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Rainwater Runoff Estimation using Empirical Formulae Computed in C Programming Software for Puriliya District of West Bengal

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Abstract

Purulia is a drought prone district of India. Monsoonal vagaries along with ustic soils and poor groundwater availability augment the sufferings of the district's residents from acute water scarcity. The main objectives of study are to identify the needs of rainwater harvesting and the possibilities of group based water distribution policy for the Bandu River basin area. Last ten years rain fall details has been collected from the meteorological department of West Bengal[4] and based on the study area soil curve number, runoff coefficient, the runoff has been estimated for the basin through empirical formulae given by SCS Relation Curve number and Aiexander Binnie[5,6] method computed by help of C programming software. Facts have been represented through suitable cartographic and statistical techniques, i.e., comparison of rainfall and runoff data. The study concludes rain water harvesting be the viable answer to the threat possessed by drought situation in Puruliya. And using software leads to increase in accuracy and speed of determination of runoff.

Keywords: Rainwater Harvesting, Runoff Estimation Programming, Statistics, Water Scarcity

1. Introduction

1.1 Geographical Details of Purulia District

Purulia district lies between 22.60 degrees and 23.50 degrees north latitudes and 85.75 degrees and 86.65 degrees east longitudes. Compass declination 0°22'W. The geographical area of the district is 6259 km^2. This district is bordered on the east by Bankura, Paschim Medinipur districts, on the north by Bardhaman district of West Bengal state5 and Dhanbad district of Jharkhandstate, on the west by Bokaro and Ranchi districts of Jharkhand state and on the south by West Singhbhum and East Singhbhum districts of Jharkhand state. Purulia is the westernmost district of West Bengal with an all-India significance because of its tropical location, its shape as well as function like a funnel. It funnels not only the tropical monsoon current from the Bay to the subtropical parts of north-west India, but also acts as a gateway between the developed industrial belts of West Bengal and the hinterlands in Orissa, Jharkhand, Madhya Pradesh and Uttar Pradesh. The latitudinal and longitudinal detail is shown in Figure 1.

1.2 Rivers and Lakes Details

Some river flow in puruliya district among them kangsabti, bandu, dwrkeswar are main one. Runoff in this area is due to undulating topography and less soil water holding capability. Some of Small dams like Murguma, Burda, Gopalpur, pardi are located in this area and are commonly used for irrigation of agriculture field. Saheb Bandh is one of the popular and famous waterbodies of Purulia. It is located in the heart of the purulia town. It is a shelter of the migratory birds which comes from Bangladesh, Burma, Pakistan, Baluchistan during December to March[2,5].

Puruliya district in West Bengal is characterized by its water scarcity and recurrence of drought often. Reasons

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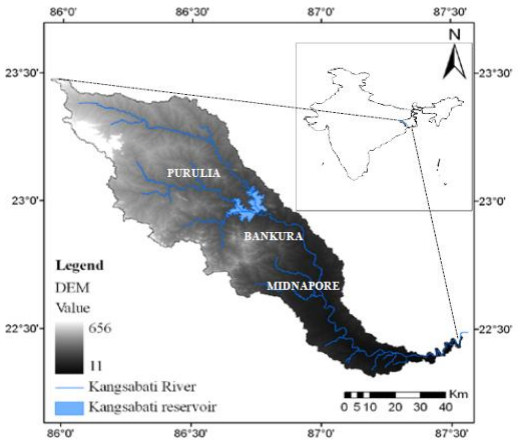


Figure 1. The latitudinal and longitudinal detail.

for drought condition are 1. Combination of monsoonal vagaries 2. Low retention capacity of soil 3. Poor yielding capacities of groundwater tables of the district have imposed a perpetual impact on its population restricting their future growth in economic and social sectors.

Rainwater harvesting is one of the way out for the water scarcity of the district if implemented and worked out with utmost care and precision. Puruliya district receives quiet good amount of rainfall at monsoon times. The amount of water received by the district is enough to support vigorous human activities if collected and utilized wisely. Thus the processes and techniques of rain water harvesting and runoff collection become foremost essential for Puruliya district[5].

