Estimation of Runoff Using Curve Number Method And Its Modifications

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Abstract

Watershed is the range covering all the land that contributes spillover water to a typical point. Propels in computational power and developing accessibility of spatial information have made it conceivable to precisely foresee the overflow. The likelihood of quickly consolidating information of various sorts in a Geographical Information System (GIS) has prompted noteworthy increment in its utilization in hydrological applications. Numerous strategies are utilized to appraise the overflow from a watershed. The bend number technique, otherwise called the hydrological soil cover complex strategy, is an adaptable and broadly utilized system for overflow estimation. This strategy incorporates a few imperative properties of the watershed to be specific, soils penetrability, arrive utilize and predecessor soil water conditions which are mulled over. In the present review, SCS strategy and its adjustments is utilized with GIS to gauge the overflow. The review territory is the Neyyar watershed. The watershed has a geological territory of 490km2. The precipitation and land utilize information were utilized alongside the test information of soil order for the estimation of the spillover for the review zone.The predicted runoff values obtained by the three methods were compared with the observed values and the results were validated.It was found that using all the rainfall data, the modified CN I performed the best (E = 0.95, R^2 =0.97), followed by the NRCS-CN method (E = 0.89, R^2 =0.95) and CN II method (E = 0.83, R^2 =0.85).

Keywords – watershed, estimate , runoff

INTRODUCTION

Runoff is that part of precipitation or any other flow contribution, which appears in the surface stream of either perennial or intermittent form[4]. It is one of the most important hydrologic variables used in most of the water resource applications. Direct measurements of runoff provide excellent and timely data but it is in limited in use to exact location where it was collected. The Curve Number method was developed by USDA Natural Resource Conservation service. Run off estimationEssential for planning water supply, navigational movement and effluent discharge into the stream.

LITERATURE REVIEW

Ashishpandey et.al (2004) has studied the runoff estimation for agricultural watershed using SCS method. This paper presents development of curve number using the soil map and landuse map of the study area.

M.Coskun, N. Musaoglua (2010) used various data sets such as Landsat satellite image, topographic map, and soil map data.. Landsat image was classified by using digital image techniques and integrated into GIS with hydrological soil map. SCS Curve Number method was used to determine curve numbers and runoff depth distribution of the basin area.

A. Purjenaieevaluated Synthetic Unit Hydrograph (SCS) and Rational Methods in Peak Flow Estimation .The run-off coefficient and rainfall intensity in each sub basin was determined and the dimensionless unit hydrograph was drawn.To determine the accuracy of these two methods, results were compared with nearest gauge. The results showed that SCS method has accurate estimation than rational method and it can be used for peak flow estimation in the similar condition watersheds.

Objective of the study

To create a combination of land use map and soil groupmap of the Neyyar watershed using GIS techniques and to estimate the runoff depth of the watershed using NRCS CN Method and its three modifications.

STUDY AREA

The study area is Neyyar watershed. It lies between latitude 8º17' N and 8º 53'2" N, and longitude 76º 40'2" E and 77º 17' E and is in Thiruvananthapuram districts of Kerala state[1-4]. The study area is the Neyyar watershed of the Kerala state. Neyyar originates from the Agasthyakudam hills, flows through Neyyattinkara taluk and joins Lakshadweep Sea near Poovar. The main tributaries are Kallar and Karavaliyar. Neyyar wild life sanctuary in this basin is a famous tourist place. The study area has a total area of 491.577 $km^2$and has a tropical humid climate characterized with oppressive summer and seasonal rainfall. There are two distinct rainfall seasons, south west monsoon (May to September) and southwest monsoon (October to November).

