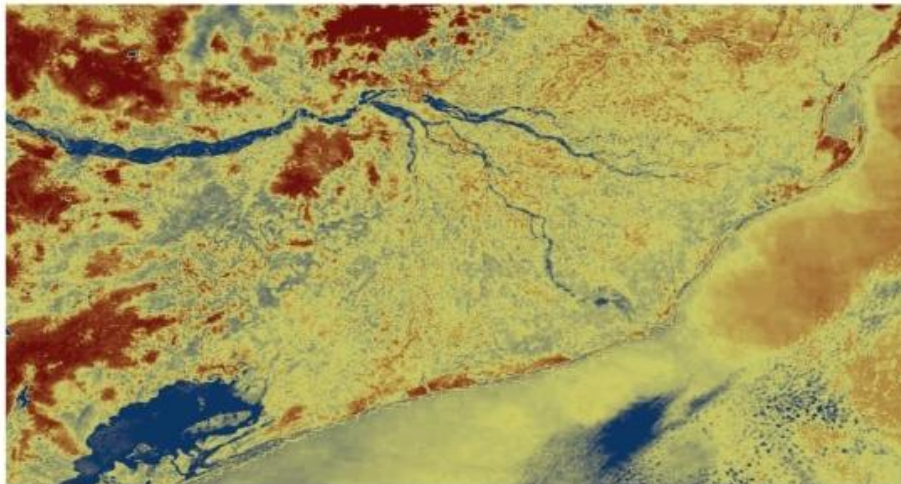


Fig.4 Satellite image of kuakhai river (collected from- [www.gettyimages.in](http://www.gettyimages.in))

#### IV. METHODOLOGY

Spatial variability is at the heart of geography, a field dedicated to understanding where things are and why. It is also a critical component in understanding many complex systems, particularly those which include interactions between wildly disparate sets of forces. Water systems, for example, can act as a powerfully unifying resource. To truly assess water resources in their most holistic sense, one needs to include the many aspects of hydrological cycle, from meteorology to surface hydrology to soil sciences to groundwater to limnology to aquatic ecosystems. And that is just physical system. The thematic map developed from a variety of perspectives of the basin provides a view of the water shed and are being used for hydrological analysis.

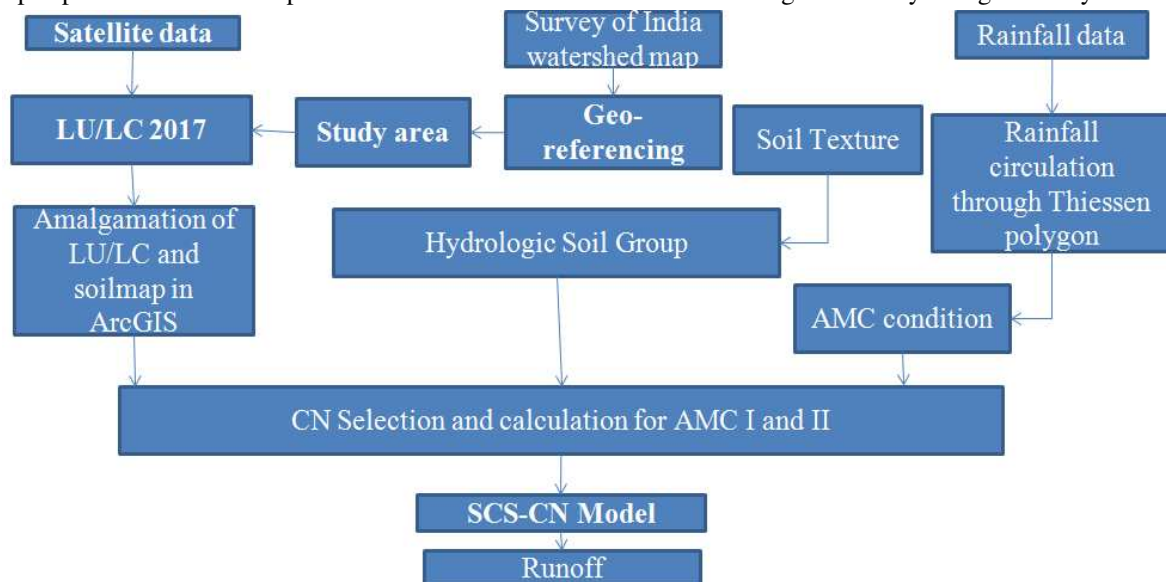


Fig.5 Flow chart of Methodology for Rainfall-Runoff

##### A. Development Study Area Maps

In the present study, the basin area of Kuakhai river system lying in Odisha and its sub-basins are delineated using a tool of Geographic Information Systems (GIS) based software called Arc-GIS. Spatial Analyst tool which is a graphical user interface of Arc-GIS delineates the basin into sub-basins and hydrologic response units (HRUs) using the digital elevation model (DEM) map, Contour map, land use map. For modeling purposes, the basin is divided into number of sub-basins. The use of sub-basins in a simulation is particularly beneficial when different areas of the basin are dominated by different land uses or soils, which may have impact on hydrology.

The conventional method of drainage basin delineation is obtained by using the topographic map. The basin divide is drawn starting from the outflow profile, drawing a line by using poly line over the area toposheet map, encompassing the headwaters and the entire stream network. This is usually done using scanned maps in CAD or GIS software, where the polygon properties can be easily calculated.

