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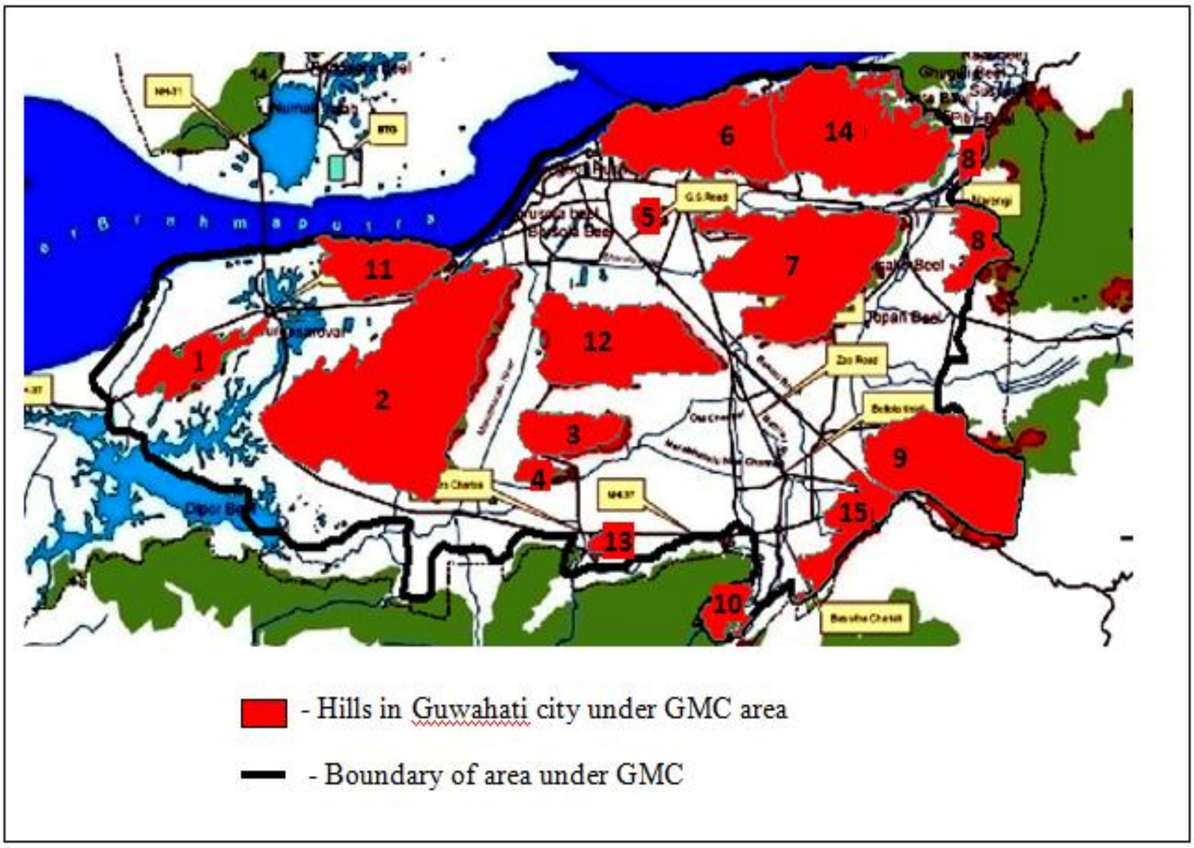
ASSAM STATE DISASTER MANAGEMENT AUTHORITY

REPORT

ESTIMATING SEDIMENT AND WATER YIELD FROM HILLS OF GUWAHATI CITY



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

North Guwahati, Guwahati – 781 039
ASSAM, INDIA

2017

Final Report

ESTIMATING SEDIMENT AND WATER YIELD FROM HILLS OF GUWAHATI CITY

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Guwahati -781039

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Working Team

Prof. Arup Kumar Sarma, Chair Professor, Principal Consultant

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BACKGROUND

Sediment yield and high runoff generation from the hilly terrain of Guwahati City is one of the important factors responsible for urban flooding of Guwahati City. For efficient and adequate design of Drain, Silt Trap and EMPs (Ecological Management Practices) for water and sediment management a reliable estimate of water and sediment loss from the hilly terrain is essential.

Prof. A.K.Sarma of IIT Guwahati, in one of his earlier research project during 2002-2004, estimated sediment and water yield from different watersheds (105 watersheds). However, while delineating those watersheds, both plains and hilly area were done as a whole. Another project carried out in 2008-2013 showed that landuse pattern has undergone significant changes during this period and as such the sediment and water yield is also expected to increase significantly. Also, for flood management of the Guwahati City, it is more important to know the sediment yield and water yield at the foot hill of all the hilly watersheds. Therefore, re-estimation of the sediment and water yield from the hill at the foothill is therefore necessary to adopt management practices.

Considering the above needs, Assam State Disaster Management Authority requested Prof. A.K.Sarma of IIT Guwahati to evaluate water and sediment yield from the hills of Guwahati City for the present landuse situation. Accordingly the project was registered at IIT Guwahati on Dec 2016 with Prof. Arup Kr. Sarma as Principal Consultant.

1 INTRODUCTION

1.1 INTRODUCTION

Sediment yield and high runoff generation from the hilly terrain of Guwahati City is one of the important factors responsible for urban flooding of Guwahati City. For efficient and adequate design of Drain, Silt Trap and EMPs (Ecological Management Practices) for water and sediment management, a reliable estimate of water and sediment loss from the hilly terrain is essential. In this study finer delineation of the hilly watershed is carried out to enable better management and a total of 612 watersheds have been delineated.

Sediment and water yield from the watershed depend on the rainfall characteristic, soil type, terrain slope and land-use/land-cover condition of the watershed. For Indian condition, availability of data is always a problem and therefore, selection of a method for estimating these quantities is another important aspect.

Considering availability of data Rational Method, which is widely used for computing peak runoff from a small watershed, has been used to compute the runoff from different hills. For estimation of sediment loss RUSLE method is applied, as sediment management is generally taken up on yearly basis and not on event to event basis.

1.2 PURPOSE OF THE STUDY

Prime objective of the study is to estimate the sediment and water yield from the hilly watersheds of Guwahati City to help adopting management measure.

Management measures include, sizing of outlet drains, sediment control measures to arrest sediment at the source as well as in the valley in contour trench or other appropriate silt trap.

Earlier study carried out by the Principal Consultant of this project showed that with control of sediment and water yield from the hilly catchments, it is possible to mitigate the flood problem of Guwahati City, which is aggravating day by day due to blockage of drain by sediment and increase of runoff from the denuded hilly terrain.

1.3 METOD OF INVESTIGATION

The study has been carried out in the following phases:

a) Delineation of Watersheds of the Hills of Guwahati City was taken up as the first step. For this purpose 30m resolution Digital Elevation Model (DEM) has been used. Considering objectives of this study, micro level delineation of the hilly watersheds of Guwahati City has been carried out so that maximum possible sediment and water yield at the foothill can be ascertained.

b) To have idea about the present situation, satellite data of 2011 and 2015 has been used for developing Landuse/land-cover map for the hills of Guwahati.

This data set has been used to prepare the land-use input for computing both sediment and water yield using mathematical model. Although the situation analysis in future time period is not within the scope of this project, considering academic interest, a probable future value of runoff coefficient at 2025 has also been computed considering *business as it is* condition.

c) Estimation of yearly sediment yield at the outlet of each of these watersheds is carried out using Revised Universal Soil Loss Equation (RUSLE) model.
d) Estimation of peak discharge for different return period at outlet of each of these watersheds has been computed using Rational Method for the year 2011 and 2015.

2. RUNOFF CALCULATION

2.1 HILLS OF GUWAHATI

There are total 15 numbers of hills in Guwahati city under GMC area. The name of the hills are - 1. University (2.10 sq. km) 2. Fatasil (15.91 sq. km) 3. Kalapahar (1.98 sq. km) 4. Sonaighuli (0.36 sq. km) 5. Sarania (0.34 sq. km) 6. Kharguli (6.54 sq. km) 7. Japorigog (9.65 sq. km) 8. Burha-gosain (2.01 sq. km) 9. Khanapara (6.63 sq. km) 10. Garbhanga (0.95 sq. km) 11. Kamakhya (3.05 sq. km) 12. Kahilipara (6.62 sq. km) 13. Betkuchi (0.24 sq. km) 14. Chunsali (8.93 sq km) 15. Koinadhara (2.22 sq km). Areas of the hills are shown within brackets. Out of these hills, Burha-gosain, Khanapara, Koinadhara and Garbhanga hills partly lie in the study area. Location of these hills are shown in Fig.1.

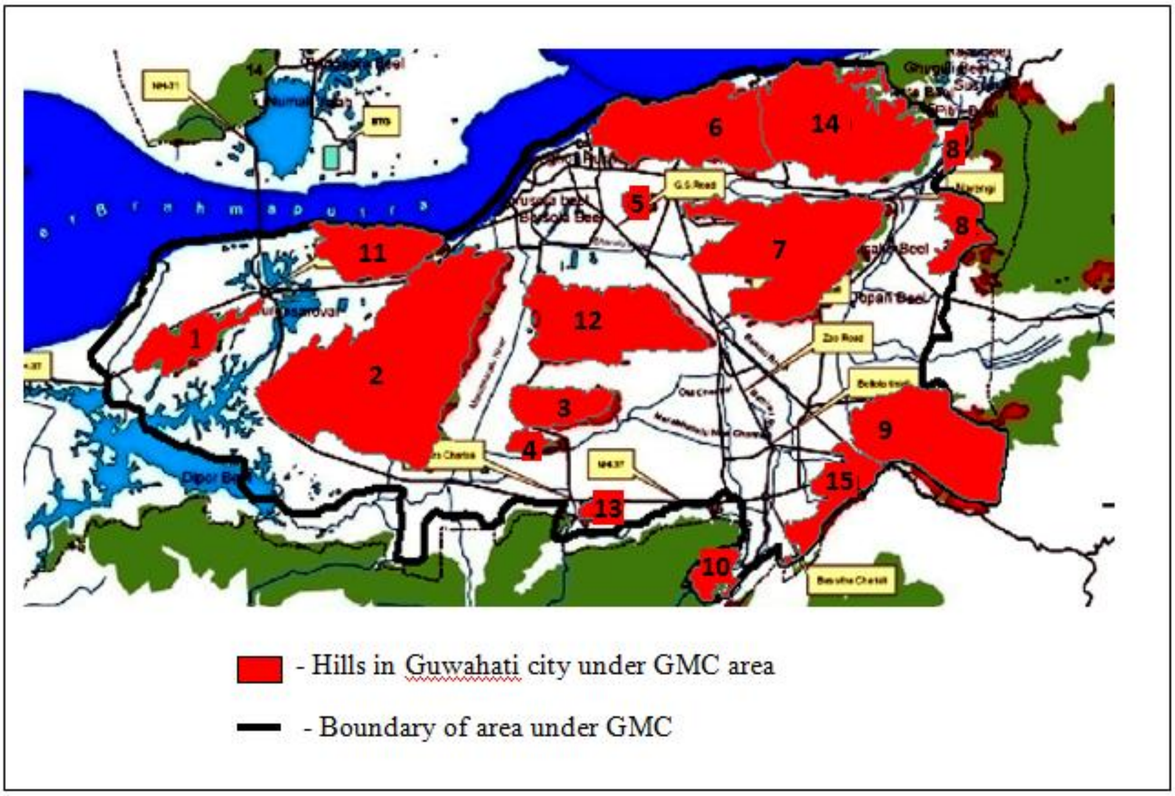


Fig. 1: Locations of hills in Guwahati city

2.2 COMPUTATION OF PEAK DISCHARGE

Rational method which is one of the most widely used methods, has been applied to determine the peak runoff generated from the watersheds of hills of Guwahati city on peak runoff generation it has been decided to use the rational method. The empirical formula used in this method is:

$$Q=CiA$$

Where, Q is the peak runoff which is to be determined, C is the Runoff coefficient (dimensionless) indicating the ratio of surface runoff generated from a watershed due to the occurrence of a rainfall event, i is the rainfall intensity and A is the area of the watershed.

2.2.1 Watershed delineation

Watershed delineation of the hills has been carried out in ArcSWAT interface of the SWAT model. Watersheds of Khanapara (Hill ID: 9) and Koinadhara (Hill ID: 15) hills are delineated jointly as some watersheds of these two hills are common. Delineated watersheds with watershed ID for every hill are shown below:

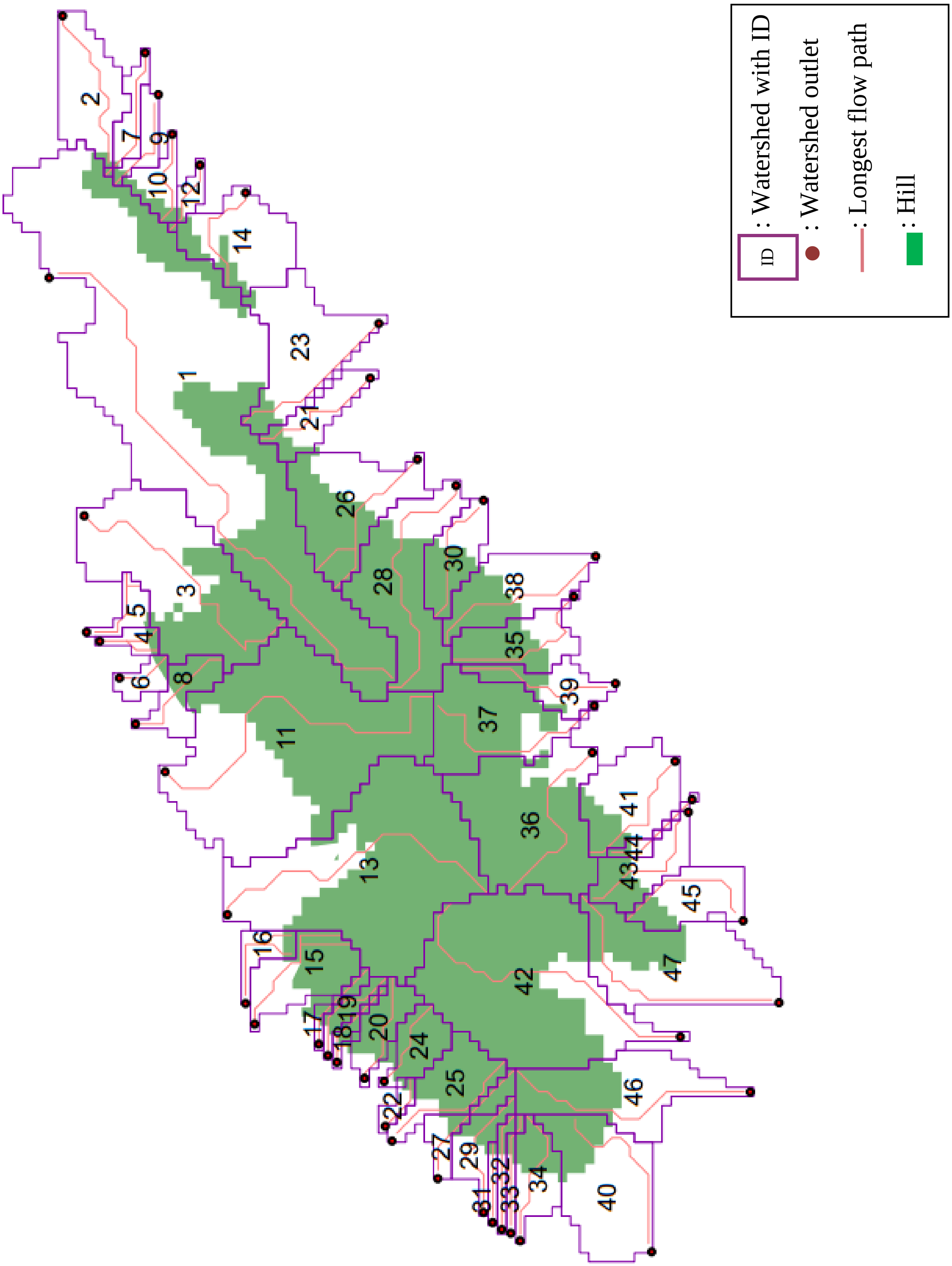


Fig. 2: Watersheds of University Hill

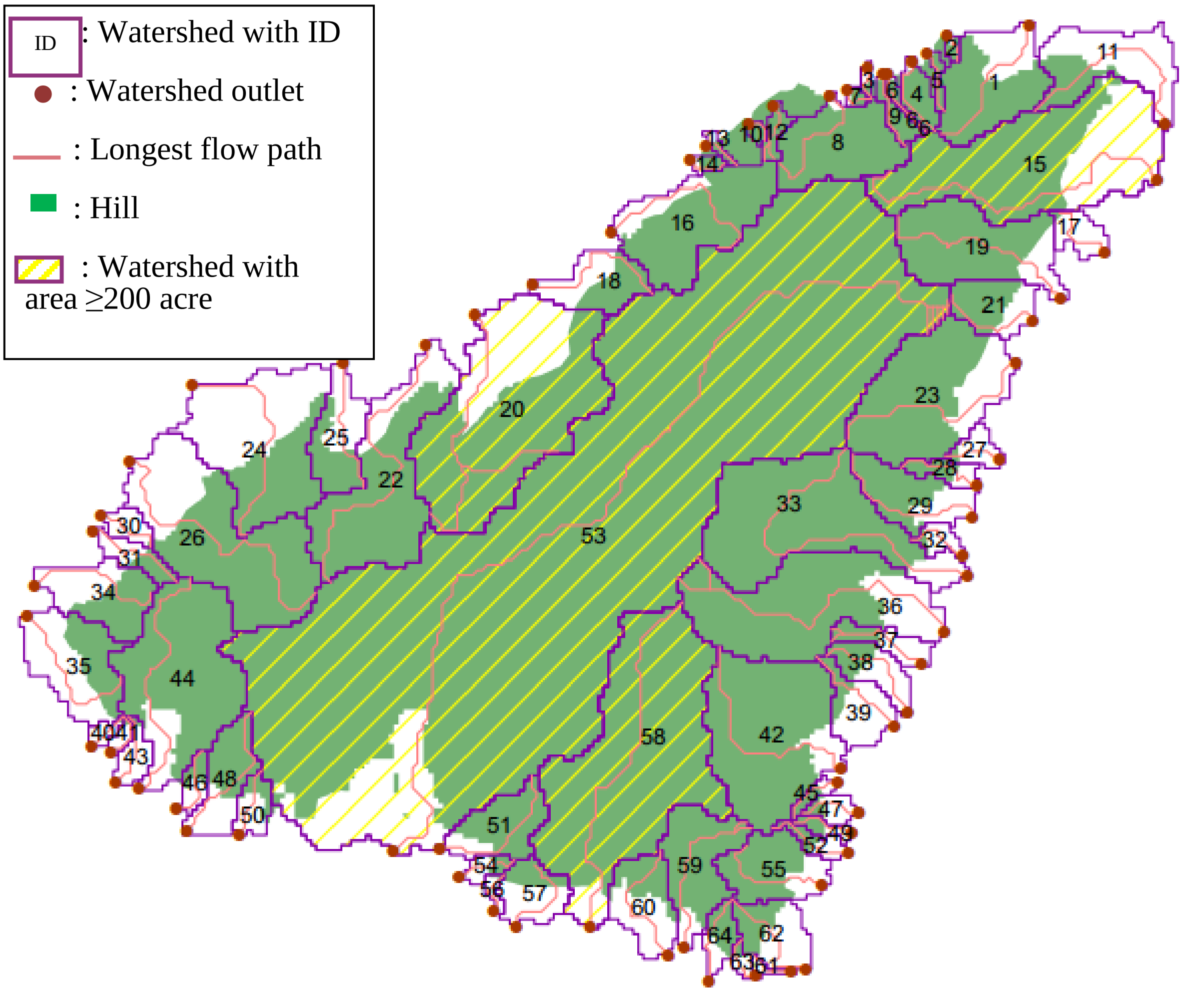


Fig. 3: Watersheds of Fatasil Hill

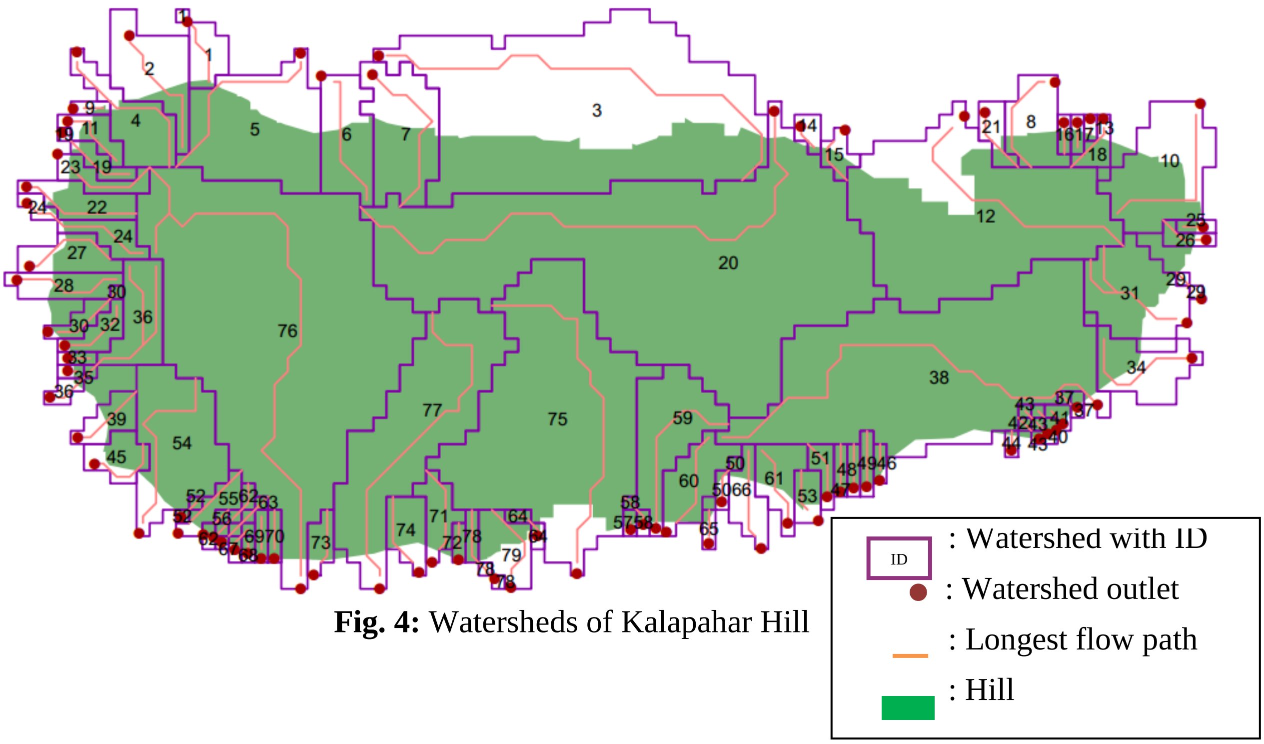


Fig. 4: Watersheds of Kalapahar Hill

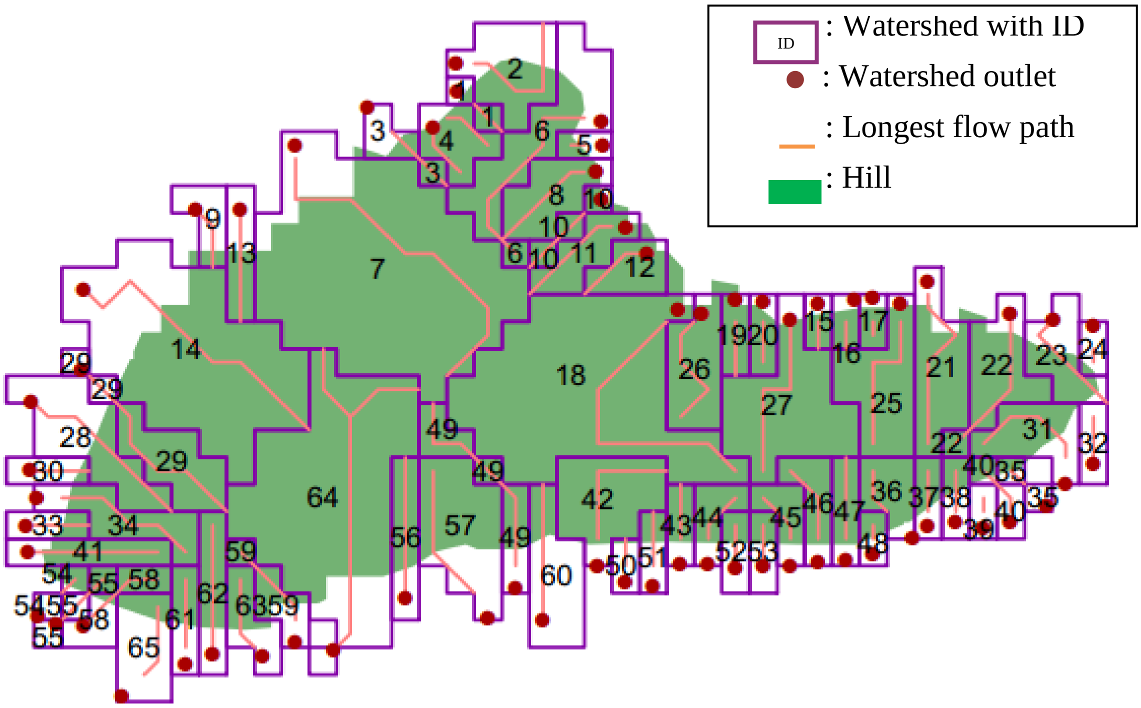


Fig. 5: Watersheds of Sonaighuli Hill

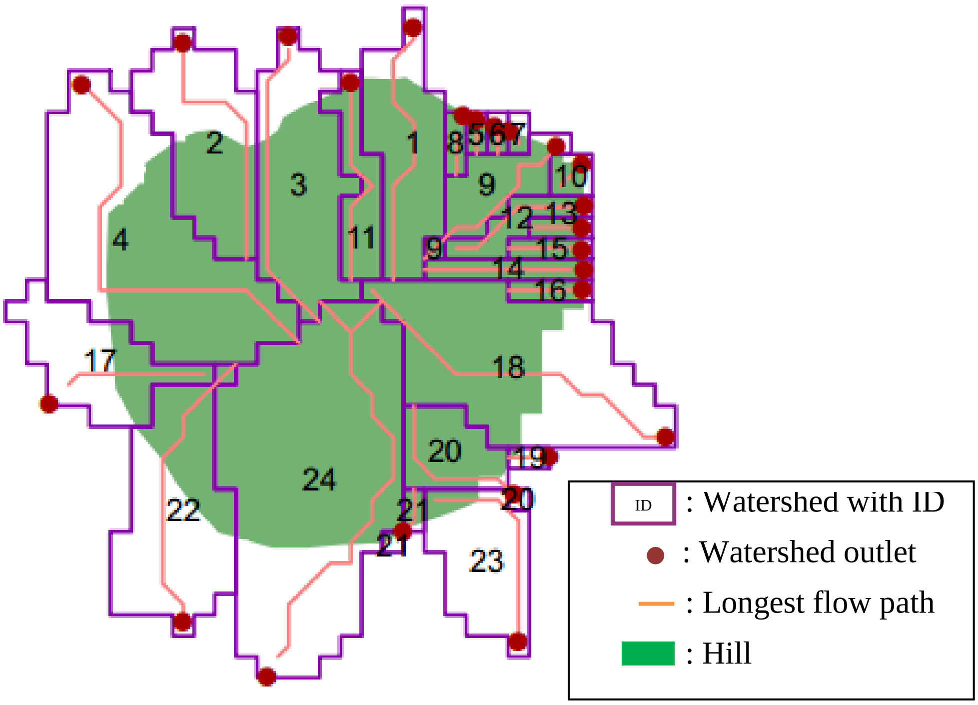


Fig. 6: Watersheds of Sarania Hill

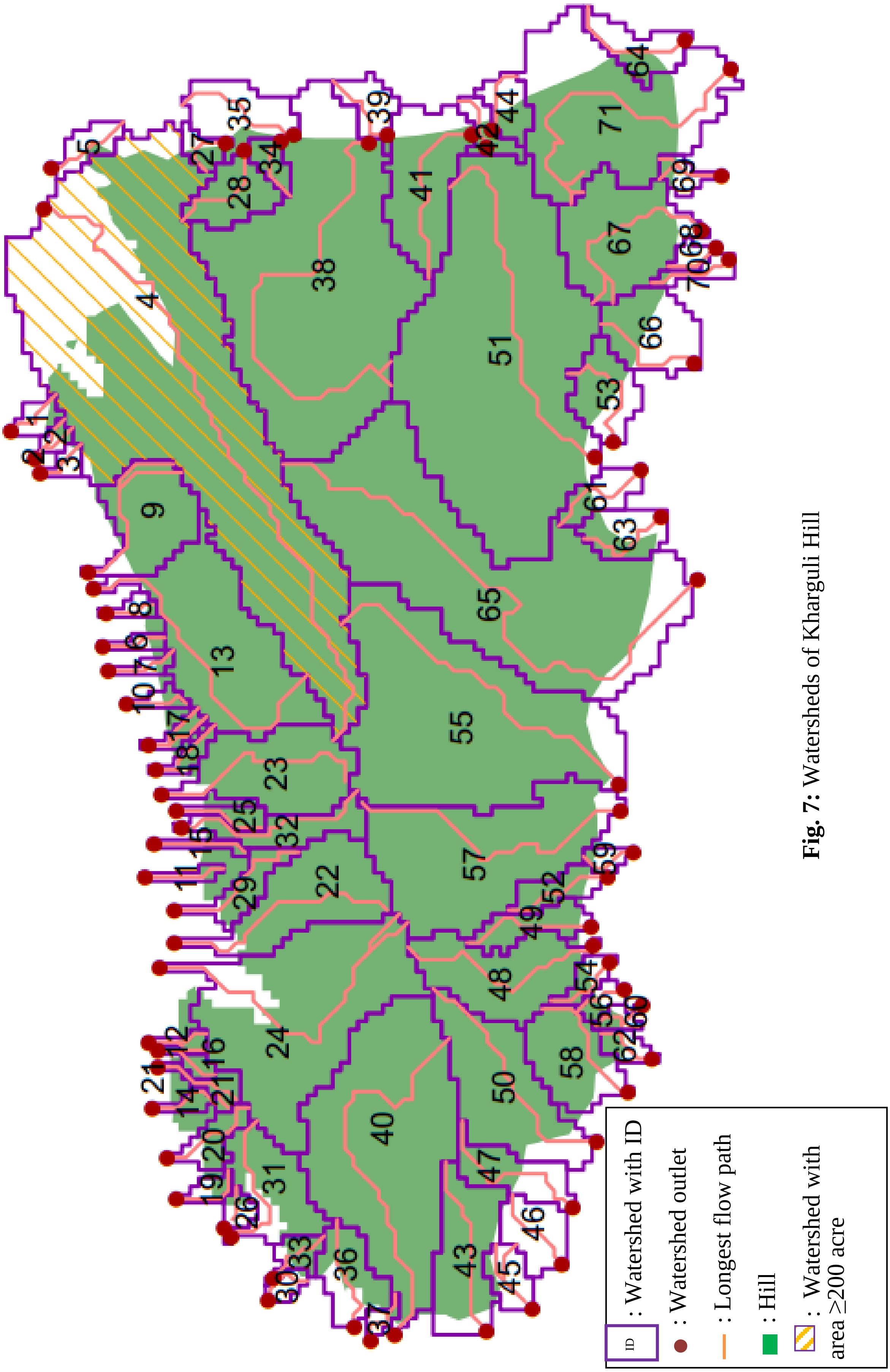


Fig. 7: Watersheds of Kharguli Hill

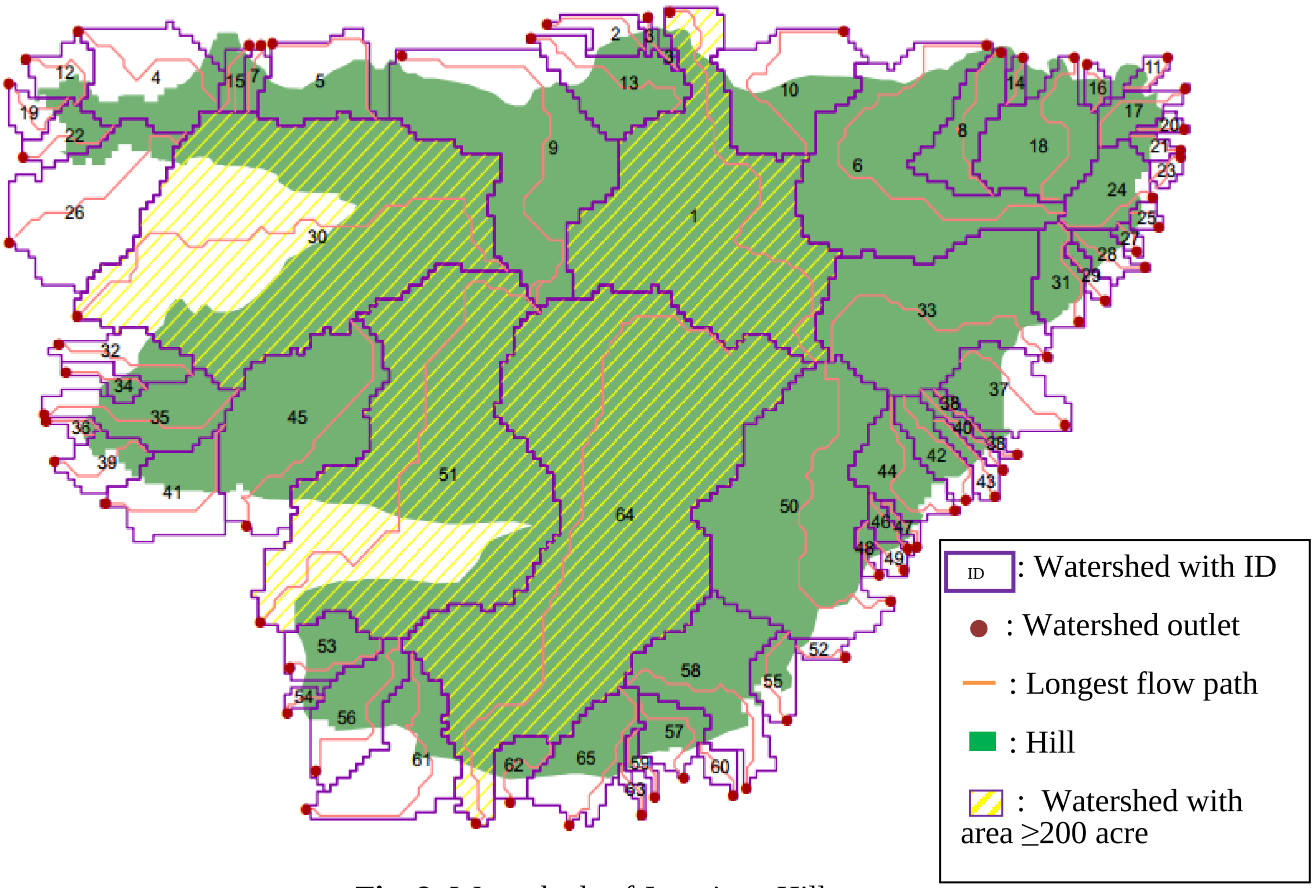


Fig. 8: Watersheds of Japorigog Hill

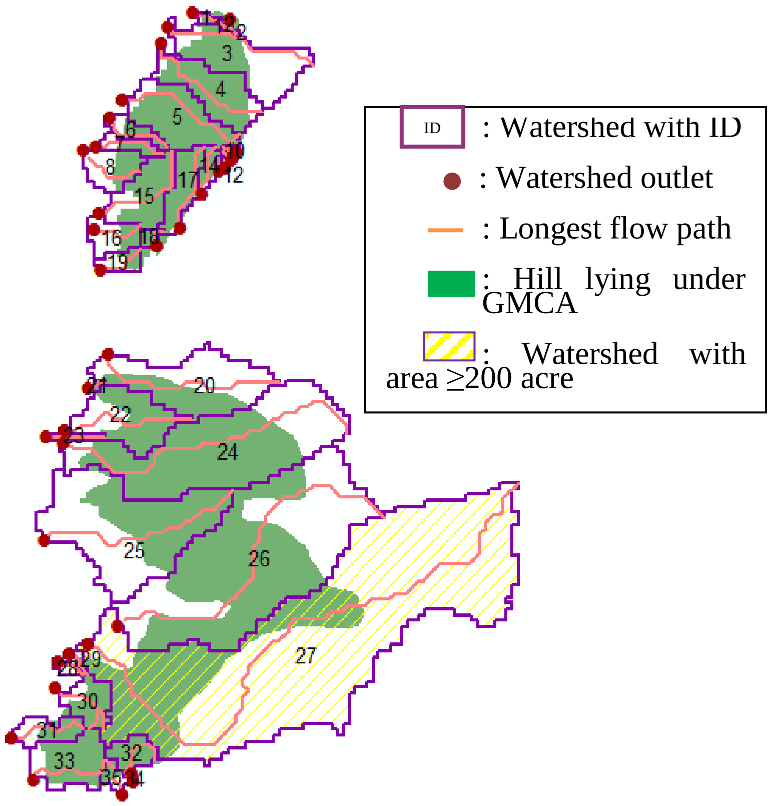


Fig. 9: Watersheds of Burhagosain Hill

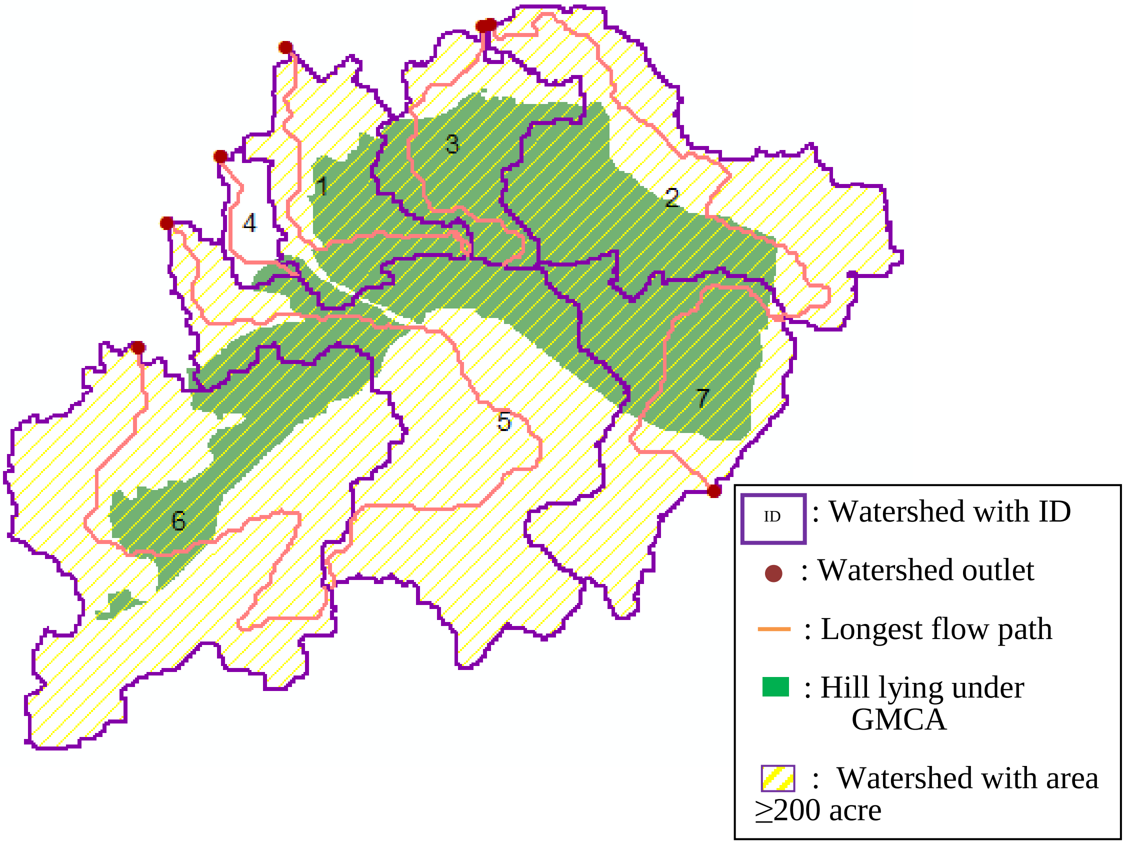


Fig. 10: Watersheds of Khanapara and Koinadhara hill