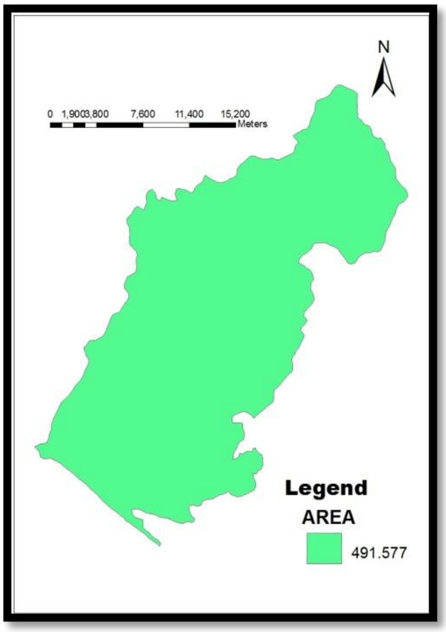

***Fig 1:** Boundary of the study area*

METHODOLOGY

Curve number method

NRCS-CN method

The NRCS-CN method is based on the water balance equation and two fundamental hypotheses (SCS, 1956). The firsthypothesis equates the ratio of the amount of direct surfacerunoff Q to the total rainfall P (or maximum potential surfacerunoff) with the ratio of the amount of infiltration Fc to theamount of the potential maximum retention S. The secondhypothesis relates the initial abstraction Ia to the potential maximum retention. Thus, the NRCS-CN method consisted of the following equations[:2]

(a) Water balance equation:

$$P = Ia + Fc + Q` \qquad (1)$$

(b) Proportional equality hypothesis:

$$\frac{Q}{P-Ia} = \frac{Fc}{S} \qquad (2)$$

(c) Ia_S hypothesis:

$$Ia = \lambda S \qquad (3)$$

Where P is the total rainfall;Ia the initial abstraction; Fc thecumulative infiltration Fc excluding Ia; Q the direct runoff; Sthe potential maximum retention or infiltration; and l theregional parameter dependent on geologic and climaticfactors (0.1plp0.3). The relation between Ia and S wasdeveloped by analyzing the rainfall and runoff data fromexperimental small watersheds and isexpressed as

$$Ia = 0.2S \qquad (4)$$

Combining the water balance equationand proportional equality hypothesis, the NRCS-CN method isrepresented as:

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \qquad (5)$$

The potential maximum retention storage S of watershed isrelated to a CN, which is a function of land use, land treatments, soil type and antecedent moisture condition of watershed. The CN is dimensionless and its value varies from 0 to 100. The S-value in mm can be obtained from CN by using the relationship:

$$S = \frac{25400}{CN} - 254 \qquad (6)$$

Modified CN method (CN I)

The modified CN I method is based on the concept of zeroinitial abstraction (Ia = 0), i.e. immediate ponding for calculating the runoff depth Q from a given rainfall depth P. Using this concept in the original NRCS-CN proportionality hypothesis the resulting equation for surface runoff estimation was obtained:[3]

$$Q = \frac{P^2}{P+S} \qquad (7)$$

The two extremely dry and wet conditions, which may produce runoff, were not considered in the original CN method due to its concept of runoff occurring only after fulfilling the initial abstraction Ia requirements. So this modified CN method was considered in this study to account for the conditions prevailing in watershed systems in high-intensity rainfall events.

Modified CN Method (CN II)

In this modification of the CN method, the initial abstraction Ia was modified by associating a non-dimensional parameter λ with the potential maximum retention S,which is represented as $I_a = \lambda S$. The parameter λ depends on the time of ponding t_p and Horton's constant a and are associated as $\lambda = \alpha t$. In the original NRCS-CN method, the time of ponding was assumed to be zero, whereas in this method, the time of ponding was considered from the beginning of rainfall to the initiation of the runoff process. Under these modifications, the equation for estimation of surface runoff using the modified CNII method

$$Q = \frac{(P-\lambda S)^2}{P-S(\lambda-1)} \qquad (8)$$

The curve number method was developed as a means for estimating the value of potential maximum retention, for computing the runoff for a given rainfall. A curve number is an index that represents the combination of a hydrologic soil group, land use and treatment class. Soil data is usually contained in the hardcopy soil survey of the area and soil surveys list soil types by name, which is based on certain physical characteristics of the soils.

The information needed to determine a curve number is the hydrologic soil group, which indicates the amount of infiltration the soil will allow. Some amount of infiltration occurs in sandy soil while no infiltration occurs on heavy clay or rock formations [1]. Soil characteristics that are associated with each group are in table.