The Arc-GIS requires one spatial raster data set: digital elevation model (DEM). This map is created in the 3D Analyst Tool with the raster interpolation and elevation in meters. The digital elevation model (DEM) used in the present study, is created by using base map collected from SECHA SADAN and ARC –GIS softwear. In ARC –GIS by using Digitization Procedure we can draw the contour liens. Here is the procedure how to creat DEM of the study area. First we have to scan the toposheet and placed it in ARC- GIS softwear and then georeference that map. Geo referencing is the process which help to registerd the map by using its co-ordinate system. Once registration process complited then map is ready for Digitization process. Digitization process is very important part in ARC-GIS. In Digitization process we have to creat a shape file folder with polyline shape file for contour digitization. Then we have to go editing part in main window then select the start editing and then creat feature window will come. After that select that polyline shape file by use of mouse icon and draw the contour line over the topomap. By using this procedure we can draw the whole contour map.(fig.6) shown below.

For DEM preparation we have to select contour map as a main map and go to the Arc tool box in main window of Arc GIS . Select the 3D Analyst tool from catalog and go to the Raster Interpolation and fillup the required data and double enter in Topo to Raster. In Topo to raster fillup the Input feature data which are contour and boundary of the study area and in Outpt surface raster fill the location where you have to save the data and then press ok button. Depending on your system process it will take time and give the output as a digital elevation model(DEM).(Fig.7).The maps generated from Arc-GIS during the basin delineation process are presented in Figure 6.

**B. SCS-CN model**

The SCS–CN (1985) method has been established in 1954 by the USDA SCS (Rallison 1980), defined in the Soil Conservation Service (SCS) by National Engineering Handbook

(NEH-4) Section of Hydrology (Ponce and Hawkins 1996). The Soil conversations Service-Curve Number approach is based on the water balance calculation and two fundamental hypotheses had been proposed (Jun et al. 2015). The first suggestion states about that the ratio of the real quantity of direct runoff to the maximum possible runoff is equal to the ratio of the amount of real infiltration to the quantity of the potential maximum retention. The second hypothesis states about that the amount of early abstraction is some fraction of the probable maximum retention. The Soil Conservation Service Curve Number approach is frequently used empirical methods to estimate the direct runoff from a watershed (USDA 1972) in the study area (Table 2). The infiltration losses are combined with surface storage by the relation of

$$Q = \frac{(P-Ia)^2}{P-Ia+S} \quad (1)$$

where, Q is the gathered runoff in mm, P is the rainfall depth in mm, Ia is the initial abstraction in mm and surface storage, interception, and infiltration prior to runoff in the watershed and empirical relation was developed for the term Ia and it is given by, The empirical relationship.

The empirical relationship is,

$$Ia = 0.3S \quad (2)$$

For Indian condition the form S in the potential maximum retention and it is given by,

$$S = \left( \frac{25400}{CN} \right) - 254 \quad (3)$$

Where, CN is known as the curve number which can be taken from SCS handbook of Hydrology (NEH-4), section-4 (USDA 1972). Now the equation can be rewritten as,

$$Q = \frac{(P - 0.3S)^2}{P + 0.7S} \quad (4)$$

Significant the value of CN, the runoff from the watershed was calculated from Eqs. (3) .

The SCS curve number is a purpose of the ability of soils to allow infiltration of water with respect to land use/land cover (LU/LC) and antecedentsoil moisture condition (AMC) (Amutha and Porchelvan 2009). Based on U.S soil conservation service (SCS) soils are distributed into four hydrologic soil groups such as group A, B, C & D with respect to rate of runoff probable and final infiltration.

**C. Antecedent moisture condition (AMC)**

Antecedent Moisture condition (AMC) is considered when little prior rainfall and high when there has been considerable preceding rainfall to the modeled rainfall event. For modeling purposes, AMC II in watershed is essentially an average moisture condition. Runoff curve numbers from LU/LC and soil type taken for the average condition (AMC II) and Dry conditions (AMC I) or wet condition (AMC III), equivalent curve numbers (CN) can be computed by using the following Eqs. 5 and 6. The Curve Number values recognized in the case of AMC-II (USDA 1985) (Tables 2).

The following equations are used in the cases of AMC-I and AMC-III (Chow et al. 2002):

$$CN(I) = \frac{CN(II)}{2.281 - 0.0128 CN(II)} \quad (5)$$

$$CN(III) = \frac{CN(II)}{0.427 + 0.00573 CN(II)} \quad (6)$$

Where, (II) CN is the curve number for normal condition, (I) CN is the curve number. For dry condition, and (III) CN is the curve number for wet conditions.

$$CN_w = \sum CN_i * A_i / A \quad (7)$$

Where CN<sub>w</sub> is the weighted curve number; CN<sub>i</sub> is the curve number from 1 to any number N; A<sub>i</sub> is the area with curve number CN<sub>i</sub>; and A the total area of the watershed.

To calculate the surface runoff depth, apply the hydrological equations from 3 to 4. These equations depend on the value of rainfall (P) and watershed storage (S) which Calculated from the adjusted curve number. Thus, before applying Eq. (3) the value of (S) should be determined for each antecedent moisture condition (AMC) as shown below. There are three conditions to hydrologic condition results are summarized in the Table 3.

