Statistical Assessment of Hydrological Feasibility for Converting Open-Cast Mine into Reservoir

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Abstract

Paravanar and its environment often receives high-intensity short-duration rainfall which results in flood hazards. But due to the lack of conservation of floodwater and high elevation difference within the basin, it is affected by drought in the subsequent years. The main aim of this study is to check the possibilities to convert the completed open cast mine into a water storage structure which is situated inside the basin and to make sure that it serves as both flood and drought mitigation measure. To identify the amount of rainfall, which is converted to direct runoff, rainfall-runoff estimation was done. The average runoff coefficient is estimated as 0.46. It states that almost half of the rainfall is converted into the runoff. Next, the magnitude of rainfall for different return periods such as 2, 5, 10, 25, 50, 100 and 200 years was predicted. Since it is a small river basin with high intensity short duration rainfall, storage is a major concern. There are two major tanks in Paravanar River Basin named Walajah Tank and Perumal Eri. The capacity of the Walajah tank is 90.72Mcft and the Perumal eri is 574Mcft. The capacity of the mine which is proposed to be converted as a water storage structure is also calculated and it is estimated as 1125Mcft. It provides higher storage than the prevailing tanks due to the depth of the mine. Therefore, if it gets converted then it will be a floodwater harvesting structure as well as a drought mitigation measure.

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Introduction

The main motive of the study begins with the consecutive floods and droughts in Paravanar River Basin. This basin experiences flood frequently, but since the floodwater had not been harvested and left to join the sea, the basin experiences drought in the subsequent years. The annual rainfall of Paravanar River Basin was 1190mm, 1820mm, 790mm, 1420mm and 810mm for the years 2014, 2015, 2016, 2017 and 2018 respectively. The study area was examined thoroughly and identified many possible storage structures and conservation measures. One of the advantages of this basin is the completed open cast mine which can be converted to a reservoir. The implementation of these measures can be started only if it is evident that the basin will receive heavy rainfall in the upcoming years. Hence the rainfall was predicted for different return periods using Annual Maximum Daily Rainfall Events.

Extreme rainfall creates many hydrological impacts like flash flooding, modified flow regime, modified channel form, increased bank erosion, loss of species habitat, modified nutrient content, decreased infiltration, changes in river geometry which led to the collapse of the river system. Extreme rainfall events are the predominant reason for flood hazards throughout the world [8]. Flood disaster alone had accounted for 47% of all the weather-related disasters within 10 years, that affects 2.3 billion people in which 95% lives in Asia. These floods had caused sudden outbreak of several water-borne diseases in the past. It is essential to identify the suitable probability distribution function accurately so that the damages which arise due to extreme rainfall can be prevented [11]. Although rainfall is erratic, and it changes with time and space it is possible to fairly predict using different probability distribution functions [16].

Occurrences of floods in and around Paravanar River Basin due to extreme rainfall have been documented through Rapid Rural Appraisal. It is a participatory approach in which the details will be collected from the people who have witnessed or gone through the events. The Appraisal was done during the site visit with the people and the village heads in and around the study basin. In 1969 heavy rainfall of magnitude 280mm was recorded, then in November 1976 extremely heavy rainfall with 480mm magnitude was recorded along with the consecutive heavy rainfall that happened during 1985, 1996, 1998, 2005 and 2015. In December 2008, Cyclone Thane hits and damages the surroundings of the Paravanar river basin which damaged the crops heavily. Then on the 4th and 6th of December 2010, heavy rainfall down poured and damaged around 5068 livestock and 15 lakh acres of standing crops throughout southern Tamil Nadu including the study basin. During 2015, extremely heavy rainfall occurred and 100 villages had been inundated and around 200,000 people were marooned in the effect of these floods. Also, in October and November 2017, heavy rainfall happened and caused floods. Recently in November 2020, Cyclone Nivar heavily affected the surroundings of the Paravanar river basin, in which many families had been stranded due to the floodwater.

One of the major reasons for flood in this basin is 70% of excess rainfall above the average level. The precipitation of this region is majorly depending on the northeast monsoon which happens due to cyclones and the creation of a low-pressure regions in the Bay of Bengal [14]. Rainfall-runoff percentage needs to be estimated so that the amount of water that is left as runoff can be calculated and the possibilities for storing that water can be identified. The Soil Conservation Service – Curve Number method is one of the essential ways to estimate the runoff [15]. The Curve Numbers were calculated by using the soil groups and the Antecedent Moisture Condition.