Table 1: *Characteristics of different soil groups*

Classification	Type of soil
A(low runoff potential)	Soil with high infiltration capacities, even when thoroughly wetted. Chiefly sands and gravels, deep well drained
B	Soil with moderate infiltration rates when thoroughly wetted. Usually have a layer that impedes vertical drainage, or have moderately fine to coarse textures
C	Soil with slow infiltration rates when thoroughly wetted. Usually have a layer that impedes vertical drainage, or have moderately fine to fine textures.
D(high runoff potential)	Soil with slow infiltration rates when thoroughly wetted. Chiefly clays with a high swelling potential; soils with a high permanent water table ; soils with a clay layer at or near the surface ;shallow soils over nearly impervious materials.

RESULTS AND DISCUSSIONS

Runoff of the area is computed by curve number method and its modifications and the following maps of the area were prepared.

Table 3. *Comparison of discharge -2004*

Month	Observed runoff (Cumec)	Predicted runoff (Cumecs)		
		NRCS CN	CN 1	CN 2
January	13.7	4.3	8.675	6.20
February	25.05	7.315	16.28	11.59
March	27.137	19.87	32.93	40.23
April	29.73	26.25	29.99	33.728
May	228.53	78.69	110.68	92.65
June	190.74	56.82	182.62	75.89
July	247.39	98.35	220.98	180.88
August	388.26	200.51	312.89	250.26
September	217.5	139.43	199.89	150.82
October	183.91	140.26	185.92	160.29
November	400.29	285.29	380.98	160.85
December	131.563	85.61	128.78	90.86

Table 4. *Comparison of discharge -2005*

Month	Observed runoff (Cumecs)	Predicted runoff (Cumecs)		
		NRCS CN	CN 1	CN 2
January	6.314	1.18	7.35	4.89
February	37.18	25.89	37.74	10.36
March	8	1.454	8.016	3.88
April	157.01	64.09	79.88	53.89
May	240.03	142.72	198.89	150.29
June	314.42	220.80	331.9	250.81
July	684.73	429.81	500.88	450.91
August	163.87	70.89	98.26	88.29
September	336.13	287.3	341.58	238.29
October	126.8	87.89	113.26	92.85
November	511.67	329.81	401.89	350.98
December	261.3	189.26	249.81	150.89

Table 5. *Comparison of discharge -2006*

Month	Observed runoff (Cumecs)	Predicted runoff (Cumecs)		
		NRCS CN	CN 1	CN 2

January	17.54	2.79	15.32	9.81
February	75.123	50.57	62.3	55.29
March	111.935	79.25	109.50	92.31
April	71.34	38.79	52.61	41.89
May	117.69	87.98	110.29	92.38
June	183.75	139.66	173.26	150.26
July	200	163.138	198.38	181.98
August	110.36	88.32	103.82	92.35
September	756.79	508.88	689.4	592.89
October	800.07	675.31	715.28	692.31
November	975.66	572.88	611.68	490.81
December	62.5	59.8	61.89	58.8

Table 6. *Comparison of discharge -2007*

Month	Observed runoff (Cumecs)	Predicted runoff (Cumecs)		
		NRCS CN	CN 1	CN 2
January	15.6	5.78	18.92	11.83
February	42.4	20.8	39.85	28.99
March	50.74	32.69	47.89	38.28
April	124.366	98.25	134.25	117.76
May	183.16	162.68	190.10	170.81
June	252.78	168.28	200.71	180.22
July	787.958	516.28	621.89	580.21
August	515.69	356.12	492.88	370.22
September	987.7	753.29	812.28	790.28
October	1040.61	829.22	939.48	888.76
November	700.99	498.32	555.81	520.38
December	80.437	62.87	79.23	65.89

Table 7. *Comparison of discharge -2008*

Month	Observed runoff (Cumecs)	Predicted runoff (Cumecs)		
		NRCS CN	CN 1	CN 2
January	33.74	15.9	27.08	18.29
February	0	0.58	0.27	0.45
March	64.698	38.33	58.92	47.69
April	385.792	229.87	342.87	290.5
May	107.92	98.88	127.3	142.8
June	53.21	43.28	59.88	47.2
July	389.06	276.82	372.58	289
August	187.24	100.28	177.7	105.8
September	0	19.28	0.88	17.29
October	1080.47	714.88	819.28	750.18
November	508.74	333.79	471.147	380.00
December	41.98	28.39	38.26	30.56