Table-2 Hydrological Calculation in the Watershed

| AMC | CN   | S     | P > 0.3S |
|-----|------|-------|----------|
| I   | 28.4 | 640.4 | 192.12   |
| II  | 75.4 | 82.9  | 24.87    |
| III | 87.5 | 36.3  | 10.89    |

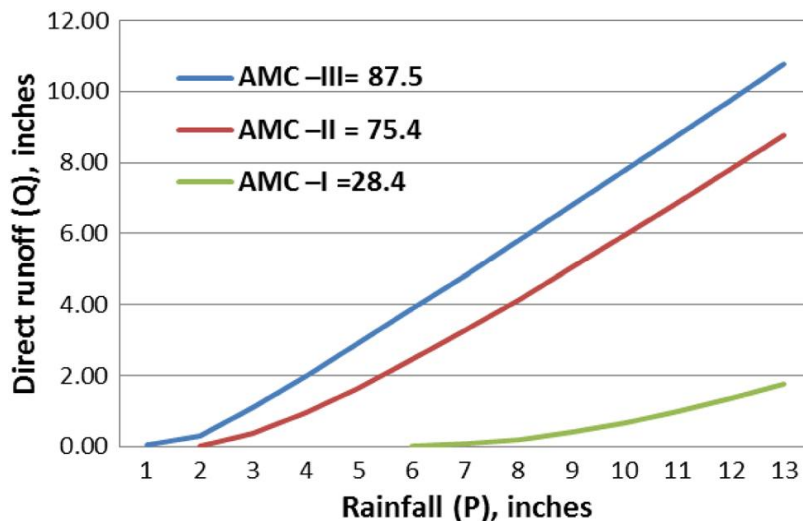


Fig.6 Solution of runoff equation (from s. satheeskumar 2016)

**D. Runoff estimation**

For runoff estimation, the above CNII is adjusted according to Antecedent Moisture Condition (AMC) of the watershed, which can be defined as the initial moisture condition of the watershed prior to the storm event of interest. The SCS-CN methodology expresses this parameter as an index based on seasonal limits for the total 5-day antecedent rainfall as follows:

1. AMC I represents dry soil with a dormant season rainfall (5-day) of less than 12.7 mm and a growing season rainfall (5-day) of less than 35.56 mm,

2. AMC II represents average soil moisture conditions with dormant season rainfall averaging from 12.7 to 27.94 mm and growing season rainfall from 35.56 to 53.34 mm, and
3. AMC III conditions represent saturated soil with dormant season rainfall of over 27.94 mm and growing season rainfall over 53.34 mm.

Later, depending on the 5-day precipitation amount, AMC II (CNII) is convertible to AMC I (CNI) or AMC III (CNIII) using any of the relations (Table 2.) given by Sobhani (1975), Chow et al. (1988), Hawkins et al. (1985), and Neitsch et al. (2002), and also directly from the NEH-4 table (SCS, 1972). A critical review on the CN conversion formulae is in order. Here, the subscripts I-III in Table 3, and elsewhere in the text refer to AMC I-AMC III, respectively.

Table 3 Group of Antecedent soil moisture classes (AMC)

| AMC Group | Soil Characteristics | Five day antecedent rainfall in mm |                |
|-----------|----------------------|------------------------------------|----------------|
|           |                      | Dormant season                     | Growing season |
| I         | Wet Condition        | Less than 13                       | Less than 36   |
| II        | Average Condition    | 13 -28                             | 36 -53         |
| III       | Heavy rainfalls      | Over 28                            | Over 53        |

**E. Hydrologic soil group (HSG)**

The soil texture map of the study area was traced, scanned and rectified in ArcGIS software by using the registered topographic maps. Different soil textures were digitized up to boundaries and the polygons representing many soil s classes were assigned and different colours for recognition. The hydrologic soil groups (HSG) divided into A, B, C, and D was carefully thought about in the classification of soils in the watershed (Table 4). recognition procedures. Despite their inherent simplicity, nearest neighbor algorithms are considered versatile and robust. Although more sophisticated alternative techniques have been developed since their inception, nearest neighbor methods remain very popular (Ly et al.)

A indicated low runoff potential, high infiltration rate, the soils of group B indicated moderate infiltration rate, moderately well drained to well drained. The soils of group C pointed to moderately fine to moderately rough textures, moderate rate of water transmission and the soils of group D pointed to slow infiltration and possible high runoff.

Table 4 Soil Conservation Service Classification (USDA 1974)

| Hydrologic Soil(HSG) | Soil textures  | Runoff potential | Water transmission | Final infiltration |
|----------------------|--|------------------|--------------------|--------------------|
| Group A              | Deep, well drained sands and gravels                                 | Low              | High rate          | >7.5               |
| Group B              | Moderately deep, well drained with Moderate                          | Moderate         | Moderate rate      | 3.8 -7.5           |
| Group C              | Clay loams, shallow sandy loam, soils with moderate to fine textures | Moderate         | Moderate rate      | 1.3 – 3.8          |
| Group D              | Clay soils that swell significantly when wet                         | High             | Low rate           | <1.3               |

**V. RESULT AND DISCSSION**

The result we got from the base map (Fig.2) by using of Arc GIS are

1. HYDROLOGY MAP
2. CONTOUR MAP
3. LAND USE AND LAND COVER MAP

By using of hydrology map we can calculate the total amount of water covered in study area and the direction of the flowing water of river, nala, canal and drainages. In this study area there are one major river Kuakhai and two no of nala Gangua and Jhamka is the main resources of water. The area covered by kuakhai river is 73.6km. Kuakhai river is also having a distributed rive on that area named as Daya river. Area covered by Daya river is 9.5km. Normal annual rain fall in this area is 156mm.