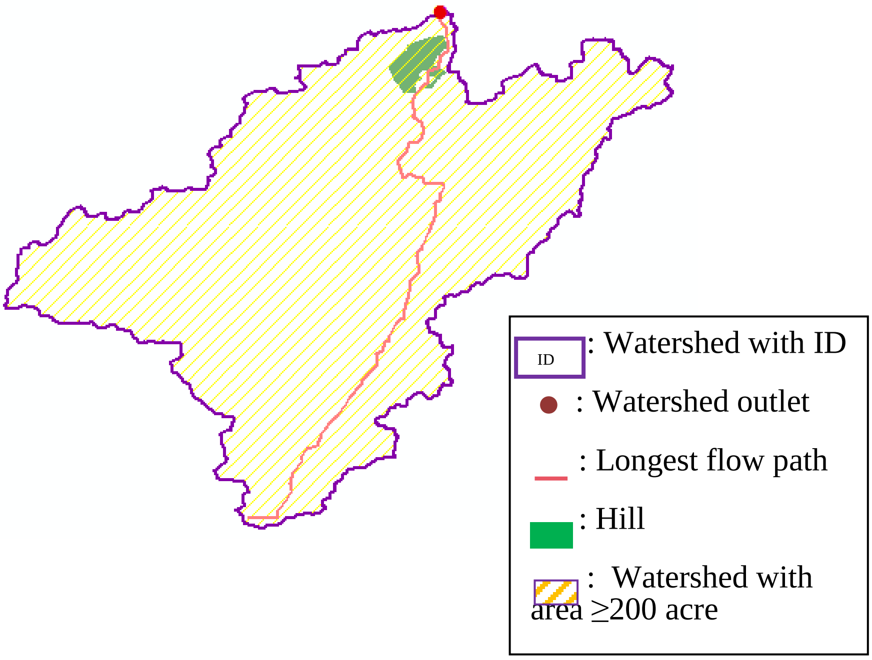


Fig. 11: Watersheds of Garbhanga Hill

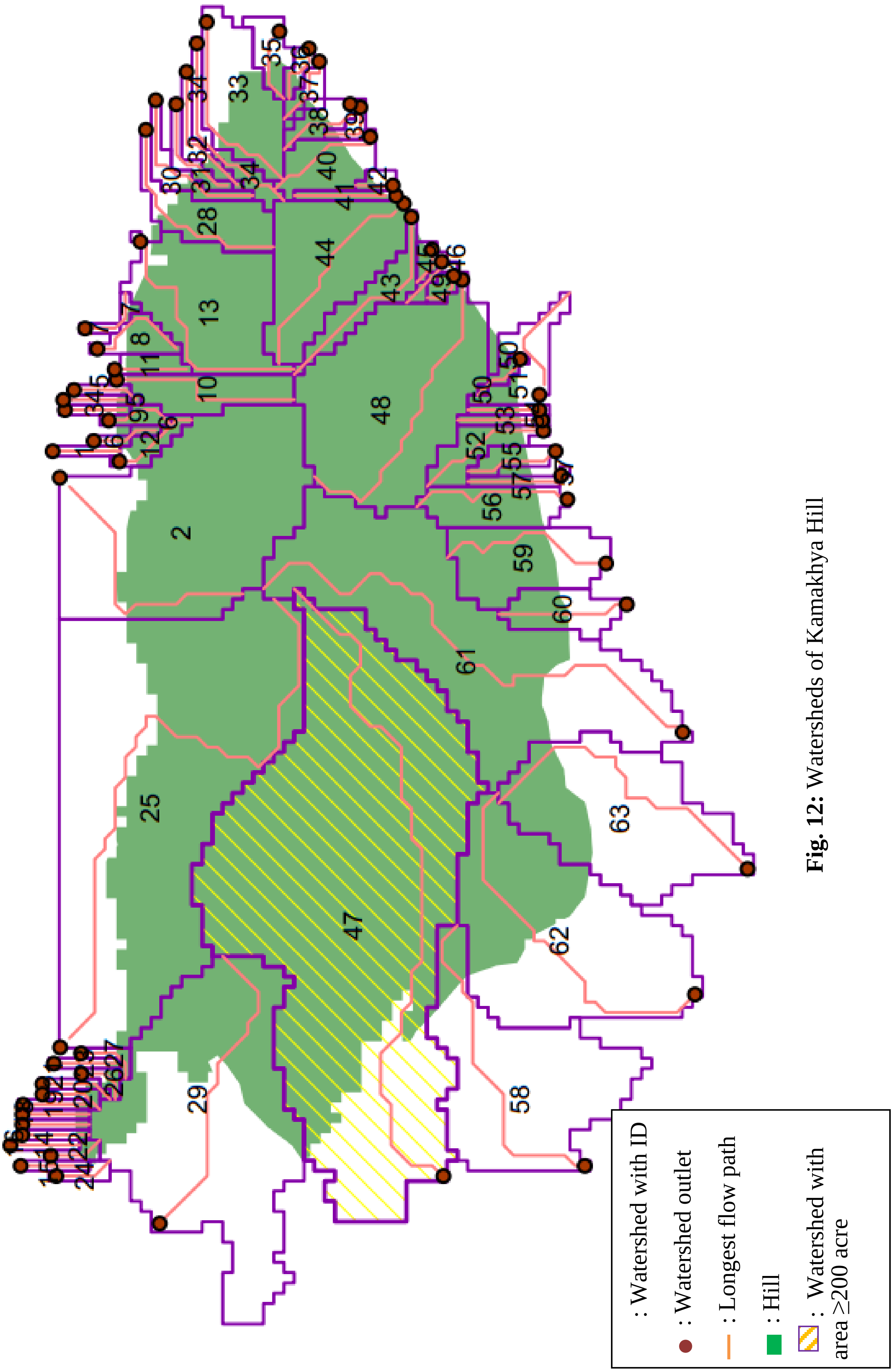


Fig. 12: Watersheds of Kamakhya Hill

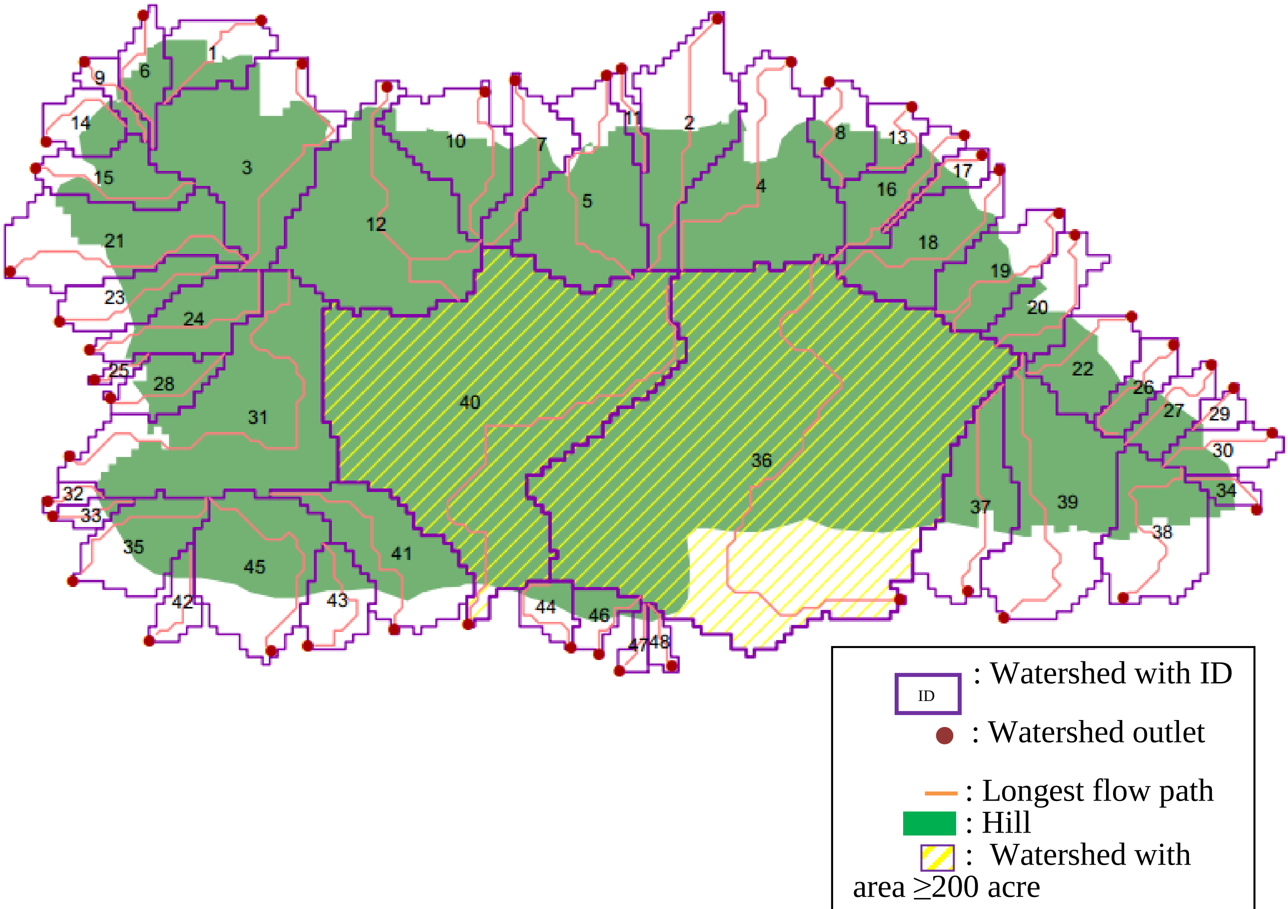


Fig. 13: Watersheds of Kahilipara Hill

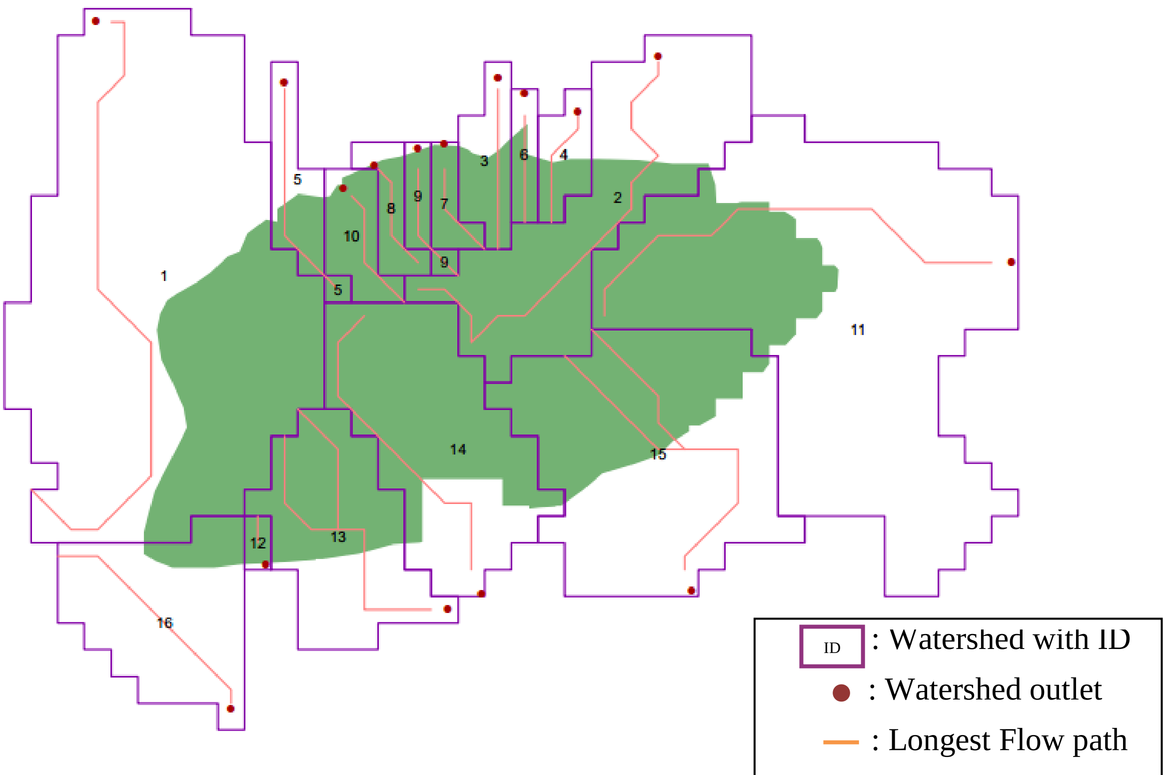


Fig. 14: Watersheds of Betkuchi Hill

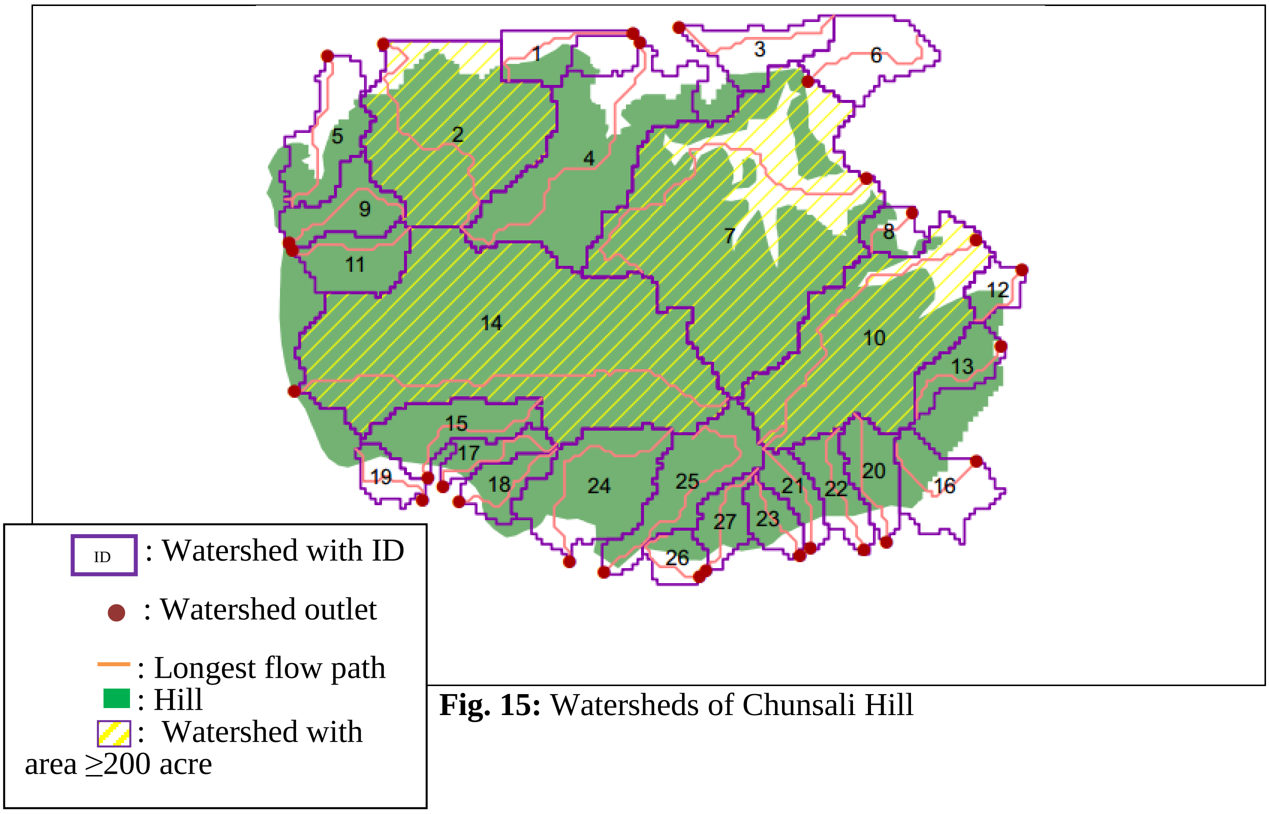


Fig. 15: Watersheds of Chunsali Hill

2.2.2 Calculation of peak discharge

To calculate time of concentration for the watersheds Williams's equation (1992) has been used. It is given by-

$$T_c \,(\text{minute}) = 0.057948\ L_c A^{-0.1} S_c^{-0.2}$$