VALIDATION OF THE RESULTS

The figured overflow profundities were contrasted and the watched spillover profundity values recorded at the watershed outlet for various precipitation occasions under normal AMC condition. This was achieved by using two standard statistical significance estimators, namely, the model efficiency factor E and the coefficient of determination R^2.The expression for model efficiency E (James and Burgess, 1982; Sarangi and Bhattacharya, 2005) is given as

$$E = 1 - \frac{\sum_{i=1}^{n}(p_i - o_i)^2}{\sum_{i=1}^{n}(o_i - \bar{o})^2}$$

The efficiency for each method is listed below:

Table.8*Efficiency of methods*

Method	Efficiency
NRCS-CN	0.89
CN I	0.95
CN II	0.83

In order to correlate the predicted and observed values a straight line is fitted between them for all the three methods taking 72 rainfall events.

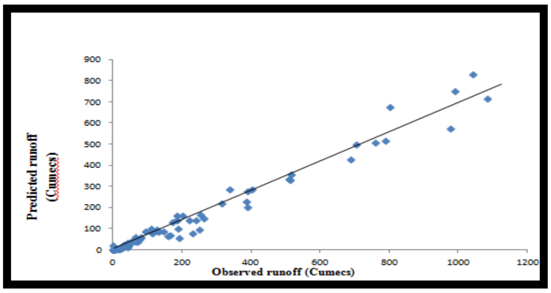

Fig.2 *NRCS-CN Method*

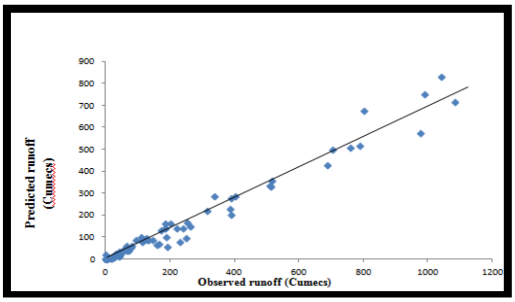

Fig.3*CN I Method*

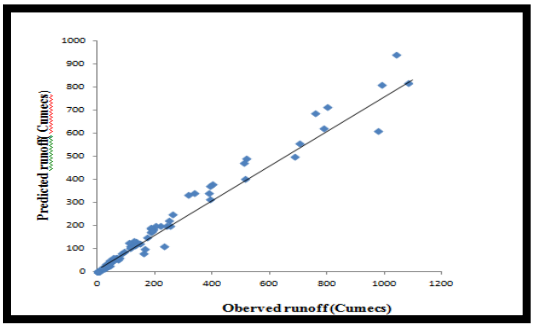

Fig. 4*CN II Method*

From the graphs plotted it is clear that there is a strong correlation between the observed and predicted values for CN I method. The R^2 values of each method are shown in the table below:

Table 9. *R^2 valueof methods*

Method	R^2
NRS CN	0.95
CN I	0.97
CN II	0.85

Thus it is clear that CN I method gives better results compared to another two methods. Hydrograph was plotted on CN I method for the year 2003-2008. It gives a comparison between observed runoff and predicted runoff.