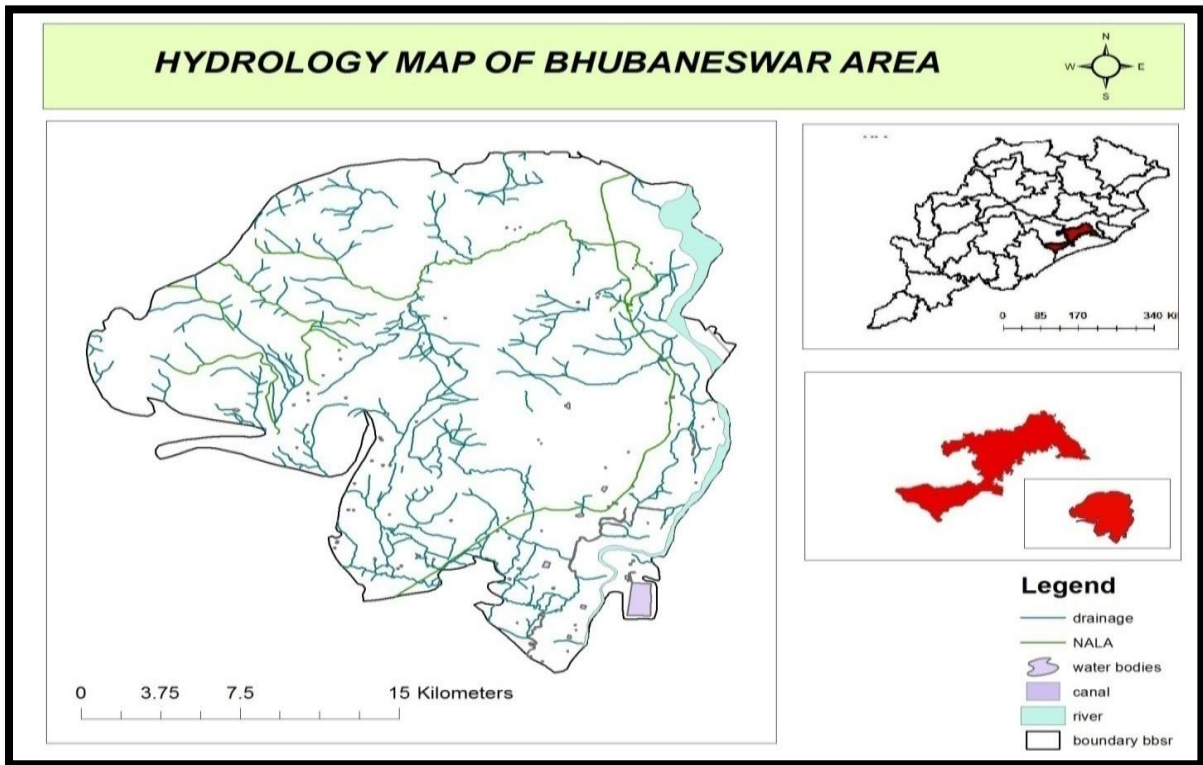


Fig.7 Hydrology map

By using of land use and land cover map we can get the type of area covered in the study area such as crop land, road, wet land, built up area, water bodies, settlement area, degraded forest, waste land, forest land, sandy area and its occupied area in km<sup>2</sup>. Total area covered in the study area is 45729 ha . From recent data the no of population are 153441. The geographical area of the study area is 234.47sq.km. The name and size of area covered by the polygons in GIS giving the results are forest land-295.1km<sup>2</sup>, cropland- 20.13km<sup>2</sup>, Baren land-5km<sup>2</sup>, Fallow land-1.83km<sup>2</sup>, Built up land- 119.27km<sup>2</sup>, Road- 0.58km<sup>2</sup> and water bodies-11.65km<sup>2</sup>.