1.3 River Basin Details

Rivers in Puruliya district drain into three major basins.

- The rivers of northwestern and northern part of the district drain into Damodar basin.
- Southwestern and south portion drain into Subernarekha river basin.
- The central and eastern part which cover the largest area of the district, are drained by Kasai – Kumari river system.

Apart from these three, there are upper catchment regions of Dwarkeswar and Silai rivers in the eastern boundary of the district. Thus Puruliya district contains numerous watersheds with variable size, slope, topography, soil, land cover and land use. Each watershed has its own characteristic features, hence cannot be addressed by a single strategy[2,3,5]. Here 'Bandu river basin' is taken up as a case for detailed study. River basin detail is shown in Figure 3

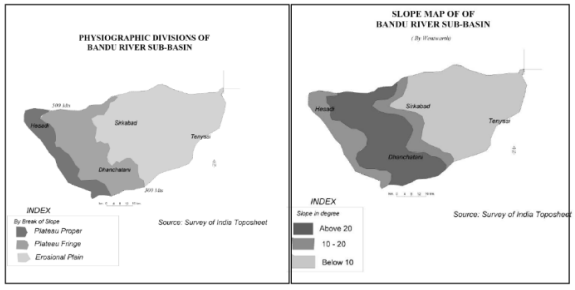


Figure 2. River and lake details.

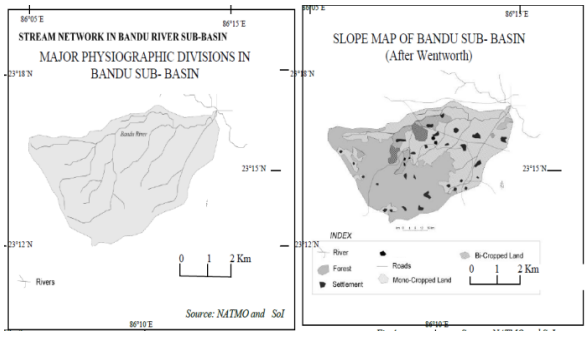


Figure 3. River basin detail.

1.4 Study Area (Bandu River Basin) Detail

Bandu river is a tributary of river Kangsabati. Its basin area covers 14,764 hectares of land divided into four micro watersheds. The basin receives 1,150 mm of rainfall even in the driest years. Our study are is between latitudes of 23°11'34.19" N to 23°19'34.19" N, longitudes of 84°04'44.54" E to 86°19'08.35" E covers area of 206.936 sq. km[2,6].

Total area covered by the basin is 14764 hectares. The basin is further subdivided into four micro watersheds; each of them covers an area between 250 and 400 hectare. Study area locations is shown in Figure 4.

1.5 Soil Detail

The soils of the area under study are residual soils developed "in-situ" mostly from granitic rocks[2]. They are mostly loamy sand to sandy loam at the surface with a heavier sub-soil showing evidence of clay illuviation at places, coloured various shades of red and are low ininherent fertility. As the region is a part of eastern fringe of Chhotonagpur plateau the soil is predominantly loamy which is not very fertile. The soil of the study area can be classified into four broad categories namely 1. Fine Loamy 2. Coarse Loamy 3. Loamy skeletal 4. Fine soil. Presence of soil detail in Puruliya district is shown in Figure 5.