where L_c is length of the longest flow channel (L_c) in m, A is area of watershed in m^2 and S_c is slope of the longest flow channel in (m/m). To determine the maximum average rainfall intensity that may persist for duration equal to the time of concentration IDF curves are generated for Guwahati city as shown in Fig. 16. Runoff coefficient values for different types of LULC are shown in Table 1. LULC maps of watersheds of hills of Guwahati city for the year 2015 are shown in Fig. 17.

Table 1: Runoff coefficient values for different surface covers (Sarma, 2011)

LULC	**Runoff coefficient C**	
Bare soil	0.5	
Forest	0.3	
Scrub land	0.3	
Marshy land	0	
Water bodies	0	
Urban settlement	0.74	

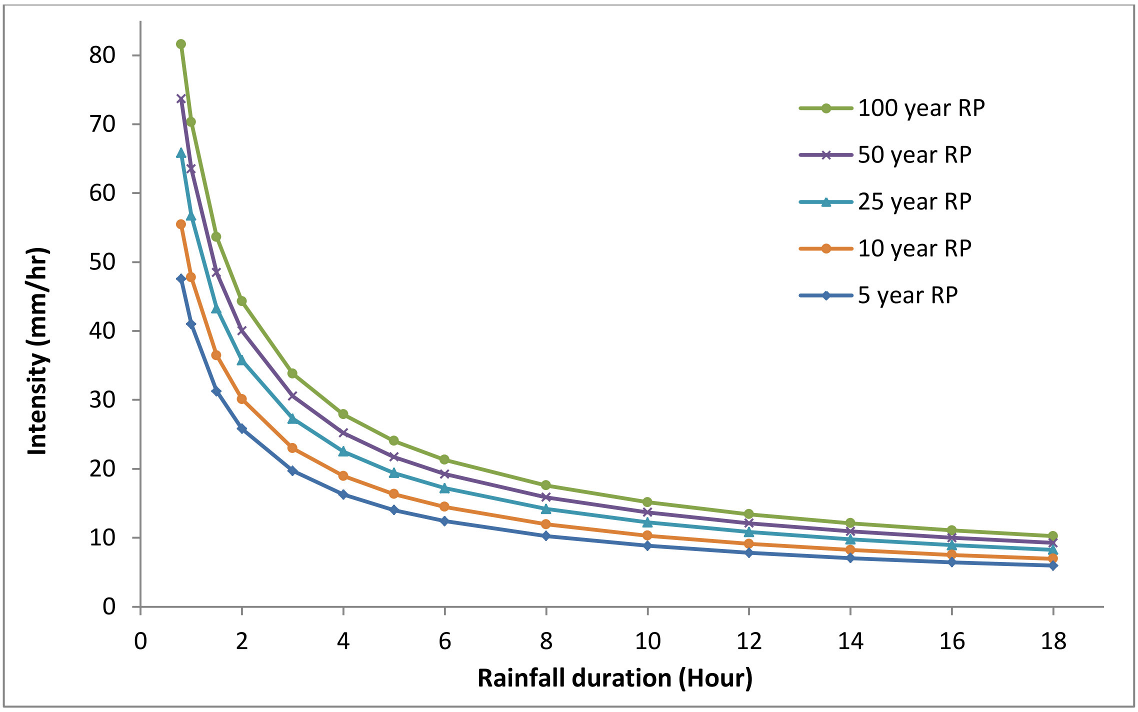
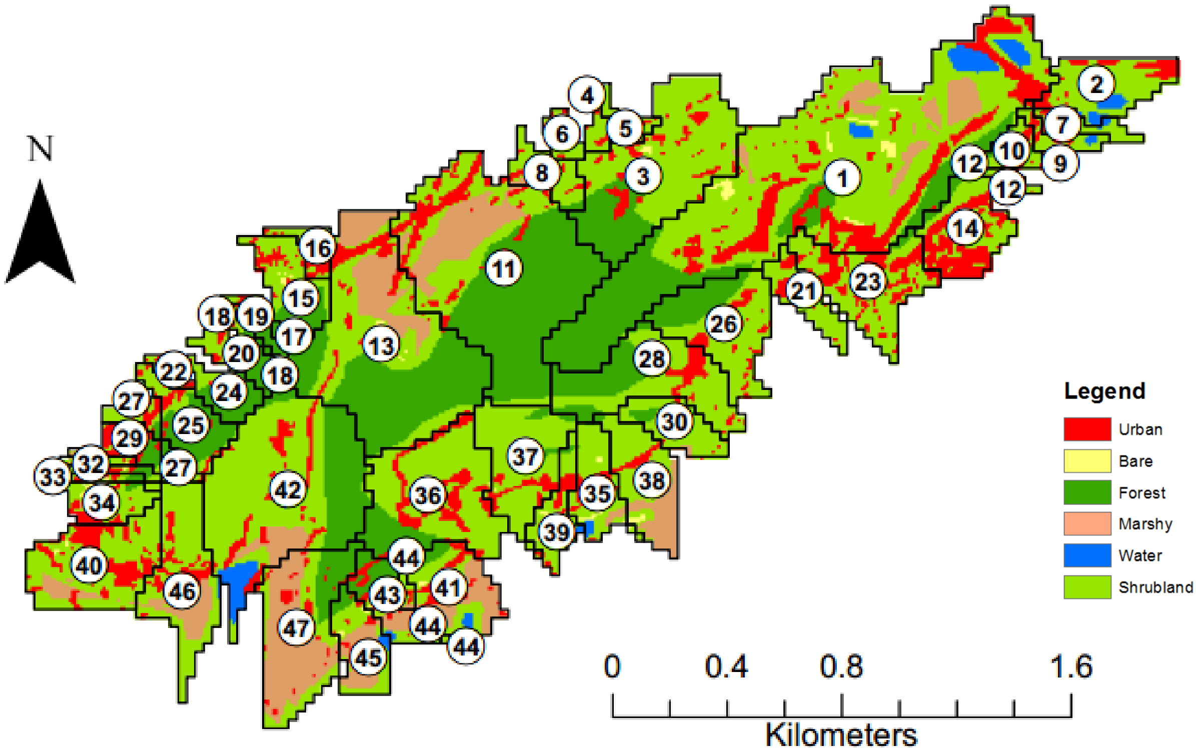
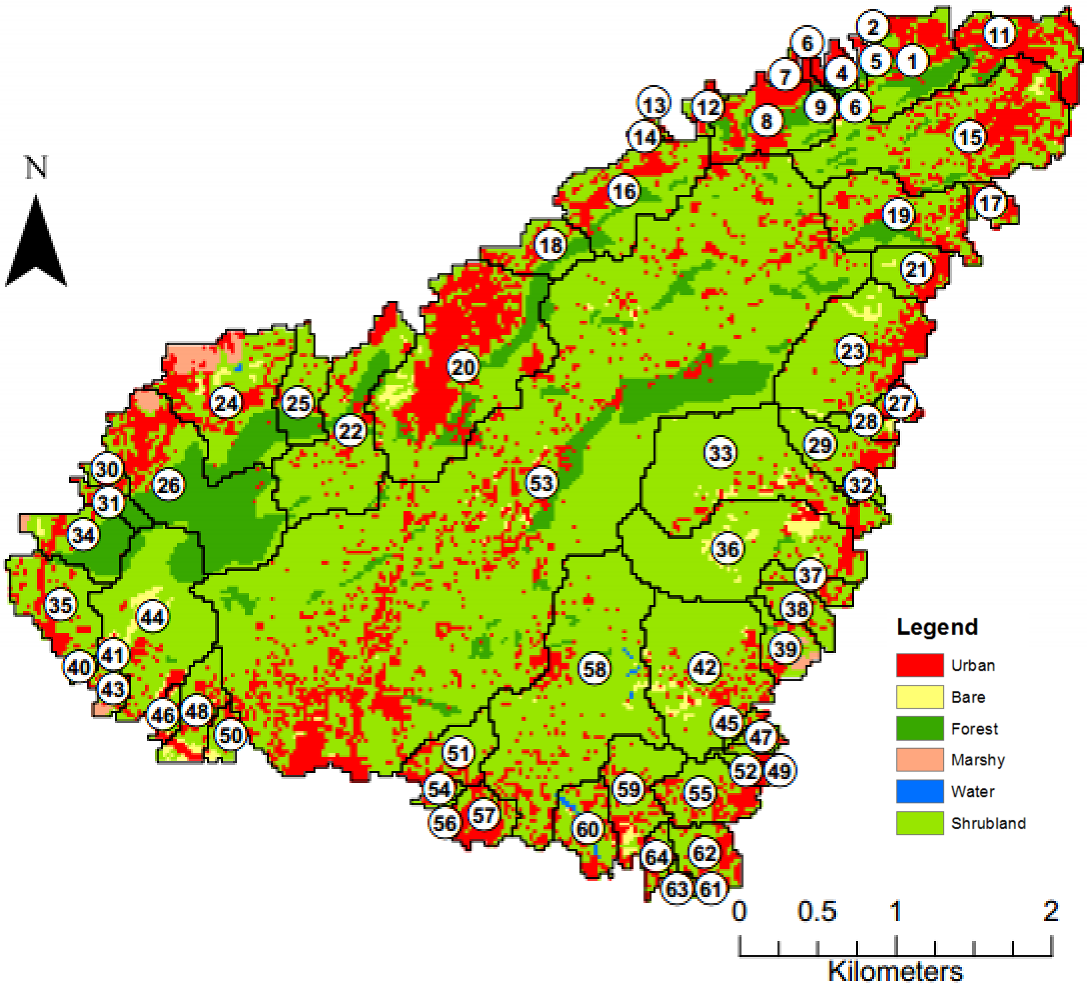