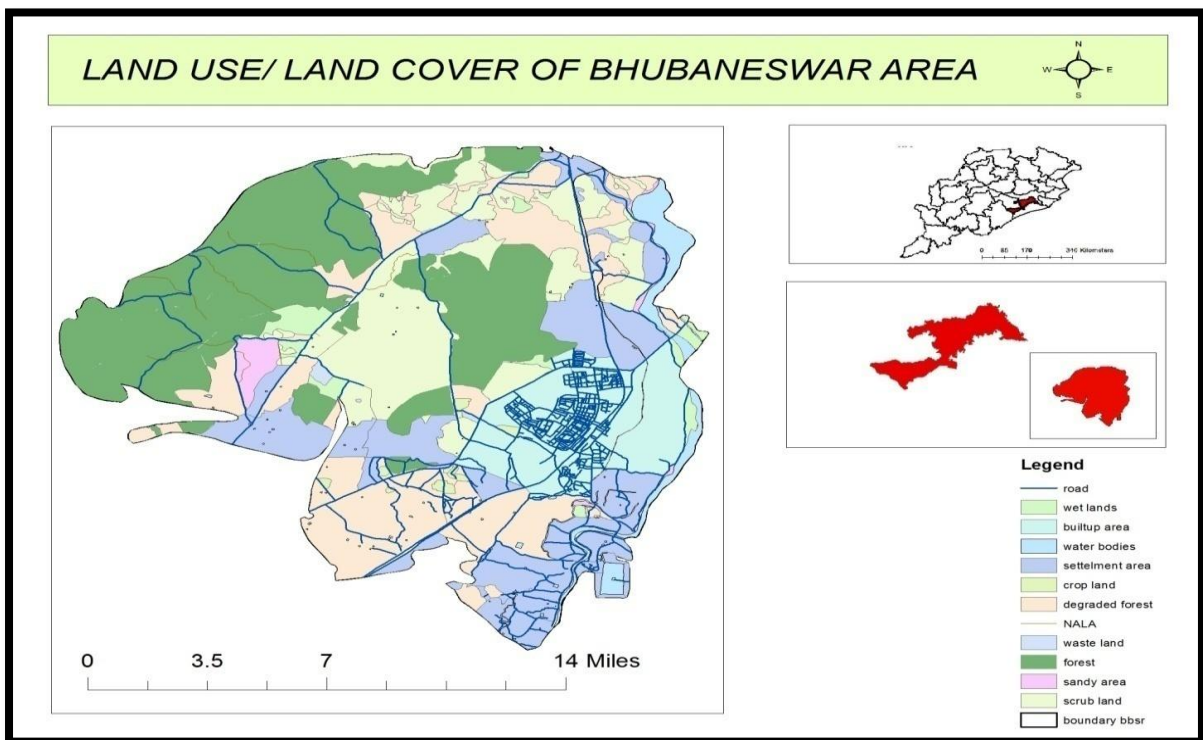


Fig.8 LANDUSE/ LAND COVER MAP

The formula used in weighted curve no calculation is

$$CN_w = \sum CN_i * A_i/A$$

Where CN<sub>w</sub> is the weighted curve number; CN<sub>i</sub> is the curve number from 1 to any number N; A<sub>i</sub> is the area with curve number CN<sub>i</sub>; and A the total area of the watershed.

Table- 5 Weighted curve number aimed at kuakhai watershed(AMC Group II)

| Land use cover | Soil type (HSG) | An area in km <sup>2</sup> | CN  | % Area | %Area * CN | Weighted Curve Number(WCN)                            |
|----------------|-----------------|----------------------------|-----|--------|------------|---|
| Crop land      | A               | 20.13                      | 72  | 13.08  | 941.76     | AMC-I = 28.4<br><br>AMC- II =75.4<br><br>AMC-III=87.5 |
|                | B               |                            | 81  |        | 1059.96    |   |
| Barren land    | B               | 5                          | 86  | 2.94   | 252.84     |   |
|                | C               |                            | 79  |        | 11927.42   |   |
| Forest land    | B               | 295.1                      | 68  | 150.98 | 10266.64   |   |
|                | C               |                            | 79  |        | 11927.42   |   |
| Fallow land    | A               | 1.83                       | 74  | 2.755  | 203.87     |   |
|                | B               |                            | 83  |        | 228.66     |   |
| Built up land  | A               | 119.27                     | 59  | 60.91  | 3593.69    |   |
|                | B               |                            | 74  |        | 4507.34    |   |
| Road           | D               | 0.58                       | 91  | 0.31   | 28.21      |   |
| Water bodies   | -               | 11.65                      | 100 | 5.88   | 588        |   |

From the base map we got the contour line in GIS through polyline method and it will give the slope and digital elevation model. from DEM we got the elevation and implication of potential runoff whether high ,low or medium. Contour map is always showing with its contour id. Here contour id is in between 20-200 with interval of 20 in each contour shown in fig.5.1.3

Digital elevation model is ageometric model developed with contour line in GIS by using Spatial analyst tool. These DEM model shows the clear features of ground with proper elevation. This model is very helpful for slope calculation. Generally slop can be generate by using of DEM. From this geographical features we can know the direction of flow of water also.