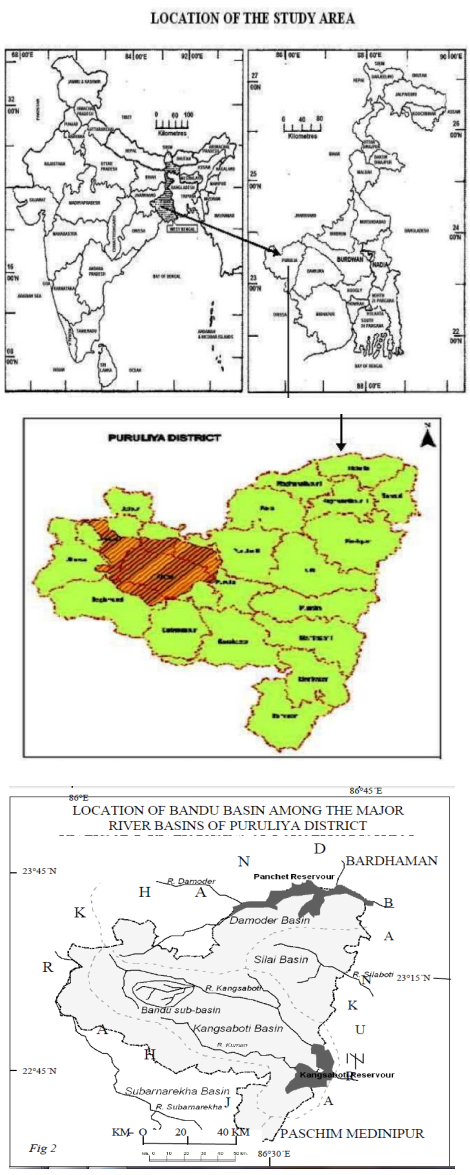


Figure 4. Study area location.

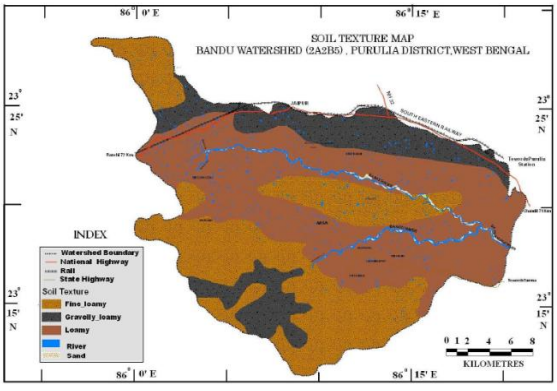


Figure 5. Soil detail in Puruliya district.

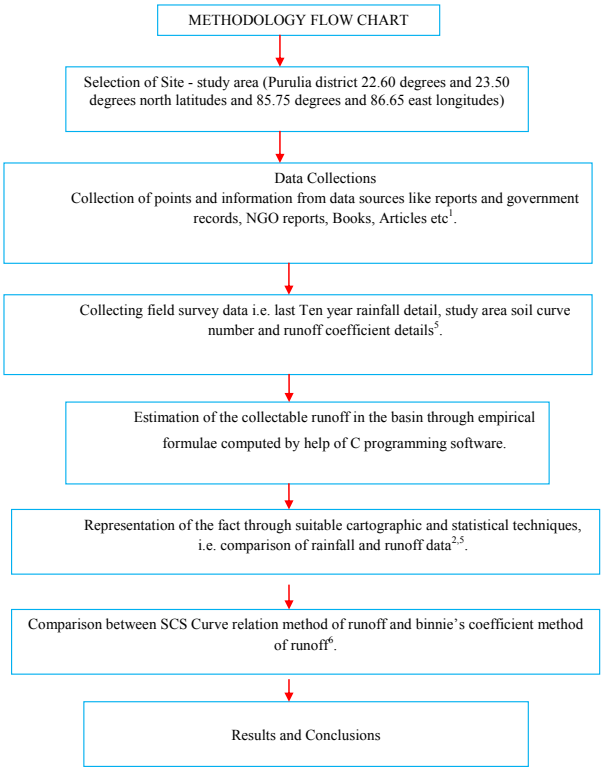
2. Need of Project and Problem Related Bandu River

- Scarcity of water for irrigation.
- Great loss of water due to run off leading to poor ground water recharge.
- Unequal and uneven distribution of monthly rain fall leading to prolonged dry season.
- Failure of monsoon leading to crops failure.
- High amount of runoff leading to great soil erosion.