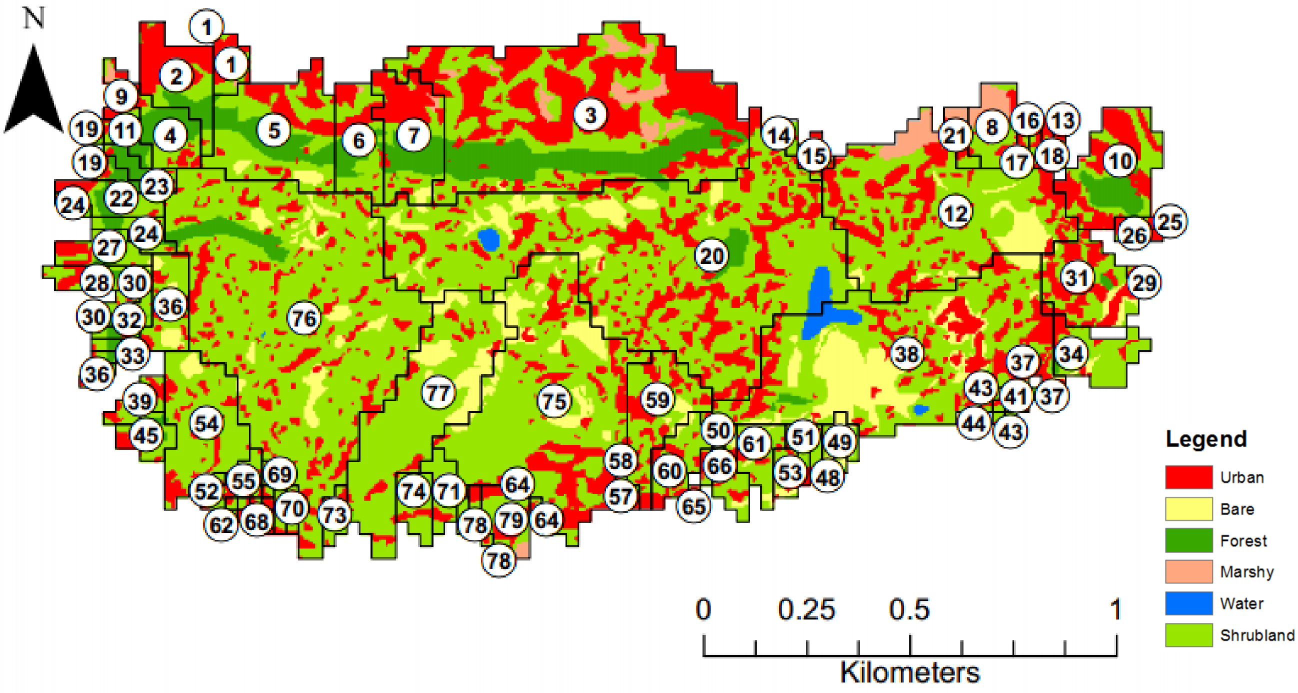
Fig. 16: IDF curves of Guwahati city.



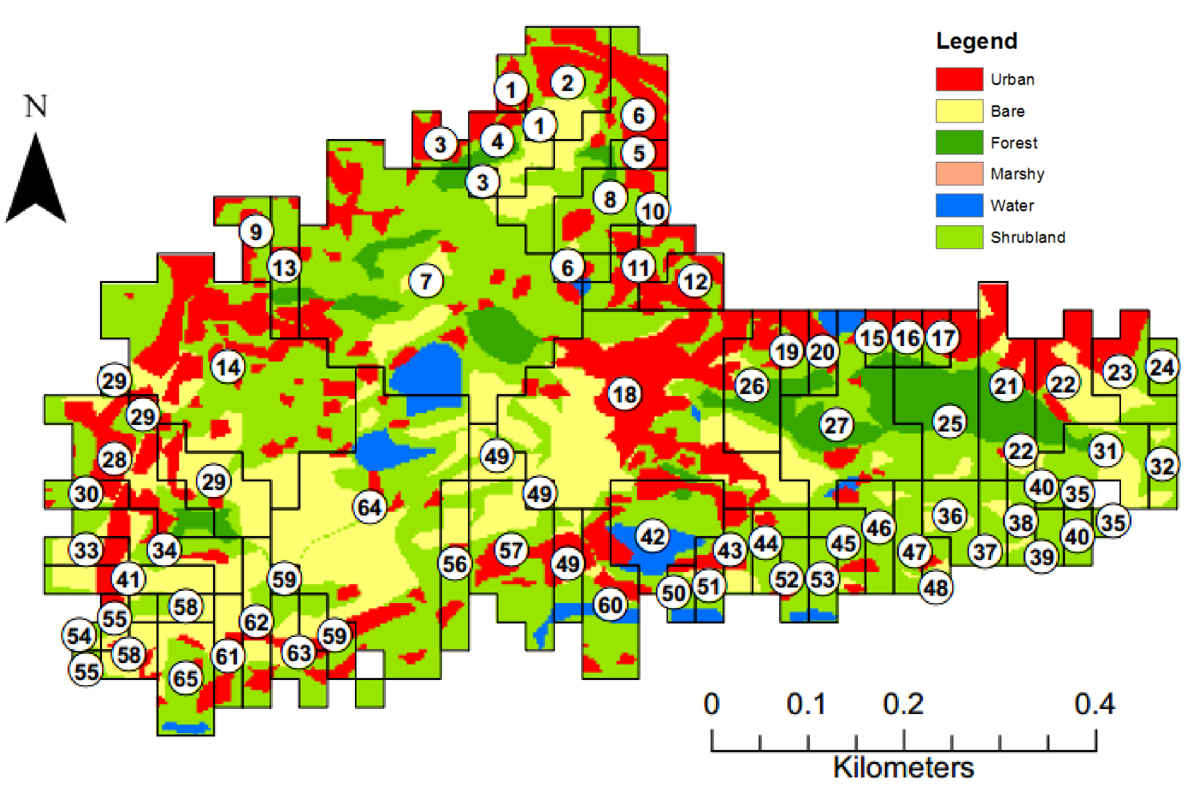
Hill ID: 1



Hill ID: 2



Hill ID: 3



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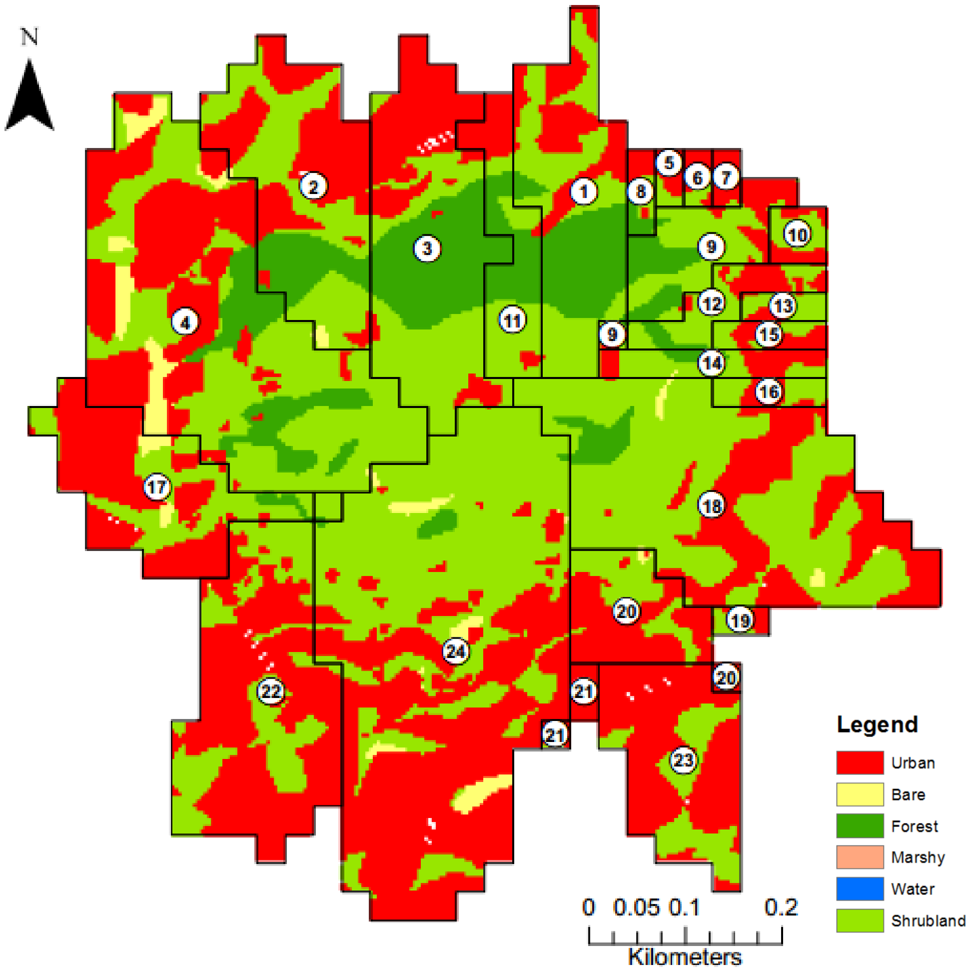