To develop mitigation or precautionary measures for reducing flood disasters, it is necessary to do frequency analysis [2]. The application of frequency analysis has been broadly recognized by a large number of researchers in this field [3]. There are many types of frequency analysis distributions that are successfully applied to hydrologic data (Selaman, 2007). The Goodness of Fit tests are one of the widely used methods in which observed continuous probability distribution function will be fitted to the expected continuous probability distribution function [2]. Currently, in India, there are only very few studies had been done to validate the statistical procedure of different probability distribution functions such as Normal, Log-normal, and Gamma [8].

The Goodness of Fit test can be effectively used for identifying the suitable distribution of frequency analysis for evaluating the annual series of data [19]. The appropriate selection of distribution plays a significant role in doing proper statistical modeling with good description and interpretation [13] Goodness of Fit tests mainly use Kolmogorov-Smirnov, Anderson-Darling and Chi-squared tests. Even though the logic they follow is similar, they differ in the type of use [5]. The chi-squared test is one of the majorly used tests for frequency distributions [4] but the additional advantage with Kolmogorov-Smirnov is that the data does not get lumped and only the discrete categories will be compared [7]. Anderson Darling fits the sample probability distribution function with the parent probability distribution function [2].

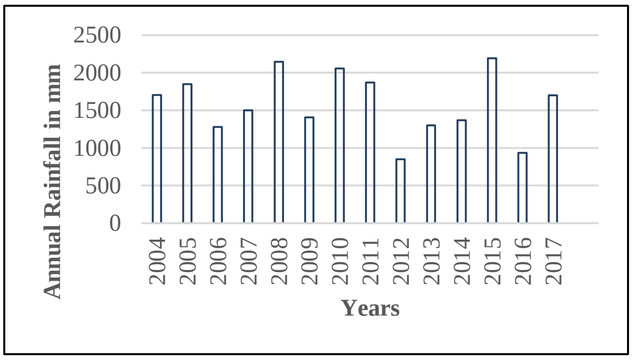

Fig. 1 Illustration of consecutive floods and droughts for Mine I Rain gauge station

Study Area

Paravanar River Basin lies within the tropical monsoon zone and this basin receives rainfall during the post-monsoon period. Hence the post-monsoon period is hydrologically significant for Paravanar River Basin. But in the case of the non-monsoon period, the rainfall is insignificant. If the monsoon fails, the entire command area will be in water deficit condition. The precipitation of this area is cyclonic and tends to develop a low-pressure region in the Bay of Bengal [14]. Even though the basin receives a moderate to heavy amount of precipitation there exist water scarcity and water quality problems [14]. This study basin is situated in the Cuddalore coastal district which is identified as one of the low-lying coastal zones, even in 2004 Tsunami had a much higher impact in this region [12]. Most of the study area is a flat plain, sloping very gently towards the sea on the east. The elevation of the Paravanar basin is higher at the dump yard from the mines and the lowermost elevation is recorded at the open-cast mines. So, the study area consists of three open-cast lignite mines with three thermal power plants. The average annual precipitation is 1369 mm in which most of the contribution from the northeast and the lesser contribution from the southwest monsoons [6]. This region is mostly covered with the C and D hydrologic groups of soil. The study area map along with its land use land cover classification is shown in figure 2.

Since it is a coastal basin, it lies in the heavy wind and cyclone zone. Mainly the downpour happens during October, November and December which inundates the low-lying areas and the coastal areas. The number of depressions and cyclones are around 124 in this region including the last cyclone Nivar which had an effect in this area during November 2020. [20]. Also, the lack of maintenance of water bodies such as the absence of desilting of water bodies regularly adds to the surface flow during floods.

Paravanar river basin was affected by floods due to extreme rainfall as well as consecutive droughts. Therefore, it is necessary to harvest floodwater to overcome the drought situation. Recently major floods had occurred during 2005, 2008, 2010, 2011, 2015, 2018 and 2020 whereas 2006, 2009, 2013, 2014 and 2016 were water scarce years which is shown in figure 1. In 2015, the number of rainy days was 36 and the magnitude was 15557.94mm but in the very next year 2016, the number of rainy days was 21 and the magnitude was 6246.14mm. This insists on the significance of floodwater harvesting.