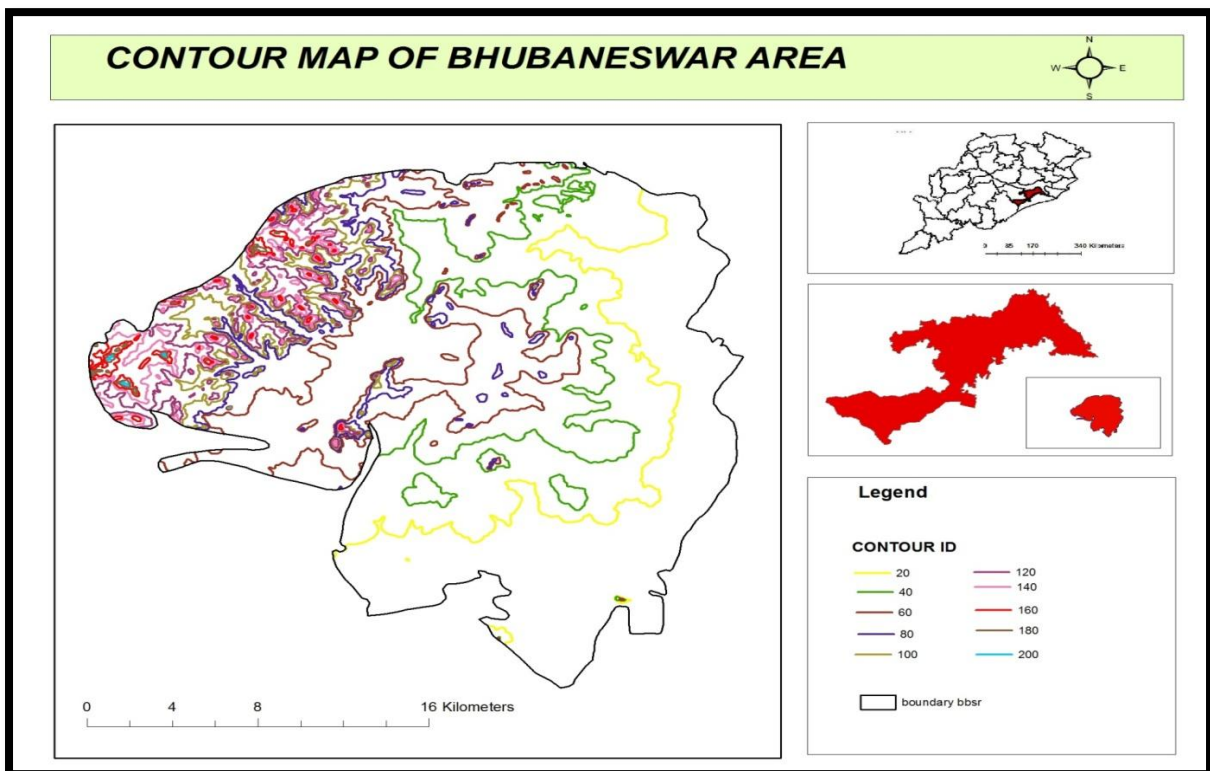


Fig.7 Contour map of the study area

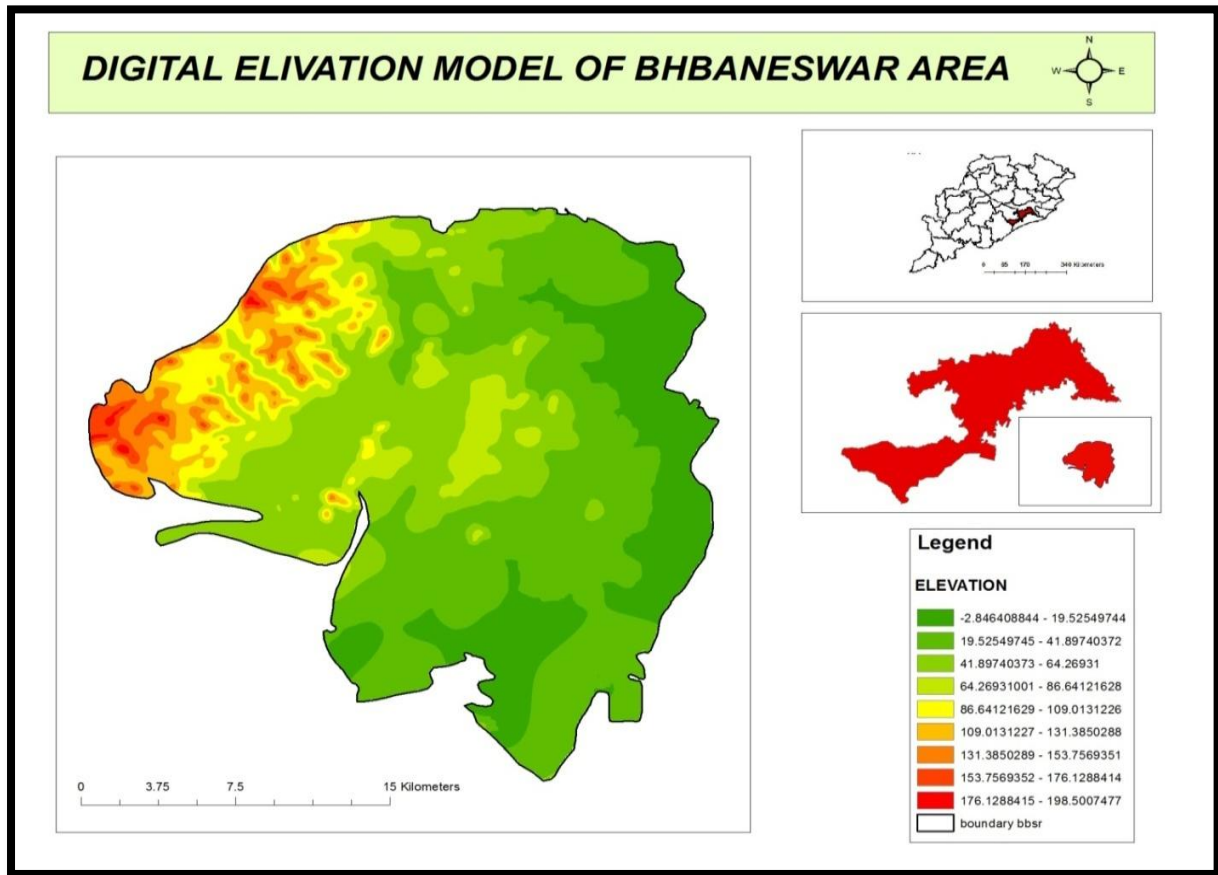


Fig.8 DEM of the study area

Here the table contain different type of slope Gentle, Moderate and steep according to the map of the study area. Depending to the slope the implication of potential can consider. In case of low level slope low surface runoff can generate whther in case of steep slope there will be high level runoff will generate. In the study area there are lots of area covered by forest and its runoff also minimum so that the area is in between Gentle and Moderate. All result is showing in the Table.6 given below.

Table 6 Slope classes of study area (IMSD 1995)

| SI. NO | % Slop       | Area in Km <sup>2</sup> | Implication of potential |
|--------|--------------|-------------------------|--------------------------|
| 1      | Nearly level | 195.85                  | Low surface runoff       |
| 2      | Gentel       | 147.57                  | Low surface runoff       |
| 3      | Moderate     | 51.68                   | Medium surface runoff    |
| 4      | Steep        | 46.54                   | High surface runoff      |
| 5      | Very steep   | 15.65                   | High surface runoff      |

Kuakhai watershed falls under Gentle to moderate slope class (Table 6) (Low to high surface runoff) representative water holding for longer time (Power et al.2008) and thus improving the chance of infiltration and recharge in this study area . This is appropriate site for artificial recharge structure such as major and minor check dams and percolation tanks beside drainage.