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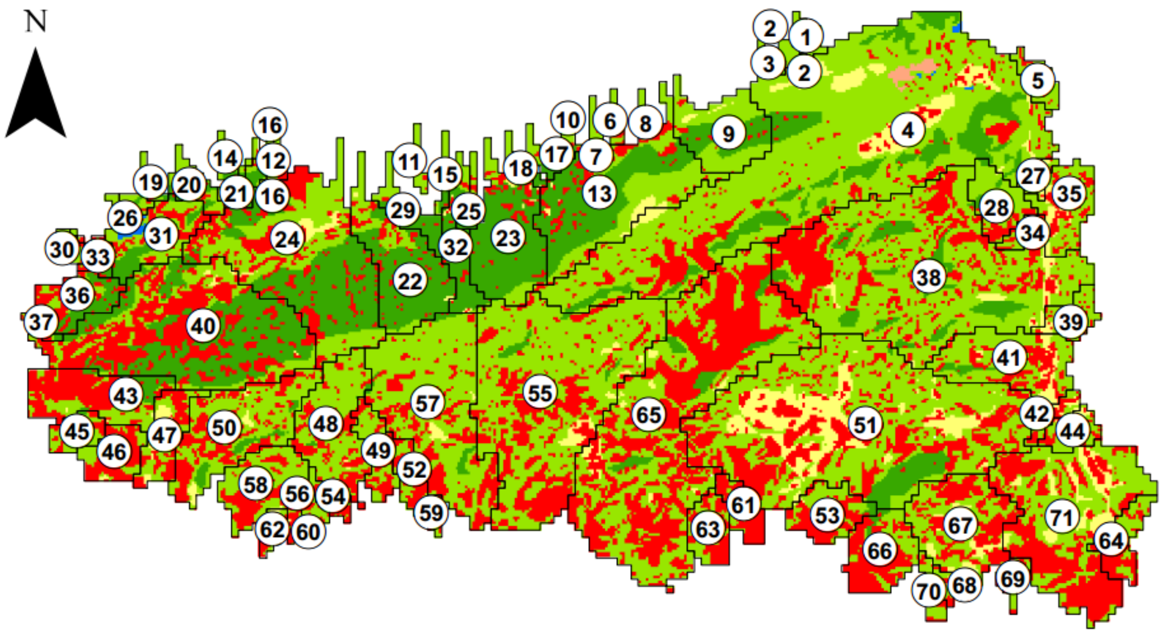
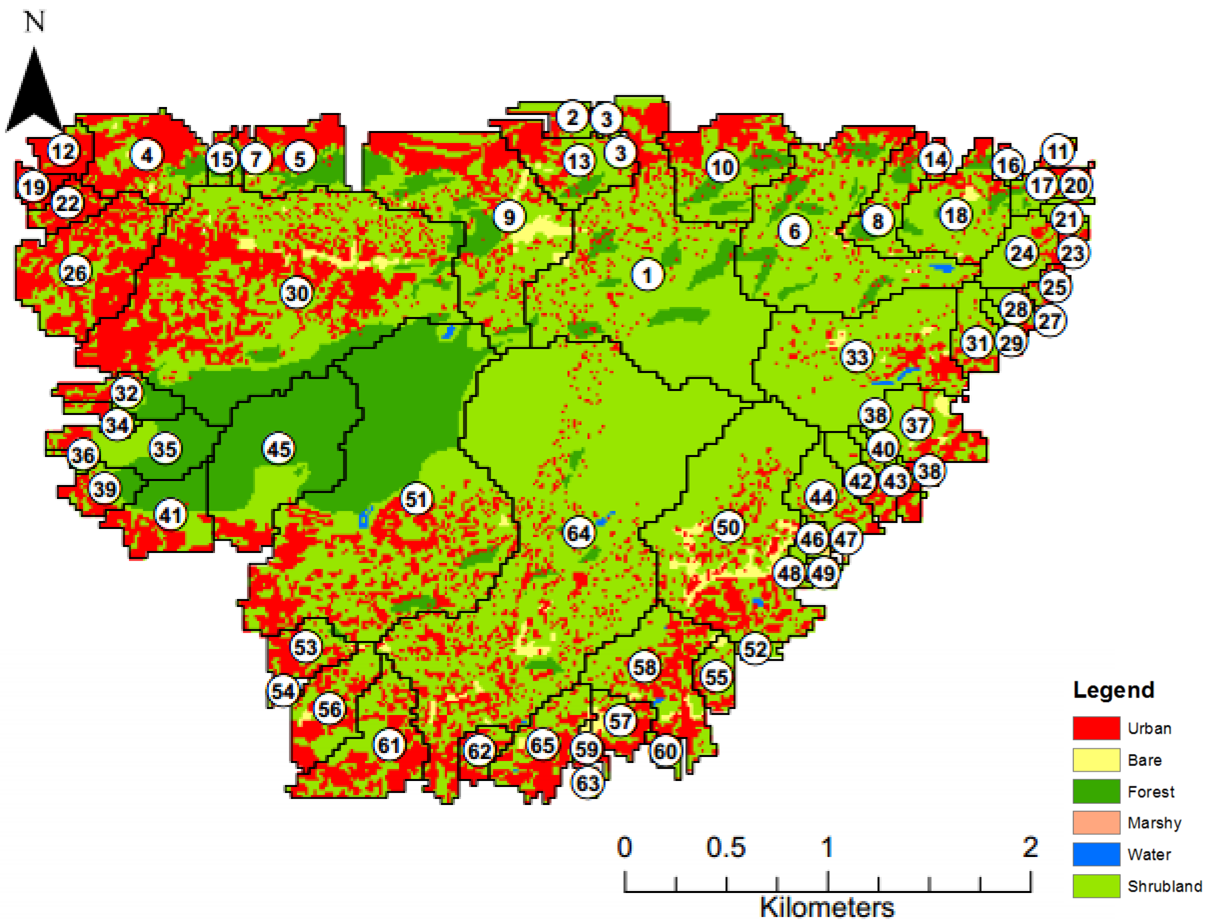
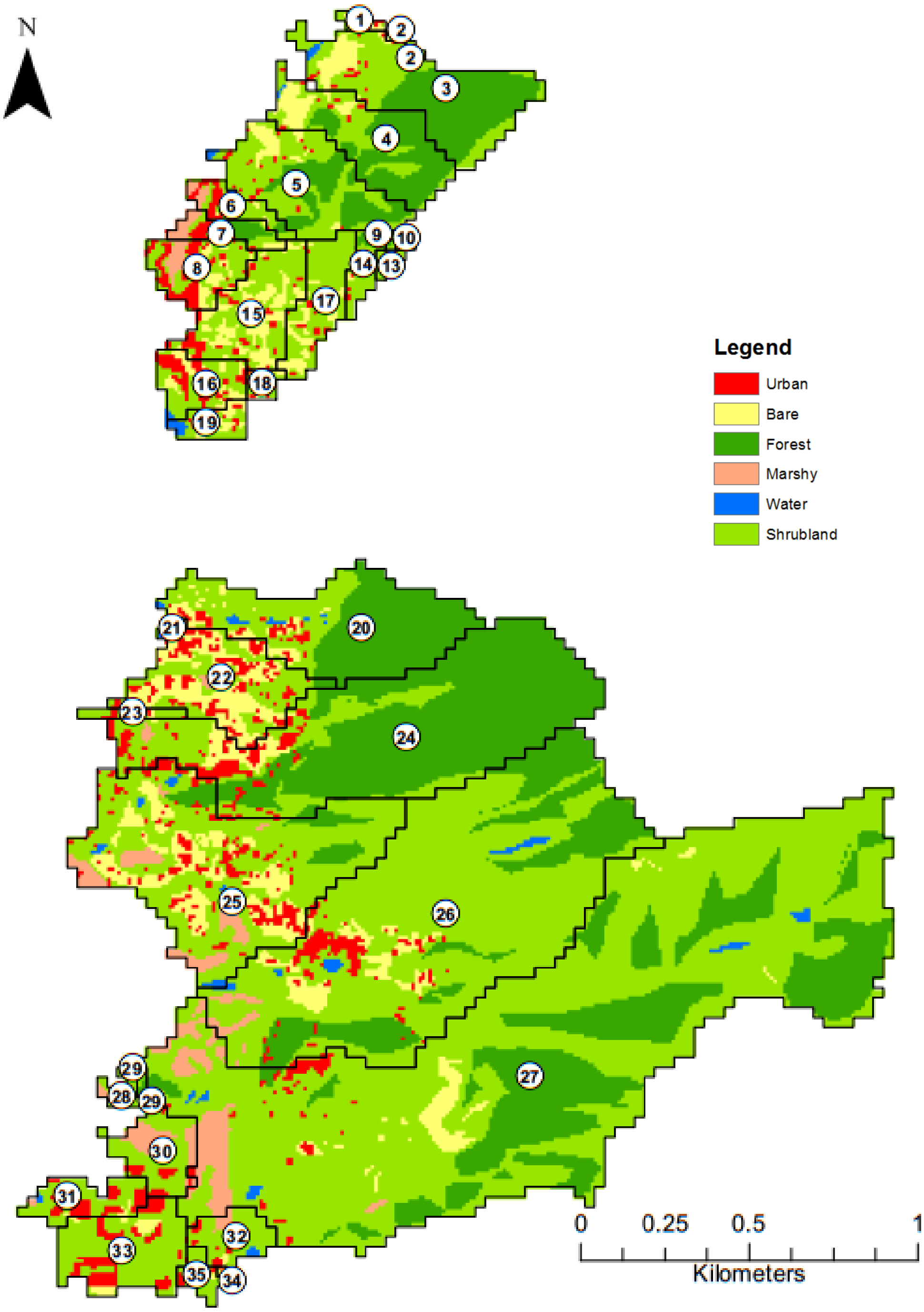


Hill ID: 6



Hill ID: 7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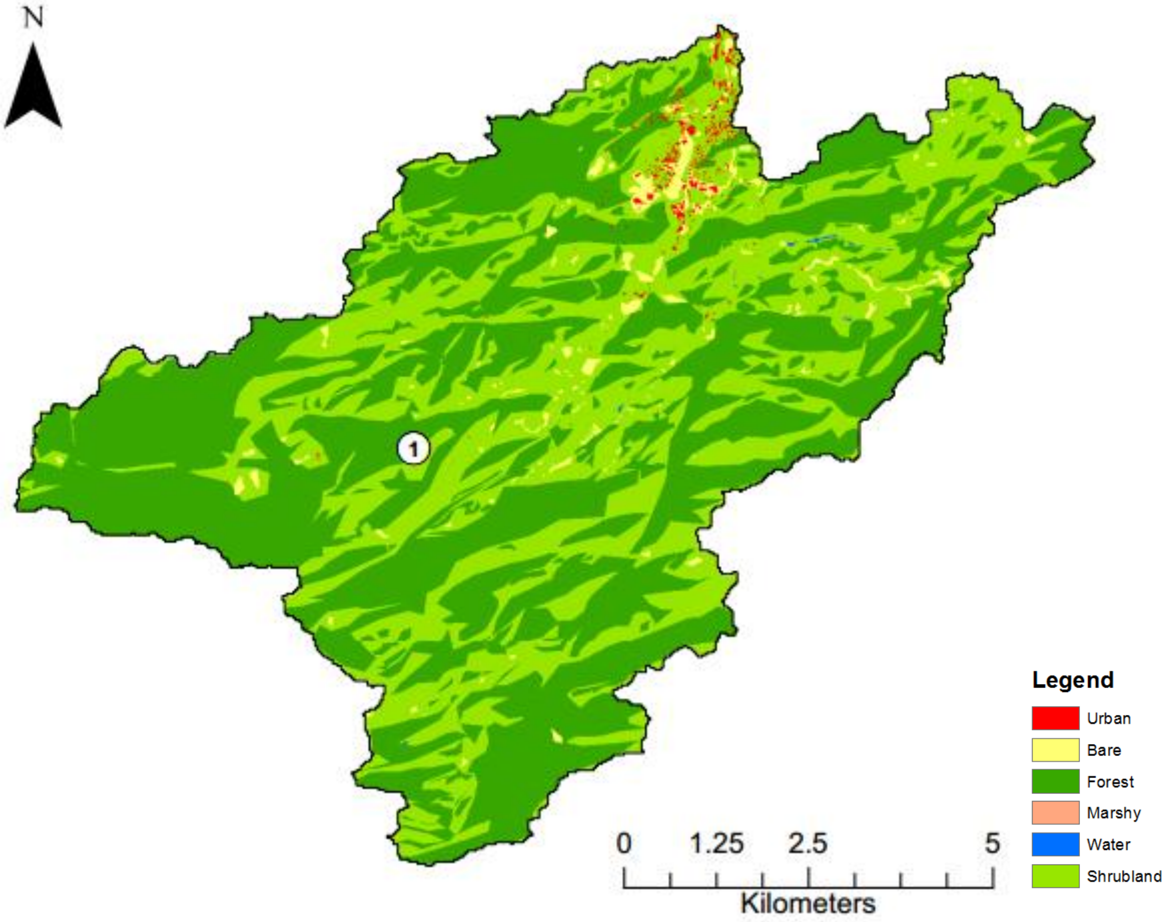
Hill ID: 8



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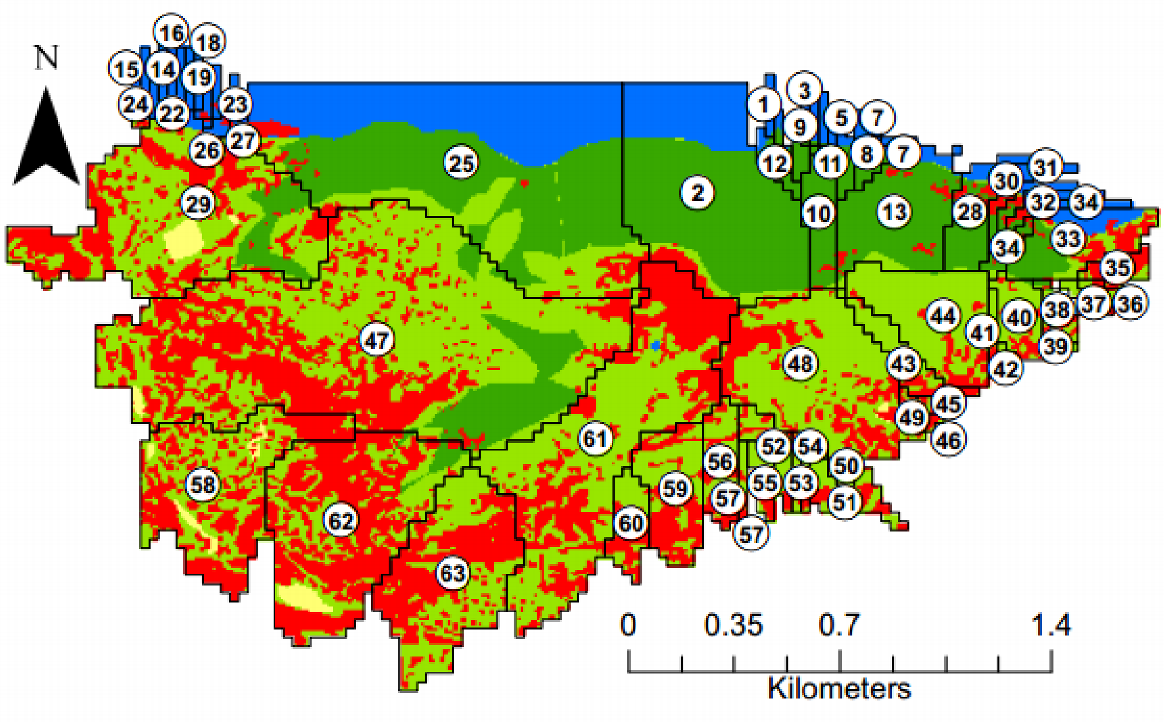

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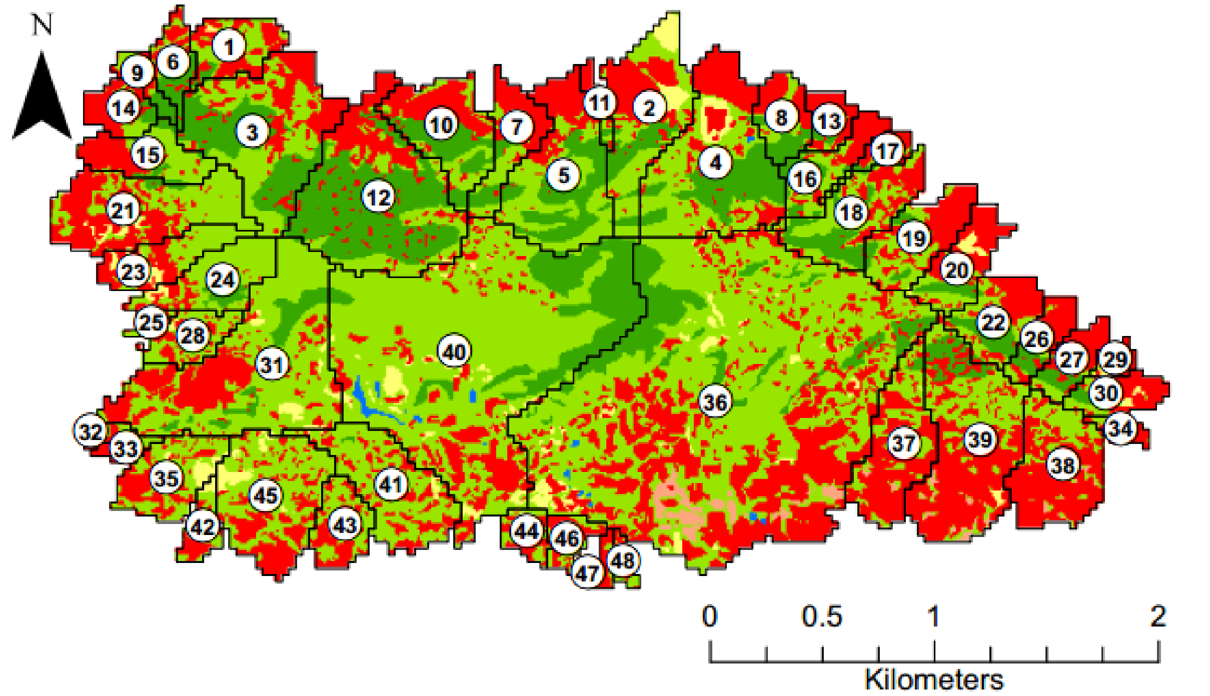