Methodology

The study basin consists of 12 rain gauge stations including the stations situated in the mine sites. The daily rainfall data for 23 years were collected from Neyveli Lignite Corporation and Institute for Water Studies. The Rainfall-Runoff was calculated using the SCS-CN method and the magnitude of rainfall was calculated using the frequency analysis using Theoretical and Empirical Probability Distribution Functions. The details of the mines were collected from the mine closure planning of Neyveli Lignite Corporation using which the capacity of the mine void is calculated. This mine void is the target area to be converted as a water storage area.

Rainfall-runoff estimation

The SCS Runoff Curve Number (CN) method is described in detail in National Engineering Handbook-4 [17]. The SCS runoff equation is

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

Q = runoff (in), P = rainfall (in), S = potential maximum retention after runoff begins (in) and Ia = initial abstraction (in).

Initial abstraction (Ia) is the overall loss of water before runoff begins. This consists of water stored in surface depressions; water captured by vegetation, evaporation and infiltration. Ia is usually varies heavily but it needs to be correlated with soil and land cover parameters [10]. After the study with many small agricultural watersheds, Ia was found to be approximated by the following empirical equation.

$$I_a=0.2\,S \quad (2)$$

By removing Ia as an independent parameter, this approximation allows the use of a combination of S and P to produce a unique runoff amount. On substitution,

$$Q=(P-0.2S)^2/((P+0.8S))\qquad(3)$$

S is in connection with CN by means of the soil and land cover situations of the watershed. The range of CN varies from 0 to 100 and equation 4 shows the relationship between S and CN [18],

$$S=1000/CN-10\qquad(4)$$

There are many factors affecting runoff such as soil type, vegetation, slope, structure, size, antecedent moisture condition, etc. Antecedent Mo isture Condition depends on the amount of preceding rainfall to the modeled rainfall. The runoff curve numbers can be calculated by using the average antecedent moisture condition, land use land cover and the hydrologic soil groups of the region.

$$CN(I)=(CN(II))/(2.281-0.0128CN(II))\qquad(5)$$

$$CN(III)=(CN(II))/(0.427+0.00573CN(II))\qquad(6)$$

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

Empirical frequency analysis

Frequency analysis is generally used to estimate the probable amount of rainfall and flood at various stages [7]. There are major probability distributions such as Log-Normal, Log Pearson, Extreme Value which can be used to compute the frequency. Weibull’s formula is used for the Empirical Frequency analysis in this present study. The theoretical probability analysis was done by using Easy-Fit software. Both the ECPDF and TCPDF were compared by using the following three goodness of fit tests namely Chi-squared, Kolmogorov-Smirnov and Anderson-Darling.

The probability of exceedance (p) was identified by the rank order method using Weibull’s formula. It is arranging the AMDR events in descending order, so the largest number will be ranked first and the least will be ranked last.

In equation 7, p is the exceedance probability, i is the rank of the event and n is the sample size that is 23 in this case.

$$p=i/((n+1))\qquad(7)$$

Also, by using Weibull's formula for return period the inverse of the probability of exceedance can be used, which is stated below. This equation is used to derive the empirical