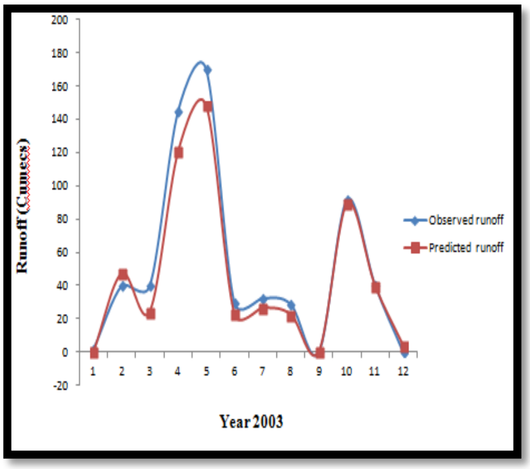

Fig.5*Hydrograph -2003*

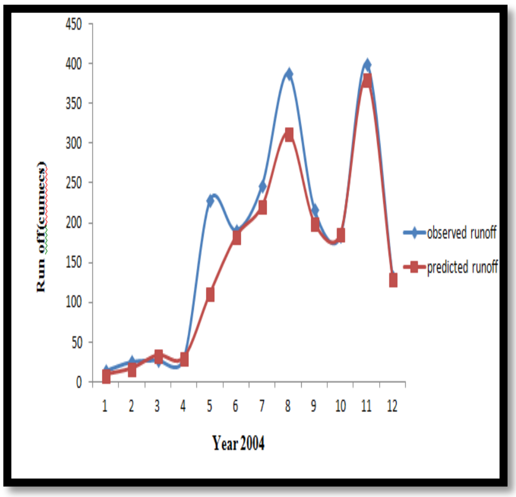

Fig.6 *Hydrograph -2004*

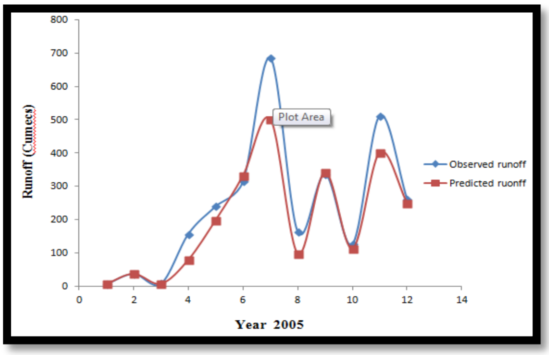

Fig.7 *Hydrograph -2005*

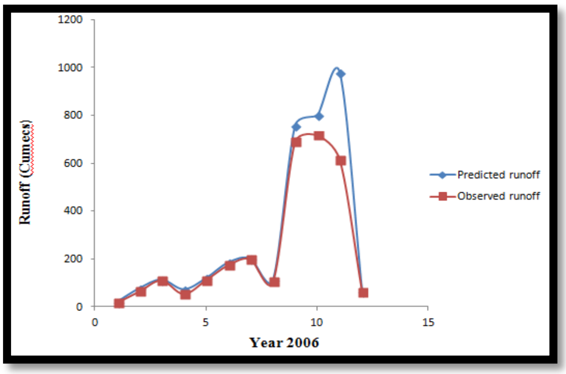

Fig.8 *Hydrograph -2006*

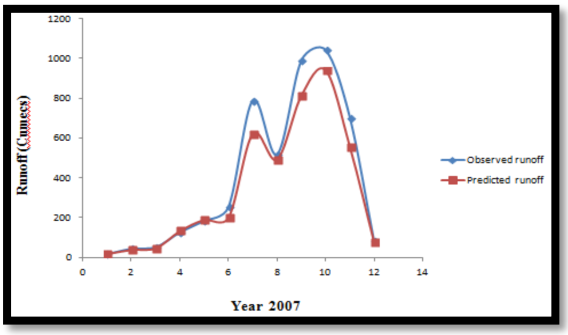

Fig.9 *Hydrograph -2007*

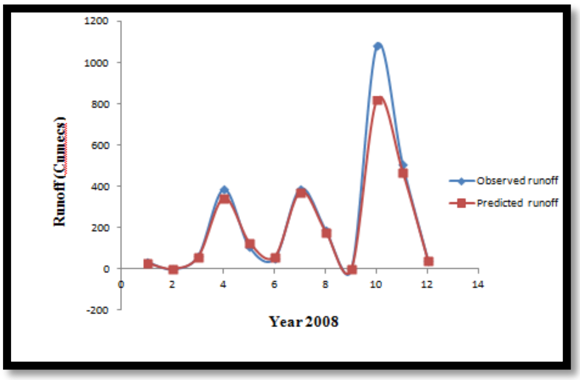

Fig.10 *Hydrograph -2008*

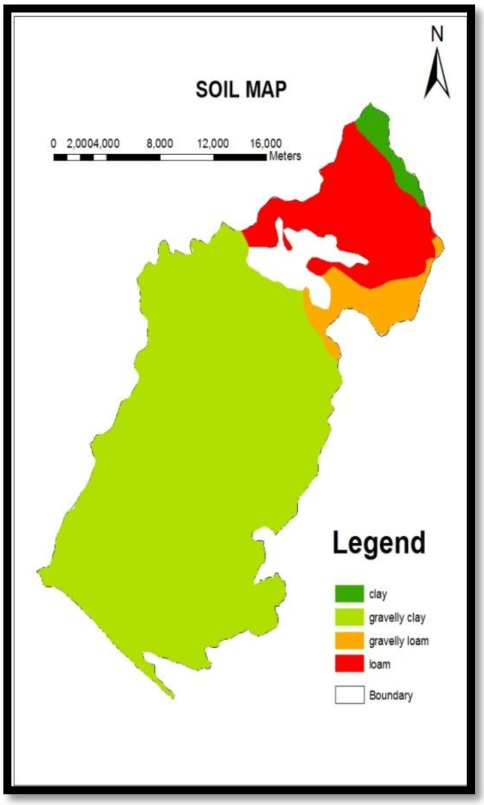

Fig.11 *Soil map*

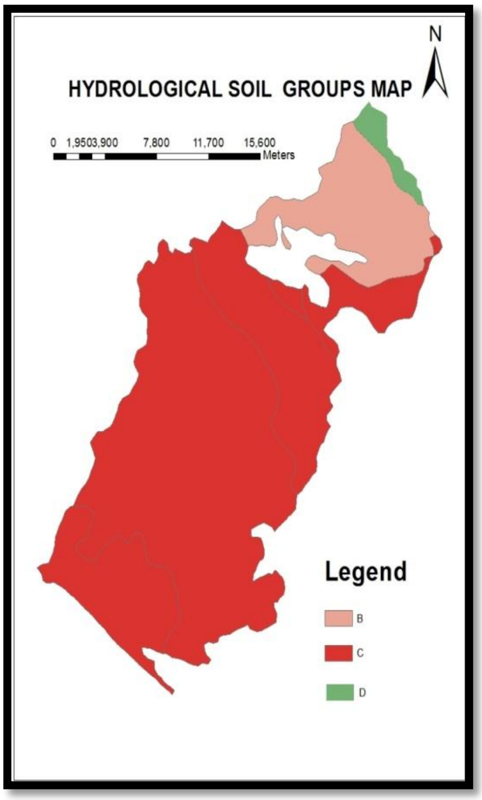