SCS method, as a result of the calculations, it was found that the average annual surface runoff depth for the last seventeen years in kuakhai watershed is equal to 25009.04 mm multiple by the area of the watershed (A= 453,500,000 m<sup>2</sup>) gives the total average volume of runoff as (66,715,293 m<sup>3</sup>), which represents 1.8% of the total annual rainfall. The annual rainfall and runoff during 2000-2016 in the study area are shown in Table-7. The calculated normal, wet and dry conditions, curve numbers are 22.06, 37.56 and 11.56 in Fig.9. The runoff varies 959-2785 mm (2000–2016) as shown in Fig.9

Table 7 Annual average runoff depth and volume

| Years   | Rainfall In mm | Runoff In mm | Volume(m <sup>2</sup> )<br>= Runoff * area |
|---------|----------------|--------------|--|
| 2000    | 1586.2         | 1482.6       | 67,235,911                                 |
| 2001    | 1881.5         | 1777.27      | 80,599,195                                 |
| 2002    | 1881.5         | 1777.27      | 80,599,195                                 |
| 2003    | 2785           | 2738.28      | 12,418,011                                 |
| 2004    | 1230           | 1127.56      | 51,134,847                                 |
| 2005    | 1284           | 1181.35      | 53,574,223                                 |
| 2006    | 1881.5         | 1777.27      | 80,599,195                                 |
| 2007    | 1644.5         | 1540.76      | 69,873,467                                 |
| 2008    | 1497.5         | 1394.14      | 63,224,250                                 |
| 2009    | 1405.5         | 1302.43      | 59,065,201                                 |
| 2010    | 1544.5         | 1441.02      | 65,350,258                                 |
| 2011    | 1528.5         | 1425.07      | 64,626,925                                 |
| 2012    | 1248.2         | 1181.55      | 53,583,293                                 |
| 2013    | 1751           | 1647.03      | 74,692,812                                 |
| 2014    | 1638           | 1534.28      | 69,579,599                                 |
| 2015    | 959            | 417.9        | 18,951,766                                 |
| 2016    | 1366.2         | 1263.26      | 57,288,841                                 |
| TOTAL   | 27112.6        | 25009.04     | 11,341,592                                 |
| Average | 1595           | 1471.12      | 66,715,293                                 |

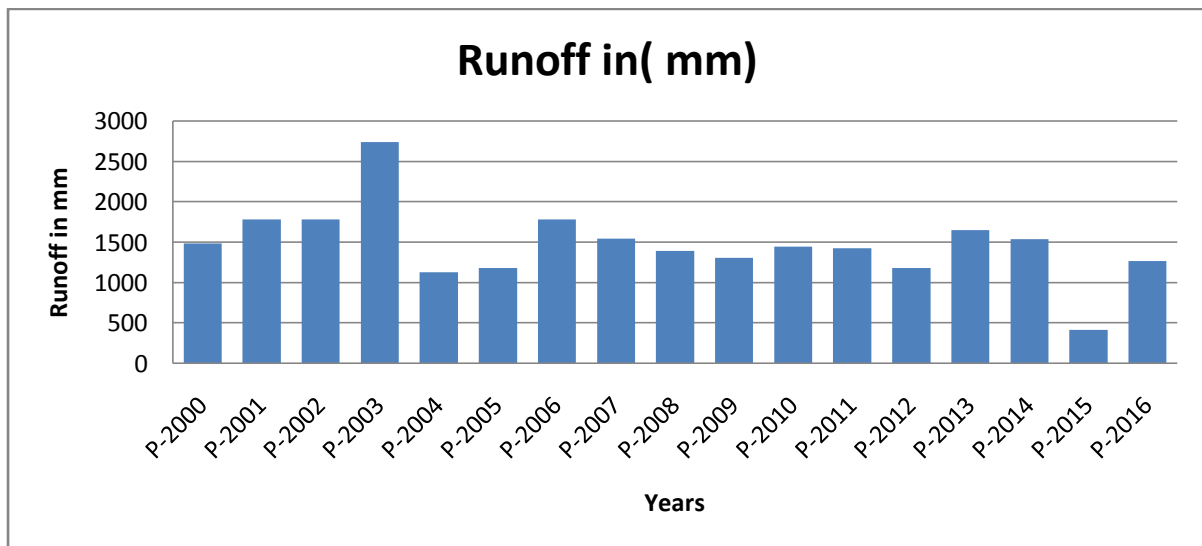


Fig.9 The runoff varies in study area

The rainfall varies between 950 to 2700mm in the watershed as shown in Fig.11. The average annual runoff calculated come to be 1471.12mm and average Runoff volume for seventeen years is 66,715,293 mm<sup>2</sup>. The rainfall runoff relationship showed in Fig.11 for kuakhai watershed, The rainfall-runoffs are vigorously correlated with a correlation coefficient R value being 0.96.

The correlation coefficient value is depends of the equation of y and x value. Here the equation value is not constant it is depending up on the rainfall and runoff quantity. In the below graphs the x axis represent 17 years rainfall data and y axis is respective rain fall runoff in mm. Here the equation gives the R value is 0.957 and eq. is  $y = 0.847x + 348.8$  in Fig 11.