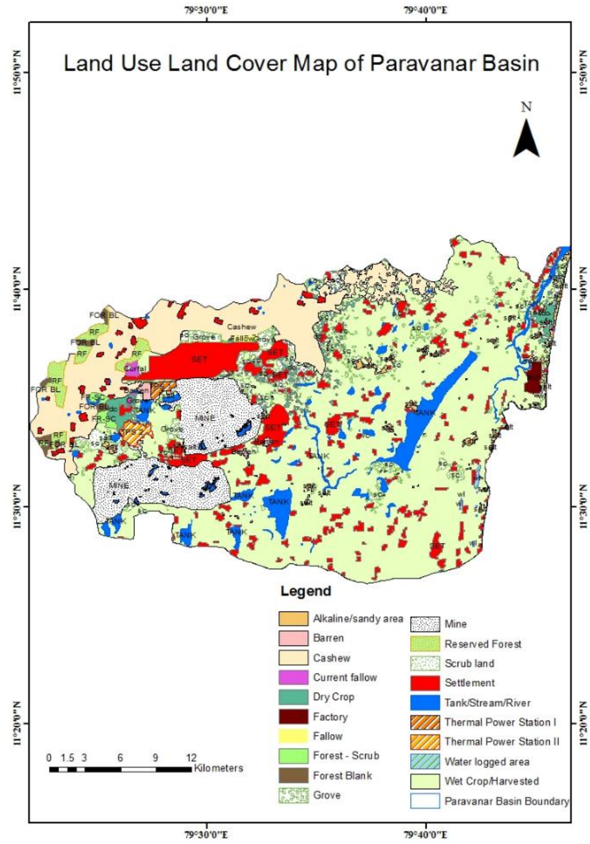

Fig. 2 LULC Map of Paravanar River Basin delineated using Arc GIS

return period of AMDR events.

$$T=1/p \quad (8)$$

Risk analysis

AMDR events that are greater than 200mm were identified as the events that caused flood disaster. Hence 200mm was considered as the threshold. Based on this the risk analysis was done by the following method. Let's take xt to be the threshold of AMDR event. The probability (p) that the event exceeds xt at least once in N years is demonstrated below,

$$p=P(X\geq x_t) \quad (9)$$

$$P(X\leq x_t)=1-p \quad (10)$$

which tells that the probability of rainfall events greater than or equal to xt can also be written as the probability of the rainfall events less than xt subtracted from 1.

$$P(X\geq x_t \text{ at least once in N years}) = 1 - P(X<x_t \text{ in all N years}) \quad (11)$$

$P(X \geq x\_t$ at least once in N years$) = 1 - (1-p)^N$

$= 1 - (1-1/T)^N$ (12)

This is the equation used for estimating the risk associated with the AMDR events with a magnitude greater than or equal to 200mm at least once in 1,2,3,4 and 5 years.

Stochastic frequency analysis

Theoretical Continuous Probability distribution functions were used to estimate the quantiles of the return period of up to 100 years. The best fir candidate Probability Distribution Function for the AMDR events was identified using Easy-Fit software. The identified TCPDF's were analyzed using three goodness of fit tests namely, Chi-squared, Kolmogorov-Smirnov and Anderson-Darling.

Theoretical probability distribution function

The identification of TCPDF was done by probability-probability plots using Easy-Fit Software from which the best-fit can be visually identified for the analysis of frequency and magnitude. The values of TCPDFs were plotted against the values of ECPDFs and the closest three distributions were identified as the best-fit distributions.

The identified best-fit distribution was now analyzed using quantile-quantile plots, where the AMDR data will be plotted against the inverse cumulative distribution function. The three goodness of fit tests analyze the data and produce the three best-fit results. So, the total number of identified best fir distributions will be 3. Each goodness of fit test ranks the best-fit distribution separately. The ranks were then added for all the three tests and the lowest rank will be titled as the best fit for the station.

Results and Discussion

Rainfall-runoff coefficient

The runoff coefficient from table 1 represents that 46% of rainfall was converted as runoff. It is based on many different facts and the major role was played by the land use and the antecedent moisture condition. It is identified that the soil groups that prevail here are majorly type C and D. These types of soils have moderately high to high runoff potential. Curve Number depends on the soil groups and the antecedent moisture condition which was considered while calculating the depth of the runoff. The curve number was found to be 74.63 for AMC I, 86.85 for AMC II and 93.86 for AMC III. The initial abstractions were calculated using the curve numbers and it was found out to be 17.26, 7.69 and 3.32 for the three different AMC conditions respectively. The average volume of runoff was calculated as 542.41m3.

Magnitude of rainfall for different return periods

The empirical return period was calculated for all the stations using Eqn. 8. The threshold value for the magnitude of rainfall was identified as 200mm. The empirical return period for the estimated threshold was around 8-10 years which varies based on the location of the rain gauge station. It is identified that the upper part of the basin which is called Uppanar receives lower rainfall when compared to the lower part of the basin called the Paravanar sub-basin.

The exceedance probability was calculated by using Eqn.12 and it is given in table 2. It describes that the probability of exceedance of rainfall which is greater than 200mm that can happen once in 5 years is 0.41.

TCPDFs were analyzed for all the rain gauge stations separately and the 3 following TCPDFs were identified as the best fit for the stations in and around the study basin. They are Log Pearson type III, Log Logistic 3 Parameter and Gumbel max distributions by using Easy Fir Software. A Probability-probability plot helps to visually identify the best-fit for each station.