Fig.12 *Hydrologic soil group map*

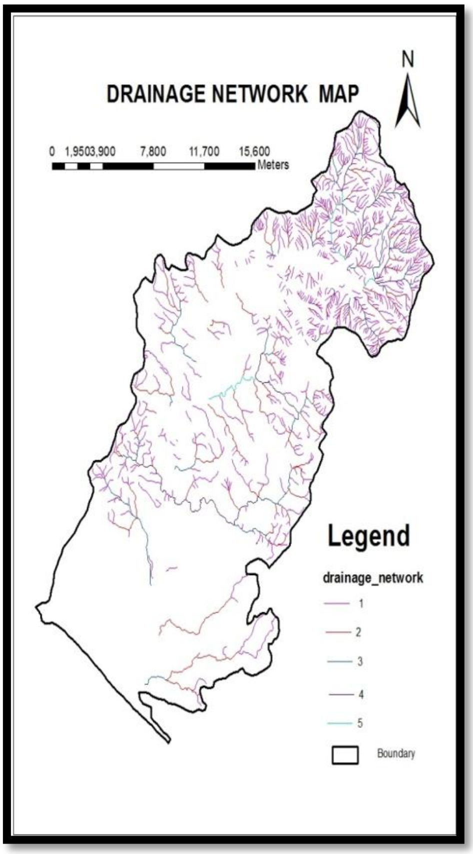

Fig.13 *Drainage network map*

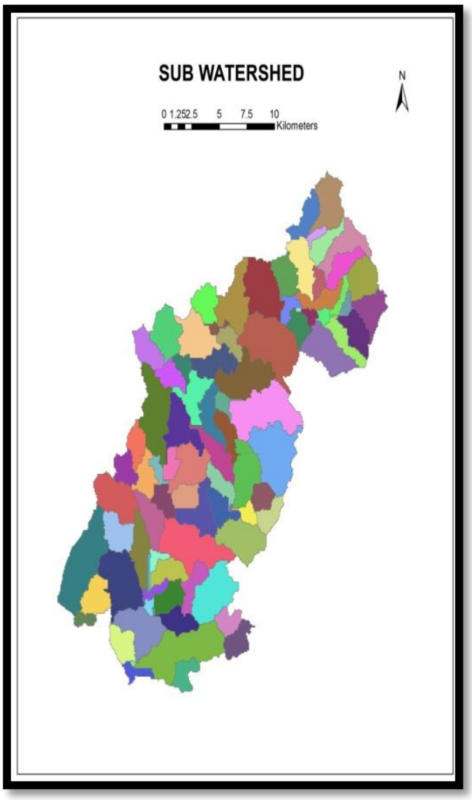

Fig.14 *Sub watershed map*

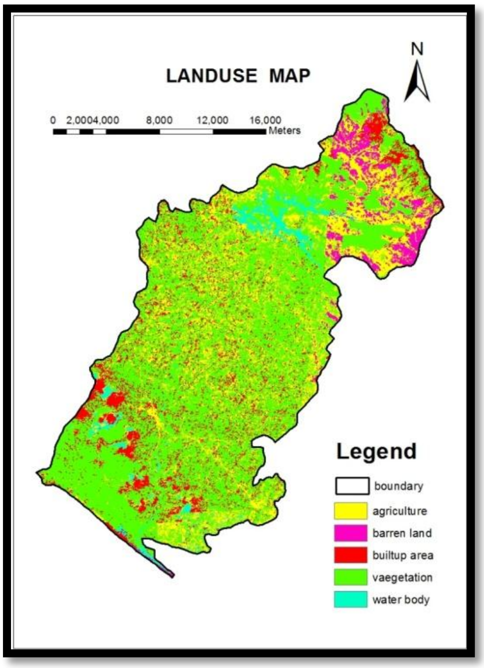

Fig.15*Landuse map*

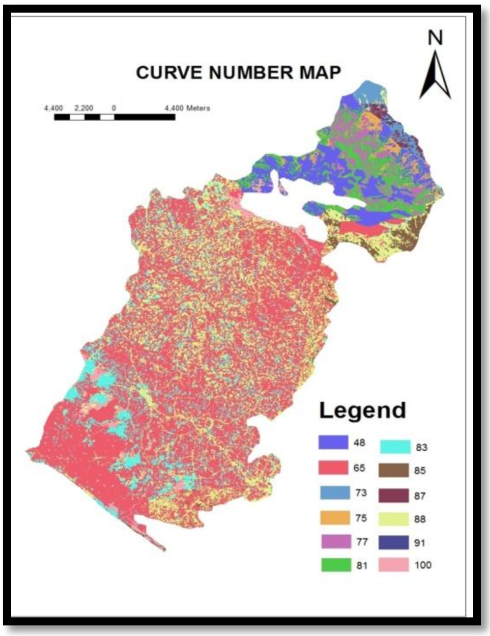

Fig.16 *Curve number map*

CONCLUSION

A combination of land use map and soil group map of the Neyyar watershed was prepared using GIS techniques. The observed runoff depths in the study watershed were compared with the predicted values of NRCS-CN methods and its two modifications (2003-2008). It was found that using all the rainfall data, the modified CN I performed the best (E = 0.95, R^2 =0.97), followed by the NRCS-CN method (E = 0.89, R^2 =0.95) and CN II method (E = 0.83, R^2 =0.85). Hence hydrographs were plotted for CN1 method showing the comparison between observed and predicted runoff at different rain fall events and validated the results.

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