3. Objective of Project

- To provide spatial distribution of average monthly precipitation, ground water, water yield and run off.
- To develop a annual and monthly water balance model of the study area.
- To estimate the runoff from the catchments.
- Increase in speed and accuracy of working.
- Identification of the needs of rainwater harvesting in Bandu river basin.
- Evaluating the need and the possibilities of group based water distribution policy for the Bandu River basin area.

4. Project Methodology



5. Estimation of Runoff

Table 1. District rainfall (mm) for last ten years[4]

Hydromet division, New Delhi India meteorological department District rainfall (mm) for last ten years

City or Town	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
2004	1	1	4	57	59	191	259	392	161	91	5	5
2005	15	19	25	20	41	140	250	204	130	209	9	17
2006	11	10	15	25	122	28	381	277	217	16	15	13
2007	33	37	39	20	69	123	549	397	348	19	13	11
2008	13	2	8	18	44	382	425	217	223	16	11	8
2009	8.9	0	11.1	1.3	113.2	55.4	293.7	337.4	262.5	72.7	9.6	0
2010	8.9	30.1	5.7	12	87.7	101.6	139.7	218	175.2	59	10.5	52.9
2011	1.2	0.2	44.2	74.6	98	523	221.8	404.6	375.4	20.3	0	0
2012	38.2	25.7	6.3	75	37.6	145.9	329	316.9	319	38.1	52.3	16.9
2013	0.7	13.8	6.7	47.1	294.1	200.9	246.6	302.8	233.8	434.6	0	0

(1) Runoff estimation by SCS Relation Curve number method computed by C programming software.

6. Output Screen

```
*********************************************
* WATER RUNOFF ESTIMATION BY C
      PROGRAMMING SOFTWARE                  *
  * MADE BY                                 *
    * SUDENT NAME - Prince Kumar Luv        *
     * Branch - Civil Engineering           *
      * Regisrtation No - 3120275           *
*********************************************
Select the method to estimate water run off
-----------------------------------------------------
PRESS 1 FOR Estimation by 'SCS RELATION' method
PRESS 2 FOR Estimation by 'BINNIE'S COEFFICIENT'
method
PRESS 3 FOR Estimation by 'BARLOW'S TABLE'
method
PRESS 4 FOR Estimation by 'INGLES AND DE
SOUZA'S FORMULE
PRESS 5 FOR Estimation by 'LACEY'S' method
PRESS 6 FOR Estimation by 'DIRECT RUNOFF'
method
1
Estimation by 'SCS RELATION' method
-----------------------------------------------
please enter value of Rainfall Jan month (in millimiter)
0.7
*********************************************
*       Hydrological Soil Group Curve Numbers *
*       ---------------------------------------*
* CATEGORY          CURVE NUMBER              *
* ------------      ------- --------------    *
*                 HSG-A    HSG-B    HSG-C     *
* Agriculture      55       69       83       *
* Plantation       39       61       83       *
* Fallow           59       70       81       *
* Scrub land       77       86       94       *
* Wasteland        45       66       83       *
* Water bodies     94       94       94       *
* Open Forest      19       40       63       *
* Forests Blank    64       71       85       *
* Degraded Forest  15       30       48       *
* Dense Forest     36       58       80       *
* River            94       94       94       *
* Sand Deposition  96       96       96       *
* Settlement's     59       74       86       *
*********************************************
please enter value of curve number from the above table
of CN = 94
(for Bandu River basin curve no. = 94)

Solution
Total Rainfall in the area      (in millimeter) P = 0.700000
Curve No. of the area     (Puruliya District) CN = 94.00000
Potential Maximum               (in millimeter) S = 0.638298
  Retention of soil
```

Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 0.270579

Like wise

Please enter value of Rainfall Feb month (in millimiter)
13.8
Please enter value of curve number from the above table of CN = 94