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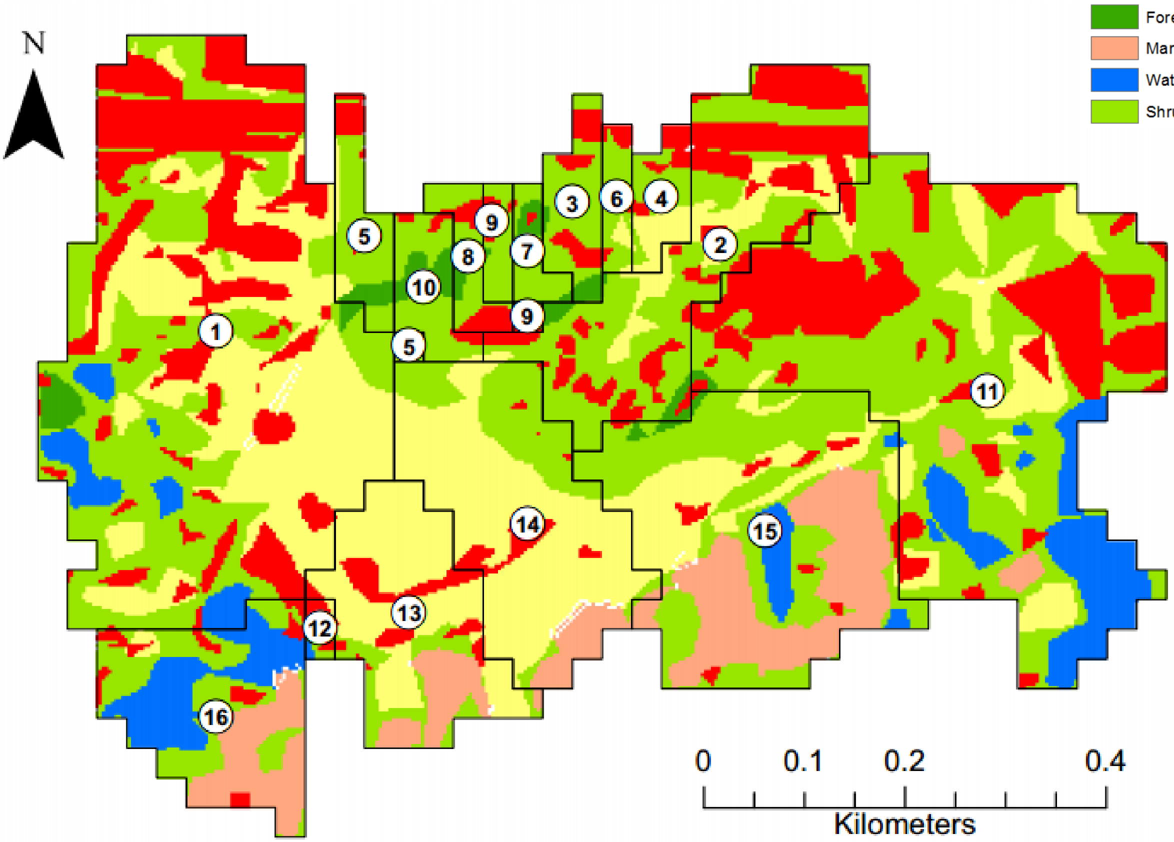
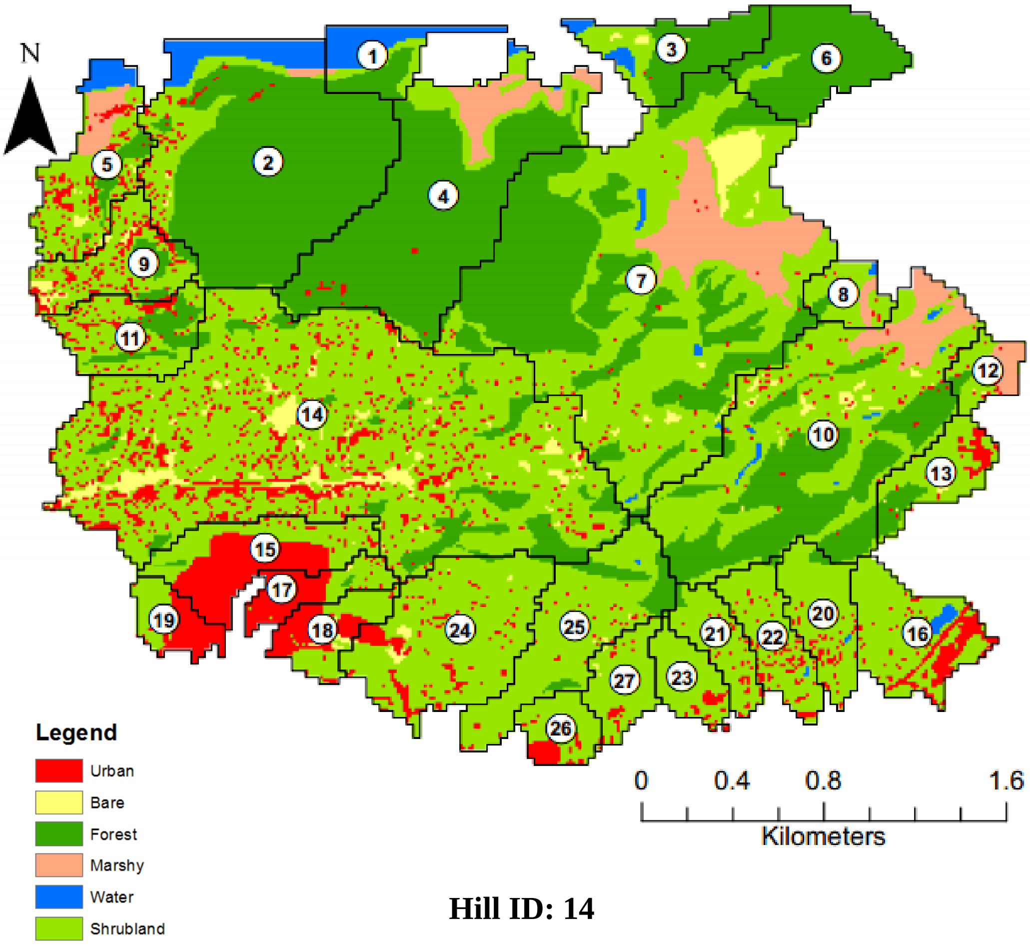


Hill ID: 13



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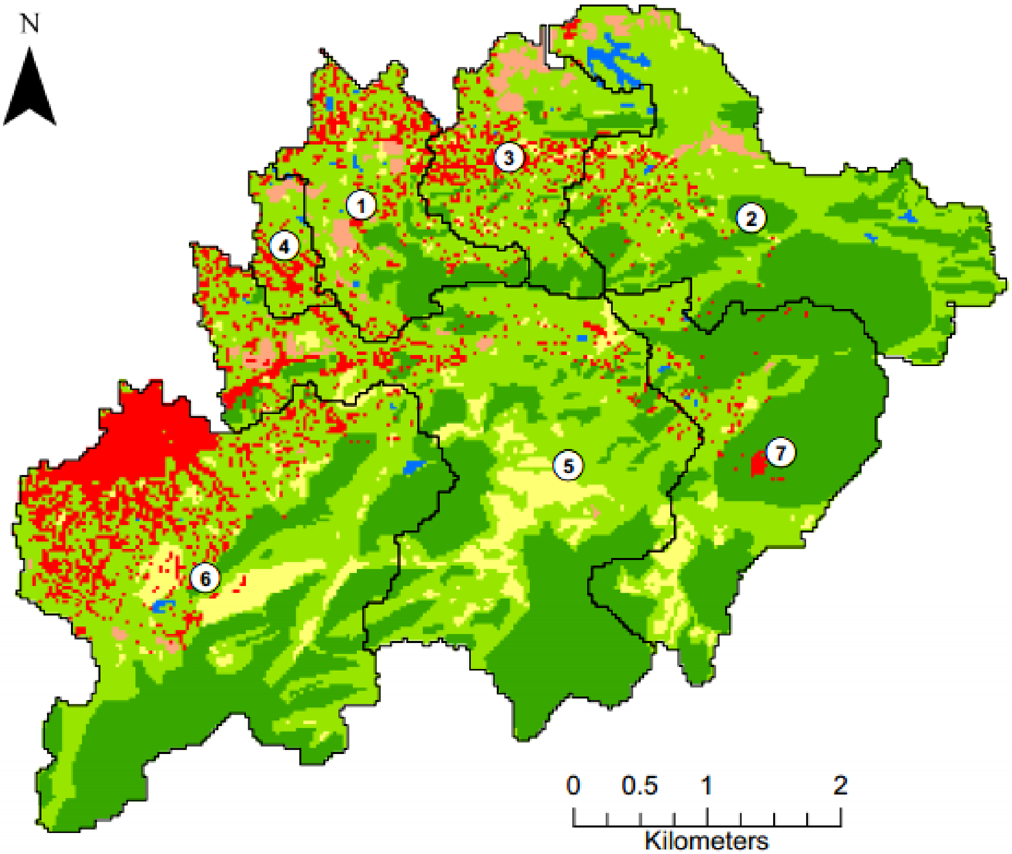


Hill ID: 9 and 15 (combined)

Fig. 17: LULC maps watersheds of hills of Guwahati city

As rational method is not directly applicable the watersheds having size greater than 200 acre, peak runoff for these watersheds are calculated with the help of junction analysis of modified rational method (San Diego County, 2003). Peak runoff calculation for all the watersheds of hills of Guwahati city is carried for the years 2011 and 2015 for the return periods 100, 50 and 25 years. These are shown in following tables.

Table 2: Peak runoff values from watersheds of University hill.

Basi-n ID	Watershed area (sq m)	Composite C for the year			Rainfall intensity (x10^{-5} m/s) for RP			Peak Q (m^3/s) in 2011 for RP			Peak Q (m^3/s) in 2015 for RP		
		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr
1	706366.91	0.32	0.32	0.34	2.12	1.92	1.71	4.75	4.30	3.84	4.82	4.36	3.89
2	77613.13	0.34	0.34	0.35	3.84	3.47	3.10	1.03	0.93	0.83	1.03	0.93	0.83
3	215398.30	0.31	0.31	0.38	3.04	2.75	2.45	2.04	1.85	1.65	2.05	1.85	1.66
4	12208.81	0.36	0.36	0.40	7.56	6.83	6.10	0.33	0.30	0.27	0.33	0.30	0.27
5	17441.17	0.39	0.40	0.40	4.87	4.40	3.93	0.34	0.30	0.27	0.34	0.31	0.27
6	16569.11	0.39	0.39	0.42	8.10	7.31	6.53	0.52	0.47	0.42	0.52	0.47	0.42
7	23545.56	0.38	0.39	0.39	4.24	3.83	3.42	0.38	0.34	0.31	0.39	0.35	0.32
8	36626.43	0.33	0.33	0.42	5.10	4.61	4.12	0.61	0.55	0.50	0.62	0.56	0.50
9	19185.29	0.38	0.38	0.40	4.99	4.50	4.02	0.37	0.33	0.30	0.37	0.33	0.30
10	26161.73	0.44	0.45	0.45	6.13	5.54	4.95	0.71	0.64	0.57	0.73	0.66	0.59
11	380217.22	0.24	0.24	0.26	2.93	2.64	2.36	2.69	2.43	2.17	2.70	2.44	2.18
12	12208.81	0.42	0.43	0.42	6.96	6.29	5.62	0.36	0.32	0.29	0.37	0.33	0.30
13	331382.01	0.23	0.24	0.27	3.22	2.91	2.60	2.44	2.20	1.97	2.55	2.31	2.06
14	84589.62	0.51	0.51	0.52	4.78	4.32	3.86	2.07	1.87	1.67	2.08	1.88	1.68
15	64532.29	0.31	0.32	0.38	5.04	4.56	4.07	1.01	0.91	0.82	1.06	0.95	0.85
16	20929.40	0.44	0.47	0.50	4.91	4.43	3.96	0.46	0.41	0.37	0.48	0.43	0.39
17	10464.69	0.29	0.30	0.32	6.77	6.12	5.46	0.20	0.18	0.16	0.21	0.19	0.17
18	9592.63	0.29	0.31	0.33	7.08	6.40	5.72	0.20	0.18	0.16	0.21	0.19	0.17
19	15697.05	0.24	0.25	0.29	6.23	5.62	5.02	0.24	0.21	0.19	0.24	0.22	0.19

20	34882.32	0.25	0.27	0.27	6.40	5.78	5.17	0.55	0.50	0.44	0.60	0.54	0.48
21	39242.61	0.43	0.43	0.43	4.73	4.27	3.81	0.79	0.71	0.64	0.80	0.73	0.65
22	9592.64	0.40	0.45	0.44	7.81	7.06	6.30	0.30	0.27	0.24	0.34	0.31	0.27
23	110751.36	0.46	0.46	0.46	4.36	3.94	3.52	2.21	2.00	1.78	2.21	2.00	1.78
24	34010.26	0.23	0.24	0.26	7.34	6.64	5.93	0.58	0.52	0.47	0.59	0.53	0.48
25	57555.84	0.29	0.30	0.30	5.40	4.88	4.36	0.89	0.81	0.72	0.92	0.83	0.74
26	112495.45	0.31	0.32	0.32	5.03	4.54	4.06	1.75	1.59	1.42	1.79	1.62	1.45
27	27905.86	0.38	0.40	0.41	5.52	4.99	4.45	0.59	0.53	0.47	0.61	0.55	0.49
28	134296.93	0.30	0.30	0.33	3.58	3.24	2.89	1.45	1.31	1.17	1.46	1.32	1.18
29	31394.09	0.44	0.49	0.49	5.25	4.74	4.24	0.73	0.66	0.59	0.80	0.72	0.65
30	47963.19	0.29	0.29	0.30	5.77	5.21	4.65	0.81	0.73	0.65	0.81	0.73	0.65
31	7848.51	0.40	0.41	0.44	6.24	5.64	5.04	0.20	0.18	0.16	0.20	0.18	0.16
32	12208.83	0.37	0.39	0.38	5.58	5.04	4.50	0.25	0.23	0.20	0.27	0.24	0.22
33	11336.74	0.34	0.35	0.34	5.63	5.08	4.54	0.22	0.20	0.18	0.22	0.20	0.18
34	41858.77	0.42	0.43	0.44	5.18	4.68	4.18	0.91	0.82	0.74	0.94	0.85	0.76
35	57555.83	0.36	0.36	0.37	4.95	4.47	4.00	1.02	0.92	0.82	1.03	0.93	0.83
36	174411.57	0.36	0.36	0.37	4.49	4.05	3.62	2.82	2.55	2.28	2.82	2.55	2.28
37	107263.13	0.33	0.34	0.34	4.45	4.02	3.59	1.58	1.43	1.28	1.61	1.46	1.30
38	81973.42	0.24	0.24	0.24	4.72	4.26	3.81	0.93	0.84	0.75	0.93	0.84	0.75
39	41858.77	0.35	0.36	0.37	4.92	4.45	3.97	0.73	0.66	0.59	0.74	0.67	0.59
40	125576.34	0.40	0.40	0.41	4.09	3.69	3.30	2.08	1.88	1.67	2.08	1.88	1.68
41	82845.50	0.25	0.25	0.25	5.32	4.81	4.29	1.08	0.98	0.87	1.09	0.98	0.88
42	298243.80	0.27	0.28	0.29	3.13	2.83	2.53	2.57	2.32	2.07	2.60	2.35	2.10
43	47963.20	0.26	0.26	0.26	5.05	4.57	4.08	0.64	0.57	0.51	0.64	0.57	0.51
44	11336.75	0.28	0.28	0.28	5.86	5.30	4.73	0.18	0.17	0.15	0.18	0.17	0.15
45	55811.68	0.20	0.20	0.20	4.47	4.04	3.60	0.49	0.44	0.39	0.49	0.44	0.39
46	115983.71	0.31	0.31	0.31	3.56	3.21	2.87	1.27	1.15	1.03	1.27	1.15	1.03
47	147377.82	0.15	0.15	0.15	3.30	2.98	2.67	0.71	0.64	0.58	0.73	0.66	0.59

Table 2: Peak runoff values from watersheds of Fatasil hill.