Cuddalore plots are shown as a sample here. The best-fit was identified from the quantile-quantile plot which is shown in figure 4. Similar kinds of plots were created by using Easy-Fit Software for all the other stations. Table 3 shows the sample of identified TCPDFs for Cuddalore, which shows the test static and their ranks for all the three goodness of fit tests separately. The ranks were then summed up and the lowest tank will be considered as the best-fit TCPDF.

Quantile functions were used to estimate the magnitude of rainfall. The quantile function for Log Pearson type III been already estimated [1] and Gumbel Max. the quantile function for the Log Logistic distribution was derived manually by inversing the Cumulative Distribution Function. The parameters needed for the estimation of quantile function were calculated using the Easy-Fit Software.

Here XT is the magnitude of rainfall,   is the mean, Sx is the standard deviation and KT value can be calculated using the given equation in which Yn and σn can be calculated using the number of events from the table [9] and YT can be calculated using the given equation in which Tr is the return period. The estimated parameters for all the three distributions for each station are shown in Table 5. Equations showed in table 4 were used to estimate the magnitude of rainfall events for the return period of 2, 5, 10, 25, 50, 100 and 200 years. The estimated total rainfall magnitude for this region for each of the above-mentioned return periods are 1461.46mm, 2114.52mm, 2593.47mm, 3282.75mm, 3885.1mm, 4568.38mm and 5492.68mm were shown in table 6. This rainfall can create runoff of 672.27mm, 972.67mm, 1192.99mm, 1510.06mm, 1787.15mm, 2101.45mm and 2526.63mm respectively. It needs to be noted that the rainfall-runoff analysis was done for the annual rainfall and the magnitude of rainfall was calculated based on every single event.

The runoff for these return periods was calculated using the runoff coefficient and hence, the average volume of runoff would be 586.46Mm3, 848.51Mm3, 1040.70Mm3, 1317.29Mm3, 1559Mm3, 1845.22Mm3 and 2196.06Mm3. The accuracy of the results can be validated here with the volume of runoff for the 2-year return period and the average runoff of this basin. Both the volumes are almost equivalent.

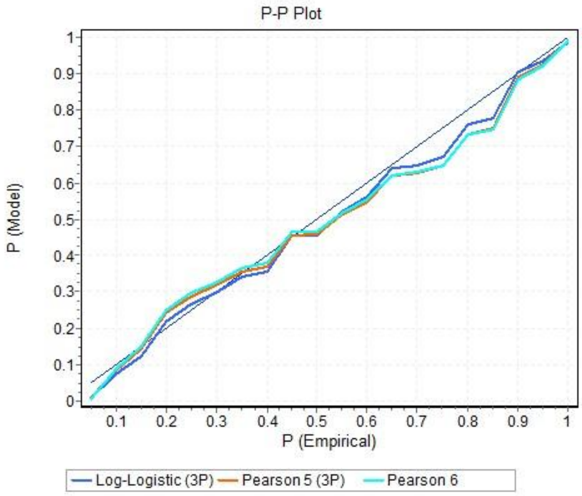

Fig. 3 Cuddalore Probability Plot

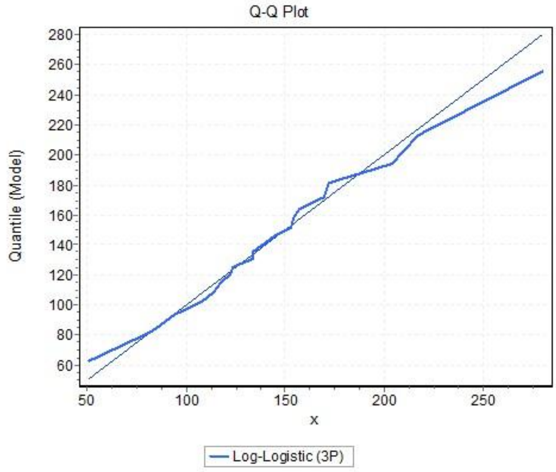

Fig. 4 Cuddalore Quantile Plot

Table 1 Calculation of Runoff Coefficient

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Rainfall in mm	1735.15	1287.34	1393.7	1847.4	1379.31	1676.52	1406.41	818.19	1171.28	1177.89	1833.7	775.68	1436.19	814.54
Runoff in mm	848.5	563.24	687.42	804.58	653.09	779.66	677.18	414.11	452.86	476.32	1030.12	249.18	681.7	387.05
Runoff coefficient = Runoff /Rainfall	0.49	0.44	0.49	0.44	0.47	0.47	0.48	0.51	0.39	0.4	0.56	0.32	0.47	0.48