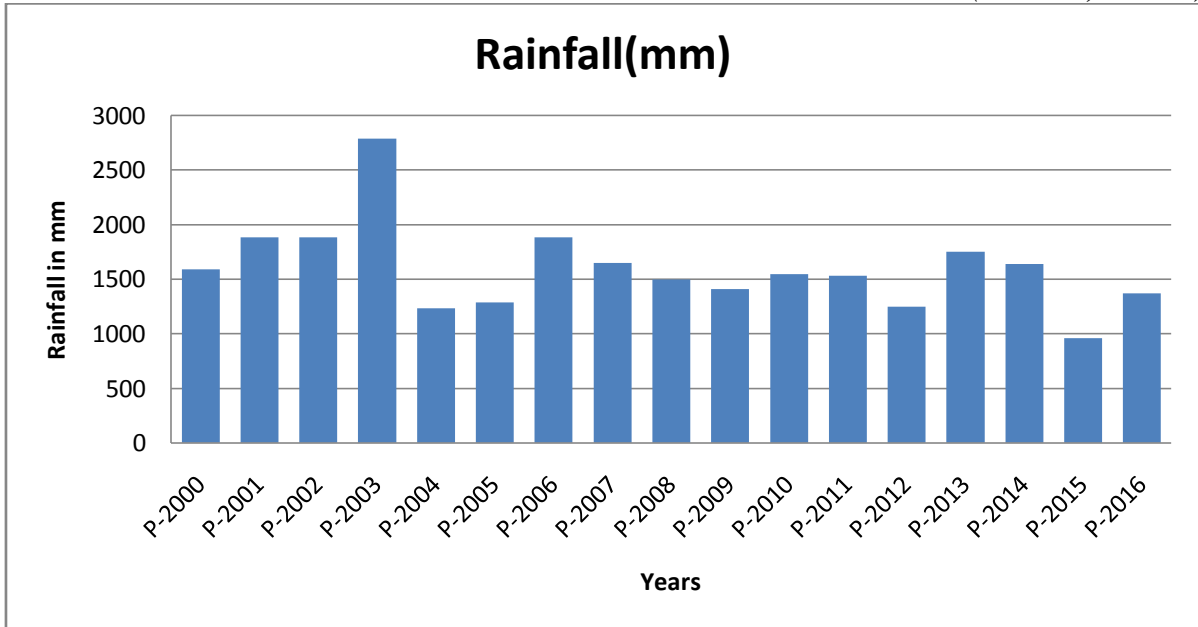


Fig. 10 The Rainfall varies in study area

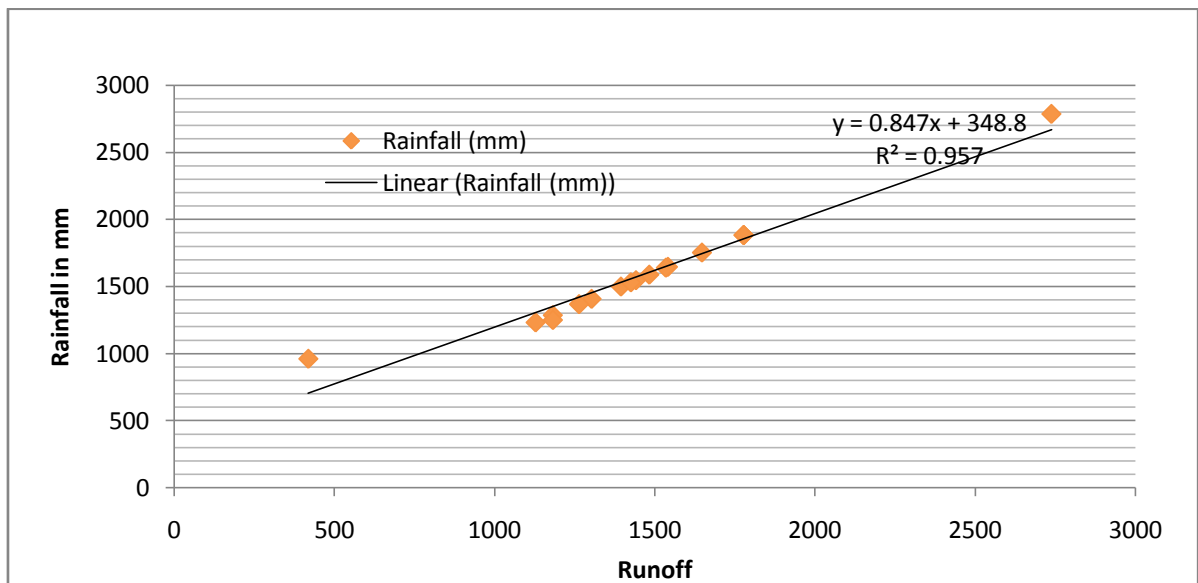


Fig. 11 Scatter plot between the rainfall and calculated runoff

## VI. CONCLUSIONS

Soil Conservation service and Curve Number model have been utilized in the present work by land use map and soil map described in Arc GIS, as input. The monthly rainfall runoff simulation found good in the watershed. The amount of runoff represents 1.8% of the total annual rainfall. In the present study, the methodology for the tenacity of runoff utilizing GIS and SCS approach could be applied in other Mahanadi watershed for orchestrating of sundry conservation measures. The good soil and water conservation measures need be planned and implemented in the watersheds such as classified as high followed by moderately high for controlling runoff and soil loss. In SCS Curve number method Antecedent moisture condition of the soil plays a very consequential role because the CN number varies according to the soil and that is considered while estimating runoff depth. For a given study area that is kuakhai watershed CN number is calculated equals to 75.4 for AMC -I, 28.4 –AMC-II and 87.5 for AMC-III (Fig. 4). In conclusion, Soil Conversations Service – Curve Number approach is efficiently proven as a better method, which consumes less time and facility to handle extensive data set as well as larger environmental area to identify site selection of artificial recharge structures.

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