Solution

Total Rainfall in the area (in millimeter) P = 13.800000
Curve No. of the area (Puruliya District) CN = 94.00000
Potential Maximum Retention of soil (in millimeter) S = 0.638298
Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 13.062510

Please enter value of Rainfall mar month (in millimiter)
6.7
Please enter value of curve number from the above table of CN = 94

Solution

Total Rainfall in the area (in millimeter) P = 6.700000
Curve No. of the area (Puruliya District) CN = 94.00000
Potential Maximum Retention of soil (in millimeter) S = 0.638298
Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 5.990546

Please enter value of Rainfall apr month (in millimiter)
47.1
Please enter value of curve number from the above table of CN = 94

Solution

Total Rainfall in the area (in millimeter) P = 47.10000
Curve No. of the area (Puruliya District) CN = 94.00000
Potential Maximum Retention of soil (in millimeter) S = 0.638298
Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 46.342598

Please enter value of Rainfall may month (in millimiter)
294.1
Please enter value of curve number from the above table of CN = 94

Solution

Total Rainfall in the area (in millimeter) P = 294.10000
Curve No. of the area (Puruliya District) CN = 94.00000
Potential Maximum Retention of soil (in millimeter) S = 0.638298
Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 293.335419

Please enter value of Rainfall Jun month (in millimiter)
200.9
Please enter value of curve number from the above table of CN = 94

Solution

Total Rainfall in the area (in millimeter) P = 200.9000
Curve No. of the area (Puruliya District) CN = 94.00000
Potential Maximum Retention of soil (in millimeter) S = 0.638298
Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 200.13603

Please enter value of Rainfall Jul month (in millimiter)
246.6
Please enter value of curve number from the above table of CN = 94

Solution

Total Rainfall in the area (in millimeter) P = 246.6000
Curve No. of the area (Puruliya District) CN = 94.00000
Potential Maximum Retention of soil (in millimeter) S = 0.638298
Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 245.835693

Please enter value of Rainfall Aug month (in millimiter)
302.8
Please enter value of curve number from the above table of CN = 94

Solution

Total Rainfall in the area (in millimeter) P = 302.8000
Curve No. of the area (Puruliya District) CN = 94.00000
Potential Maximum Retention of soil (in millimeter) S = 0.638298
Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 302.03537

Please enter value of Rainfall Sep month (in millimiter)
233.8
Please enter value of curve number from the above table of CN = 94

Solution

Total Rainfall in the area (in millimeter) P =233.8000
Curve No. of the area (Puruliya District) CN = 94.00000
Potential Maximum Retention of soil (in millimeter) S = 0.638298
Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 233.0300

Please enter value of Rainfall Oct month (in millimiter)
434.6
Please enter value of curve number from the above table of CN = 94

Solution

Total Rainfall in the area (in millimeter) P = 434.6000
Curve No. of the area (Puruliya District) CN = 94.00000
Potential Maximum Retention of soil (in millimeter) S = 0.638298
Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 433.3834

Please enter value of Rainfall Nov month (in millimiter)
0
Please enter value of curve number from the above table of CN = 94

Solution

Total Rainfall in the area (in millimeter) P = 0.000000
Curve No. of the area (Puruliya District) CN = 94.00000
Potential Maximum Retention of soil (in millimeter) S = 0.638298
Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 0.000000

Please enter value of Rainfall Dec month (in millimiter)
0
Please enter value of curve number from the above table of CN = 94

Solution

Total Rainfall in the area (in millimeter) P = 0.00000
Curve No. of the area (Puruliya District) CN = 94.00000
Potential Maximum Retention of soil (in millimeter) S = 0.638298
Total Initial Rainfall without Runoff (in millimeter) Ia = 0.127660
Total Runoff in the area (in millimeter) Pe = 0.000000
Total annual Rainfall (in millimeter) = 1781.099976
Total annual Runoff (in millimeter)= 1773.943237
Average monthly rainfall (in millimeter) = 148.4282459
Average monthly rainfall (in millimeter) = 147.8286031

(2) Runoff estimation by Aiexander Binnie method computed by C programming software.