Table 2 Probability of exceedance for events of magnitude >200mm

Year	1	2	3	4	5
P(>200mm)	0.10	0.19	0.27	0.34	0.41

Distribution		Log-Logistic (3P)	Pearson 5 (3P)	Pearson 6
Kolmogorov Smirnov	Statistic	0.07998	0.10297	0.10437
	Rank	1	4	6
Anderson Darling	Statistic	0.13944	0.23459	0.26484
	Rank	1	2	5
Chi-Squared	Statistic	1.89E-04	1.93E-04	2.96E-05
	Rank	2	3	1
Sum of Rank		4	9	12

Table 3 Goodness of Fit for Cuddalore (Easy-Fit Software)

Log Pearson type III	Log Logistic 3	Gumbel Max
$X_T = Antilog\,(Y_T)$ $Y_T = \bar{X} + (K_T \times S_Y)$	$F(x) = \frac{1}{\left[1 + \left(\frac{\beta}{x-\gamma}\right)^{\alpha}\right]}$ $F^{-1}(x) = X_T = \left(\frac{\beta}{\sqrt[\alpha]{\frac{1-x}{x}}}\right) + \gamma$	$X_T = \bar{X} + (K_T \times S_x)$ $K_T = \left(\frac{(Y_T - Y_n)}{\sigma_n}\right)$ $Y_T = -ln\left[ln\left(\frac{T_r}{T_r - 1}\right)\right]$

Table 4 Distributions with their Quantile Functions

Table 5 Best-fit Distribution and their estimated parameters

Station	Best-fit Distribution	Estimated Parameters using Easy-Fit
Bhuvanagiri	Log Pearson 3	$\bar{X}$=2.15, Sy=0.17, Coeff. Of Skewness=-0.2471
Block 16	Log Logistic 3P	a=2.8318, b=84.237, g=39.777
CARD	Log Pearson 3	$\bar{X}$=2.037, Sy=0.21, Coeff. Of Skewness=0.7437

Cuddalore	Log Logistic 3P	a=8.235, b=209.78, g=-71.722
Kothavacheri	Gumbel Max	Y_n=0.52355, σ_n=1.06283
Kuppanatham	Log Pearson 3	$\bar{X}$=2.103, Sy=0.213, Coeff. Of Skewness=0.099
Mine IA	Log Logistic 3P	a=1.658, b=40.197, g=90.842
Mine-II	Log Pearson 3	$\bar{X}$=2.096, Sy=0.1714, Coeff. Of Skewness=-0.0013
Parangipettai	Log Pearson 3	$\bar{X}$=2.203, Sy=0.1644, Coeff. Of Skewness=-0.3879
Sethiathope	Log Pearson 3	$\bar{X}$=2.162, Sy=0.1842, Coeff. Of Skewness=0.4779
Vanamadevi Anicut	Log Pearson 3	$\bar{X}$=2.045, Sy=0.2889, Coeff. Of Skewness=-0.0829

Table 6 Estimated magnitude of rainfall for respective return periods

Rain gauge Station	**Best-fit Distribution**	**Magnitude of rainfall (mm) for the respective return period**						
		2 years	**5 years**	**10 years**	**25 years**	**50 years**	**100 years**	**200 years**
Bhuvanagiri	Log Pearson 3	144.02	197.78	231.35	271.70	300.39	327.93	354.71
Block 16	Log Logistic 3P	124.01	177.22	222.79	298.54	372.71	466.57	585.91
CARD	Log Pearson 3	102.81	159.54	208.01	284.31	352.84	433.59	528.30
Cuddalore	Log Logistic 3P	138.06	176.52	202.21	236.86	264.80	294.80	327.23
Kothavacheri	Gumbel Max	145.10	233.33	291.74	365.55	420.30	474.66	528.81
Kuppanatham	Log Pearson 3	126.28	191.37	239.49	305.22	357.59	413.00	471.64
Mine IA	Log Logistic	131.0	183.5	242.1	364.1	511.2	733.29	1069.7