Output

2
Estimation by 'BINNIE'S COEFFICIENT' method
---
please enter value of Rainfall next month (in millimiter)
0.7

Soil Runoff coefficient Table	
AREA TYPE	RUNOFF COEFFICIENT
Urban Residential	0.3–0.5
Forests	0.05–0.2
Commercial and Industrial	0.9
Parks, Farms, Pastures	0.05–0.3
Asphalt or concrete pavement	0.85
River area(Puruliya District)	0.325

please enter value of Runoff coefficient from the above table = 0.325

Solution

Total Rainfall in the area (in millimeter) P = 0.700000
printf("Runoff coefficient of area (Puruliya District) K = 0.32500
printf("Total Runoff in the area (in millimeter) Pe = 0.245000

Like wise
Please enter value of Rainfall Feb month (in millimiter)
13.8
Please enter value of Runoff coefficient from the above table = 0.325

Solution

Total Rainfall in the area (in millimeter) P = 13.80000
printf("Runoff coefficient of area (Puruliya District) K = 0.32500

printf("Total Runoff (in millimeter) Pe = 4.485000
in the area

Please enter value of Rainfall mar month (in millimiter)
6.7
Please enter value of Runoff coefficient from the above table = 0.325

Solution

Total Rainfall in the area (in millimeter) P = 6.700000
printf("Runoff (Puruliya District) K = 0.32500
coefficient of area
printf("Total Runoff in (in millimeter) Pe = 2.177500
the area

Please enter value of Rainfall apr month (in millimiter)
47.1
Please enter value of Runoff coefficient from the above table = 0.325

Solution

Total Rainfall in the area (in millimeter) P = 47.10000
printf("Runoff (Puruliya District) K = 0.32500
coefficient of area
printf("Total Runoff in (in millimeter) Pe = 15.30000
the area

Please enter value of Rainfall may month (in millimiter)
294.1
Please enter value of Runoff coefficient from the above table = 0.325

Solution

Total Rainfall in the area (in millimeter) P = 294.1000
printf("Runoff (Puruliya District) K = 0.32500
coefficient of area
printf("Total Runoff in (in millimeter) Pe = 95.58200
the area

Please enter value of Rainfall Jun month (in millimiter)
200.9
Please enter value of Runoff coefficient from the above table = 0.325

Solution

Total Rainfall in the area (in millimeter) P = 200.900
printf("Runoff (Puruliya District) K = 0.32500
coefficient of area
printf("Total Runoff in (in millimeter) Pe = 65.29500
the area

Please enter value of Rainfall Jul month (in millimiter)
246.6
Please enter value of Runoff coefficient from the above table = 0.325

Solution

Total Rainfall in the area (in millimeter) P = 246.6000
printf("Runoff (Puruliya District) K = 0.32500
coefficient of area
printf("Total Runoff in (in millimeter) Pe = 21.22000
the area

Please enter value of Rainfall Aug month (in millimiter)
302.8
Please enter value of Runoff coefficient from the above table = 0.325

Solution

Total Rainfall in the area (in millimeter) P = 302.8000
printf("Runoff (Puruliya District) K = 0.32500
coefficient of area
printf("Total Runoff in (in millimeter) Pe = 98.410000
the area

please enter value of Rainfall Sep month (in millimiter)
233.8
please enter value of Runoff coefficient from the above table =0.325

Solution

Total Rainfall in the area (in millimeter) P = 233.8000
printf("Runoff (Puruliya District) K = 0.32500
coefficient of area
printf("Total Runoff in (in millimeter) Pe = 75.10000
the area

Please enter value of Rainfall Oct month (in millimiter)
434.6
Please enter value of Runoff coefficient from the above table = 0.325

Solution

Total Rainfall in the (in millimeter) P = 434.6000
area
printf("Runoff (Puruliya District) K = 0.32500
coefficient of area
printf("Total Runoff in (in millimeter) Pe = 141.2450
the area

Please enter value of Rainfall Nov month (in millimiter)
0
Please enter value of Runoff coefficient from the above table = 0.325

Solution

Total Rainfall in the area (in millimeter) P = 0.00000
printf("Runoff (Puruliya District) K = 0.32500
coefficient of area
printf("Total Runoff in (in millimeter) Pe = 0.000000
the area

Please enter value of Rainfall Dec month (in millimiter)
0
Please enter value of Runoff coefficient from the above table = 0.325

Solution

Total Rainfall in the area (in millimeter) P = 0.00000
printf("Runoff (Puruliya District) K = 0.32500
coefficient of area
printf("Total Runoff in (in millimeter) Pe = 0.000000
the area

Total annual Rainfall (in millimeter) = 1781.099976
Total annual Runoff (in millimeter) = 564.943237
Average monthly rainfall (in millimeter) = 148.4282459
Average monthly rainfall (in millimeter) = 47.8286031

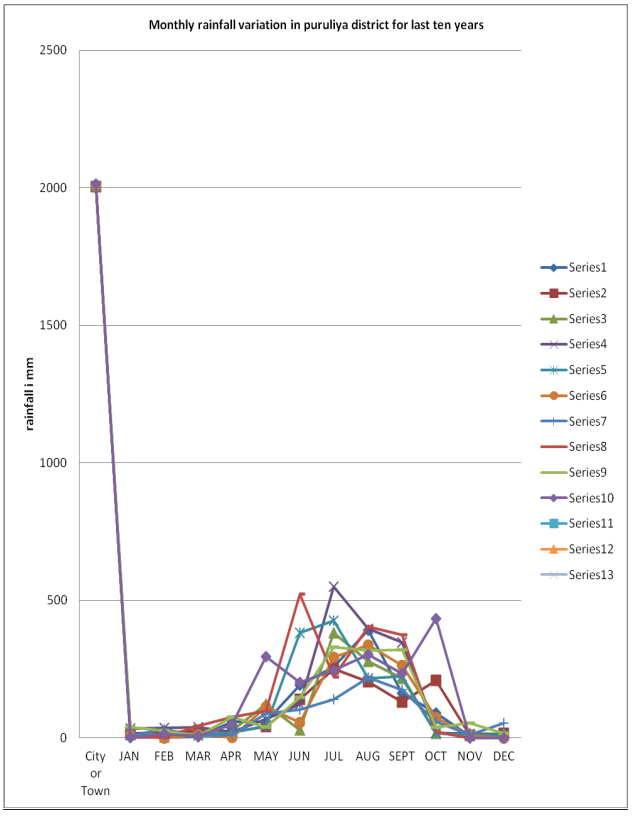


Figure 6. Graph for monthly rainfall variation in puruliya district for last ten years.

7. Representation of the Fact through Suitable Cartographic and Statistical Techniques I.E., Comparison of Rainfall and Runoff Data

The graph for monthly rainfall variation in puruliya district for last ten years is shown in Figure 6

The Rainfall and Runoff data by SCS curve relation method by 'BINNIE'S COEFFICIENT' method are computed by C programming software are compared in Figure 7 and 8. And Figure 9 compares the runoff by SCS curve relation method and BINNIE's COEFFICIENT method.

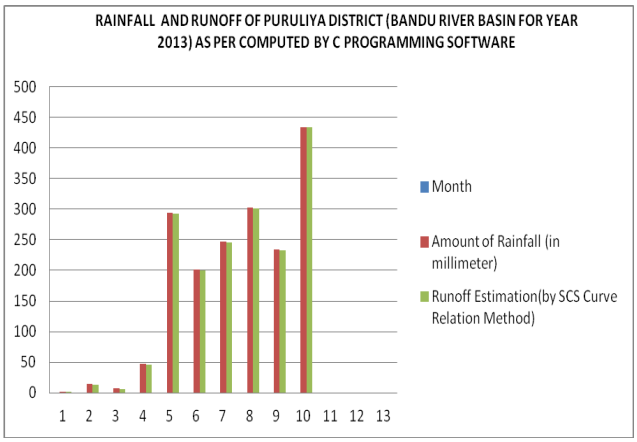


Figure 7. Graph for showing Rainfall and Runoff data by SCS curve relation method.