	3P	4	9	1	5	0		1
Mine-II	Log Pearson 3	124.78	173.95	206.92	248.97	280.56	312.33	344.67
Parangipettai	Log Pearson 3	163.40	220.42	254.32	293.41	320.13	344.96	368.47
Sethiathope	Log Pearson 3	140.53	204.89	254.57	325.81	385.42	451.06	523.32
Vanamadevi Anicut	Log Pearson 3	121.46	195.91	239.96	288.23	319.16	346.19	369.91
Total		1461.49	2114.52	2593.47	3282.75	3885.1	4598.38	5472.68

Capacity of the open cast mine

There were three mines situated in this region. The soil which was dug from the mines was being dumped at the completed portion of the same mine and which was converted into an afforestation park. Since the soil was dumped artificially it is not possible to build any structures on top of that. Even after dumping the excavated soil, some portion of the mine will be left as a void area. This void area can be converted into a water storage structure. The total quarry area of mine 1 is 10665.4Ha and the area left out as void after reclamation and afforestation is 25.5Ha, which is 0.24% of the total mined out area. The average depth of the final void area is 125m.

Capacity = $25.5 \times 100^2 \times 125$ = 3,18,75,000m^3=31.875Mm^3=1125Mcft.

Since the average volume of runoff was 542.4Mm3 the capacity of this mine can store 5.8% of the average volume of runoff. And it can hold up to 5.4% and 3.8% if the 2 and 5 – year return period of rainfall. Even though it may not serve as a good flood prevention structure, it is truly a good drought mitigation measure. The possibilities for the reuse of the excavated soil should be studied so that the whole mine site can be converted as a reservoir. If the whole area is utilized then the capacity would be 13,331.7Mm3. This will do the purpose of flood prevention along with drought mitigation. Also, this is the plan for the first mine which is closed and there are two more mines that are under operation which can also be converted after completion. This mine is situated near the Eastern Garland Canal which can be used for the distribution of the stored water. Hence, it is evident that this mine can be converted into a water storage structure which can help the surroundings of this region during the period of water scarcity. If this is implemented then three times of this storage can be done by converting the other two mines into water storage structures after completion which can lead to store 17.4% of the average volume of runoff.

Conclusion

The prime focus of this study is to estimate the magnitude of rainfall in the upcoming years which should be stored to handle the water-scarce period. Therefore, the rainfall-runoff coefficient was estimated using the land use land cover map and antecedent moisture condition. The rainfall-runoff coefficient was found out to be 0.46 which is almost 50% of the rainfall. Since the soil here is mostly clayey and loamy soil the runoff coefficient is comparatively higher. And the rainfall events were analyzed based on the threshold of the events which cause heavy floods, the threshold was identified as 200mm for the Paravanar river basin. The magnitude of rainfall which lead to flood hazards also match the magnitude which is greater than the threshold. The average magnitude of 2, 5, 10, 25, 50, 100 and 200 years were 132mm, 192mm, 235mm, 298mm, 353mm, 418mm and 497mm respectively for each station. These are considered as a good amount of rainfall, but since it reached ground during a short-duration and with high-intensity, it cannot be percolated into the ground. So, storage structures need to be created for water conservation.

The major advantage of this basin is the open-cast mines which can be readily converted into a storage structure. There are 3 mines in this area as Mine I, Mine IA and Mine II which are running under the control of Neyveli Lignite Corporation. The Mine I was completed and the next mine is yet to be completed within the next few years. The mine area was examined during the site visit and it was identified that the total capacity of the void area of the mine will be 31.875Mm3. This storage will be a great contribution during the water shortage period, mainly for the farmers. Hence this can be successfully used as a storage structure after further Environmental Impact Assessment.

Limitations of the Study

This study is limited to only 23 years of data, a higher amount of data leads to accurate predictions. Therefore, it is advised to use around 35 years of data or more if possible. And identification of threshold based on the magnitude is considered as another limitation. It is considered to be alright if it is validated with the literature or on field observations.

Recommendations

Further study should be carried out for determining the threshold of magnitude. This study can be extended further by conducting an Environmental Impact Assessment for converting the mine are into a reservoir and by estimating the exact design of the closed mine. The alternative use for the excavated soil should be identified so that the whole mine area can be used as a storage structure.

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