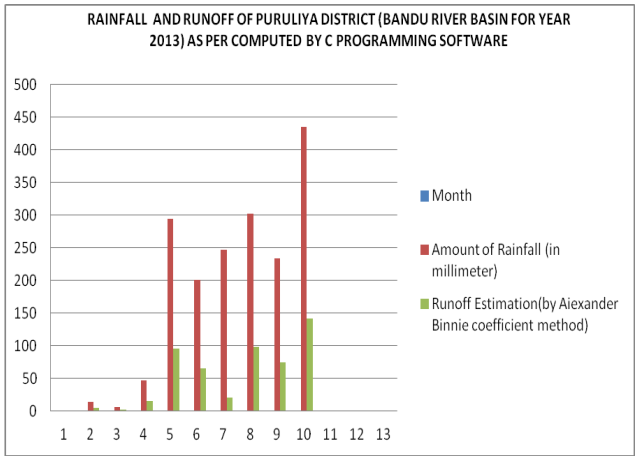


Figure 8. Graph showing Rainfall and Runoff Data by 'BINNIE'S COEFFICIENT' method.

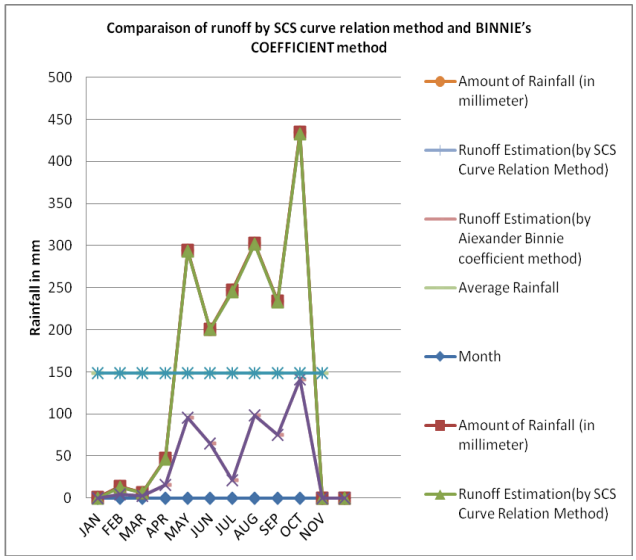


Figure 9. Comparisons of runoff by SCS curve relation method and BINNIE's COEFFICIENT method.

8. Results and Conclusion

Puruliya district is at high risk to drought hazards within the state of West Bengal all though this district gets good amount of rainfall. The only reason for prevailing of drought is improper catchment area causing excess runoff. Thus the district is called *"Ahalya Bhumi"*- the land with a stony heart. Based on the rain water runoff estimation details, planning with a particular view of rain water harvesting seems to be the viable answer to the threat possessed by drought situation in Puruliya. Proper management of the land and estimation of runoff from a particular piece of land is essential in this process[5].

The equitable share of water for each rural poor family through 'distribution group' method should be followed all over the district. It will help the district's population not only to overcome the drought situation but also bring prosperity to their life. Surface runoff, rainfall is one of the guiding factors. Sur-face runoff lag time have very good impact on temporal representation of surface runoff. However, a representative sensitivity analysis has been performed to identify the dominant factors of this basin. Thereafter it can be seen that Curve number and evapotranspiration are the key factors for predicting surface runoff and flow[5,6]. It can be seen that in monsoon periods contribution of flow through rivers in main reach is more significant. For more accurate result the model should be calibrated and validated.

9. References

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