Bas-in ID	Watershed area (sq m)	Composite C for the year			Rainfall intensity (x10^{-5} m/s) for RP			Peak Q (m3/s) in 2011 for RP			Peak Q (m3/s) in 2015 for RP		
		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr
1	327021.72	0.44	0.44	0.48	3.77	3.41	3.04	5.40	4.88	4.35	5.47	4.94	4.41
2	13080.87	0.47	0.47	0.61	8.49	7.67	6.85	0.52	0.47	0.42	0.52	0.47	0.42
3	10464.68	0.64	0.64	0.64	7.57	6.84	6.11	0.51	0.46	0.41	0.51	0.46	0.41
4	63660.23	0.42	0.42	0.48	5.36	4.84	4.32	1.43	1.29	1.16	1.43	1.29	1.16
5	20057.32	0.47	0.49	0.54	6.52	5.89	5.26	0.61	0.55	0.49	0.64	0.58	0.52
6	16569.10	0.60	0.60	0.60	5.91	5.34	4.77	0.59	0.53	0.47	0.59	0.53	0.47
7	13952.93	0.69	0.71	0.69	7.79	7.03	6.28	0.75	0.68	0.61	0.77	0.70	0.62
8	305220.26	0.47	0.47	0.50	3.77	3.41	3.04	5.39	4.87	4.35	5.40	4.88	4.36
9	42730.84	0.39	0.39	0.42	5.68	5.13	4.58	0.95	0.86	0.77	0.95	0.86	0.77
10	13080.87	0.52	0.52	0.55	10.40	9.39	8.39	0.71	0.64	0.57	0.71	0.64	0.57
11	294755.55	0.57	0.57	0.58	2.73	2.47	2.20	4.56	4.12	3.68	4.56	4.12	3.68
12	35754.39	0.63	0.64	0.64	6.19	5.60	5.00	1.40	1.26	1.13	1.41	1.27	1.13
13	13952.93	0.45	0.50	0.51	8.89	8.03	7.18	0.56	0.51	0.46	0.61	0.56	0.50
14	18313.20	0.46	0.53	0.53	7.74	6.99	6.24	0.66	0.59	0.53	0.75	0.68	0.60
15	881650.52	0.44	0.44	0.46	1.97	1.78	1.59	13.52	12.21	10.91	13.65	12.33	11.01
16	426436.31	0.41	0.41	0.45	3.04	2.75	2.46	5.26	4.75	4.24	5.31	4.80	4.29
17	68892.60	0.54	0.54	0.54	4.31	3.90	3.48	1.60	1.44	1.29	1.60	1.44	1.29
18	171795.41	0.38	0.38	0.46	3.27	2.95	2.64	2.15	1.94	1.74	2.15	1.94	1.74
19	404634.83	0.40	0.40	0.42	2.80	2.53	2.26	4.49	4.06	3.62	4.58	4.13	3.69
20	1016819.51	0.47	0.48	0.53	2.42	2.18	1.95	17.45	15.76	14.08	17.64	15.94	14.24
21	143889.55	0.44	0.44	0.45	4.95	4.48	4.00	3.12	2.82	2.52	3.16	2.85	2.55
22	571197.92	0.35	0.36	0.42	2.13	1.92	1.72	4.25	3.84	3.43	4.36	3.94	3.51
23	569453.82	0.40	0.41	0.42	3.04	2.75	2.46	6.91	6.25	5.58	7.04	6.36	5.68
24	585150.83	0.37	0.37	0.43	2.65	2.39	2.13	5.66	5.11	4.57	5.70	5.15	4.60
25	182260.12	0.33	0.33	0.43	3.65	3.30	2.95	2.20	1.98	1.77	2.20	1.99	1.78
26	710727.18	0.31	0.32	0.36	2.19	1.98	1.77	4.88	4.41	3.94	4.93	4.45	3.98
27	52323.47	0.65	0.65	0.67	5.94	5.37	4.80	2.01	1.82	1.62	2.03	1.83	1.64
28	53195.53	0.39	0.40	0.50	4.80	4.34	3.88	0.99	0.89	0.80	1.02	0.92	0.82
29	200573.33	0.38	0.39	0.44	3.67	3.32	2.96	2.83	2.56	2.28	2.91	2.63	2.35

30	47091.12	0.48	0.48	0.49	4.78	4.32	3.86	1.09	0.98	0.88	1.09	0.98	0.88
31	68020.52	0.38	0.39	0.49	4.26	3.84	3.43	1.09	0.98	0.88	1.13	1.02	0.91
32	40986.72	0.53	0.53	0.53	4.25	3.84	3.43	0.92	0.83	0.74	0.92	0.83	0.74
33	718575.74	0.33	0.35	0.35	2.10	1.90	1.70	4.99	4.50	4.02	5.30	4.79	4.28
34	221502.68	0.30	0.30	0.50	3.57	3.23	2.88	2.38	2.15	1.92	2.39	2.16	1.93
35	291267.34	0.42	0.42	0.51	3.00	2.71	2.42	3.65	3.30	2.95	3.65	3.30	2.95
36	693286.01	0.35	0.36	0.38	2.25	2.04	1.82	5.41	4.89	4.37	5.55	5.01	4.48
37	80229.34	0.41	0.44	0.44	4.28	3.86	3.45	1.42	1.28	1.15	1.51	1.37	1.22
38	110751.33	0.36	0.36	0.40	3.98	3.59	3.21	1.57	1.42	1.26	1.60	1.45	1.29
39	135168.99	0.38	0.39	0.41	4.58	4.13	3.69	2.37	2.14	1.91	2.39	2.16	1.93
40	22673.50	0.50	0.50	0.50	6.31	5.70	5.09	0.72	0.65	0.58	0.72	0.65	0.58
41	20057.33	0.44	0.45	0.44	5.65	5.11	4.56	0.50	0.45	0.40	0.51	0.46	0.41
42	649683.09	0.34	0.36	0.41	2.87	2.59	2.31	6.37	5.75	5.14	6.76	6.11	5.45
43	56683.76	0.36	0.36	0.37	4.32	3.90	3.48	0.89	0.80	0.72	0.89	0.80	0.72
44	637474.32	0.33	0.34	0.45	2.35	2.12	1.90	4.87	4.40	3.93	5.05	4.56	4.07
45	24417.62	0.46	0.47	0.46	6.31	5.70	5.09	0.72	0.65	0.58	0.72	0.65	0.58
46	45347.00	0.43	0.50	0.50	5.12	4.63	4.13	1.00	0.90	0.81	1.15	1.04	0.93
47	40986.72	0.45	0.45	0.51	6.39	5.77	5.16	1.18	1.07	0.96	1.18	1.07	0.96
48	170923.34	0.45	0.47	0.48	3.43	3.10	2.77	2.66	2.40	2.15	2.73	2.47	2.20
49	29649.97	0.47	0.47	0.55	6.18	5.58	4.98	0.86	0.78	0.69	0.86	0.78	0.70
50	64532.29	0.46	0.46	0.46	5.24	4.73	4.22	1.54	1.39	1.24	1.54	1.39	1.24
51	180515.99	0.43	0.44	0.47	3.64	3.29	2.94	2.83	2.56	2.29	2.88	2.60	2.32
52	44474.96	0.49	0.52	0.54	5.17	4.67	4.17	1.13	1.02	0.92	1.20	1.08	0.97
53	6315443.34	0.35	0.36	0.37	1.05	0.95	0.85	86.14	77.82	69.51	89.01	80.41	71.83
54	35754.37	0.56	0.57	0.58	5.12	4.63	4.13	1.03	0.93	0.83	1.04	0.94	0.84
55	214526.23	0.45	0.47	0.49	4.03	3.64	3.25	3.92	3.55	3.17	4.02	3.63	3.25
56	18313.21	0.59	0.61	0.60	5.70	5.15	4.60	0.62	0.56	0.50	0.64	0.58	0.52
57	128192.51	0.57	0.57	0.58	4.28	3.86	3.45	3.12	2.82	2.52	3.12	2.82	2.52
58	1182510.50	0.33	0.35	0.35	2.07	1.87	1.67	14.28	12.90	11.52	14.81	13.38	11.95
59	261617.40	0.40	0.42	0.42	3.31	2.99	2.67	3.44	3.11	2.77	3.61	3.26	2.91
60	186620.37	0.42	0.43	0.47	3.54	3.20	2.86	2.78	2.51	2.24	2.86	2.58	2.31
61	13080.86	0.47	0.49	0.47	5.67	5.12	4.58	0.35	0.31	0.28	0.36	0.33	0.29

62	151738.07	0.48	0.49	0.54	4.06	3.66	3.27	2.96	2.68	2.39	3.04	2.74	2.45
63	20929.38	0.48	0.48	0.50	6.00	5.42	4.84	0.61	0.55	0.49	0.61	0.55	0.49
64	63660.21	0.43	0.47	0.52	4.74	4.28	3.83	1.30	1.18	1.05	1.43	1.29	1.16

Table 3: Peak runoff values from watersheds of Kalapahar hill

Bas-in ID	**Watershed area (sq m)**	**Composite C for the year**			**Rainfall intensity ($x10^{-5}$ m/s) for RP**			**Peak Q (m3/s) in 2011 for RP**			**Peak Q (m3/s) in 2015 for RP**		
		2011	**2015**	**2025**	**100 yr**	**50 yr**	**25 yr**	**100 yr**	**50 yr**	**25 yr**	**100 yr**	**50 yr**	**25 yr**
1	12208.81	0.59	0.60	0.60	8.91	8.05	7.19	0.65	0.58	0.52	0.65	0.59	0.52
2	33138.20	0.54	0.55	0.58	7.06	6.38	5.70	1.27	1.15	1.03	1.28	1.15	1.03
3	256385.02	0.45	0.46	0.48	2.64	2.38	2.13	3.04	2.75	2.46	3.10	2.80	2.50
4	25289.68	0.34	0.34	0.41	6.19	5.59	5.00	0.53	0.48	0.43	0.54	0.48	0.43
5	72380.81	0.38	0.39	0.46	5.83	5.27	4.71	1.62	1.46	1.31	1.64	1.48	1.32
6	30522.02	0.38	0.38	0.46	7.20	6.50	5.81	0.84	0.76	0.67	0.84	0.76	0.68
7	44474.95	0.44	0.45	0.49	5.94	5.37	4.80	1.17	1.06	0.95	1.18	1.06	0.95
8	22673.49	0.28	0.28	0.29	7.11	6.42	5.74	0.45	0.41	0.37	0.45	0.41	0.37
9	2616.17	0.51	0.51	0.51	20.96	18.94	16.92	0.28	0.25	0.23	0.28	0.25	0.23
10	51451.42	0.49	0.49	0.54	5.86	5.29	4.73	1.48	1.34	1.20	1.49	1.34	1.20
11	8720.58	0.31	0.31	0.38	10.94	9.89	8.83	0.30	0.27	0.24	0.30	0.27	0.24
12	169179.23	0.42	0.42	0.45	4.43	4.00	3.57	3.11	2.81	2.51	3.16	2.85	2.55
13	1744.12	0.68	0.70	0.68	21.23	19.18	17.13	0.25	0.23	0.20	0.26	0.23	0.21
14	4360.30	0.48	0.48	0.48	15.70	14.19	12.67	0.33	0.30	0.27	0.33	0.30	0.27
15	6104.40	0.49	0.55	0.49	11.66	10.53	9.41	0.35	0.31	0.28	0.39	0.35	0.31
16	2616.18	0.43	0.43	0.43	18.44	16.66	14.88	0.21	0.19	0.17	0.21	0.19	0.17
17	2616.17	0.55	0.55	0.55	22.12	19.98	17.85	0.32	0.29	0.26	0.32	0.29	0.26
18	6104.40	0.48	0.49	0.48	12.00	10.84	9.68	0.35	0.32	0.28	0.36	0.32	0.29
19	6976.47	0.29	0.29	0.32	10.72	9.69	8.65	0.22	0.20	0.18	0.22	0.20	0.18
20	364520.18	0.40	0.41	0.44	2.65	2.40	2.14	3.87	3.50	3.12	3.99	3.61	3.22
21	7848.52	0.27	0.27	0.27	9.61	8.69	7.76	0.21	0.19	0.17	0.21	0.19	0.17
22	15697.05	0.37	0.38	0.39	7.86	7.10	6.34	0.45	0.41	0.37	0.47	0.42	0.38
23	9592.64	0.34	0.34	0.34	8.85	8.00	7.14	0.29	0.26	0.23	0.29	0.26	0.23
24	13952.92	0.37	0.37	0.37	7.09	6.41	5.72	0.36	0.33	0.29	0.37	0.33	0.30

25	2616.17	0.49	0.49	0.58	23.96	21.65	19.33	0.31	0.28	0.25	0.31	0.28	0.25
26	4360.29	0.55	0.57	0.56	13.06	11.80	10.54	0.31	0.28	0.25	0.33	0.29	0.26
27	15697.06	0.39	0.39	0.39	8.83	7.98	7.12	0.53	0.48	0.43	0.54	0.49	0.44
28	13952.92	0.38	0.41	0.38	8.06	7.29	6.51	0.43	0.39	0.35	0.46	0.41	0.37
29	1744.11	0.56	0.56	0.56	23.62	21.34	19.06	0.23	0.21	0.19	0.23	0.21	0.19
30	6976.46	0.40	0.42	0.40	10.03	9.06	8.10	0.28	0.25	0.23	0.29	0.26	0.24
31	40114.67	0.53	0.55	0.53	7.40	6.69	5.97	1.57	1.42	1.27	1.62	1.47	1.31
32	8720.58	0.33	0.37	0.33	10.62	9.60	8.57	0.31	0.28	0.25	0.34	0.31	0.28
33	2616.17	0.30	0.30	0.30	24.24	21.90	19.56	0.19	0.17	0.15	0.19	0.17	0.15
34	26161.74	0.37	0.38	0.38	6.05	5.47	4.89	0.59	0.53	0.48	0.60	0.54	0.49
35	1744.12	0.38	0.38	0.38	50.82	45.91	41.01	0.33	0.30	0.27	0.33	0.30	0.27
36	27905.84	0.44	0.44	0.44	5.43	4.91	4.38	0.66	0.60	0.53	0.66	0.60	0.53
37	1744.12	0.44	0.44	0.44	17.81	16.09	14.37	0.14	0.12	0.11	0.14	0.12	0.11
38	221502.70	0.43	0.44	0.49	2.82	2.55	2.28	2.72	2.46	2.19	2.78	2.51	2.24
39	10464.70	0.42	0.42	0.42	10.32	9.33	8.33	0.45	0.41	0.36	0.46	0.41	0.37
40	1744.12	0.38	0.39	0.38	16.89	15.26	13.63	0.11	0.10	0.09	0.11	0.10	0.09
41	2616.18	0.46	0.46	0.46	17.34	15.67	14.00	0.21	0.19	0.17	0.21	0.19	0.17
42	1744.12	0.42	0.43	0.42	10.69	9.65	8.62	0.08	0.07	0.06	0.08	0.07	0.06
43	2616.17	0.46	0.47	0.46	12.11	10.94	9.77	0.15	0.13	0.12	0.15	0.14	0.12
44	1744.12	0.40	0.40	0.40	13.43	12.14	10.84	0.09	0.08	0.08	0.09	0.08	0.08
45	12208.82	0.35	0.38	0.35	9.73	8.79	7.85	0.42	0.38	0.34	0.46	0.41	0.37
46	2616.17	0.38	0.39	0.40	16.07	14.52	12.97	0.16	0.15	0.13	0.16	0.15	0.13
47	3488.23	0.37	0.42	0.44	13.16	11.89	10.62	0.17	0.15	0.14	0.19	0.17	0.15
48	3488.23	0.38	0.38	0.44	13.02	11.76	10.51	0.17	0.15	0.14	0.17	0.15	0.14
49	4360.30	0.47	0.47	0.51	10.40	9.40	8.39	0.21	0.19	0.17	0.21	0.19	0.17
50	3488.24	0.40	0.40	0.40	13.95	12.60	11.26	0.19	0.18	0.16	0.19	0.18	0.16
51	6104.41	0.45	0.48	0.49	10.68	9.65	8.62	0.30	0.27	0.24	0.31	0.28	0.25
52	1744.12	0.42	0.42	0.42	21.39	19.32	17.26	0.16	0.14	0.13	0.16	0.14	0.13
53	6976.47	0.38	0.48	0.42	14.16	12.80	11.43	0.37	0.34	0.30	0.48	0.43	0.38
54	55811.70	0.40	0.40	0.41	5.19	4.69	4.19	1.16	1.05	0.94	1.16	1.05	0.94
55	8720.58	0.41	0.43	0.41	9.67	8.74	7.81	0.35	0.32	0.28	0.36	0.32	0.29
56	1744.12	0.51	0.51	0.51	21.39	19.32	17.26	0.19	0.17	0.15	0.19	0.17	0.15

57	1744.12	0.60	0.60	0.60	21.23	19.18	17.13	0.22	0.20	0.18	0.22	0.20	0.18
58	2616.17	0.56	0.56	0.56	11.84	10.69	9.55	0.17	0.16	0.14	0.17	0.16	0.14
59	40986.72	0.44	0.46	0.44	5.54	5.00	4.47	0.99	0.90	0.80	1.03	0.93	0.84
60	20929.39	0.42	0.44	0.43	8.17	7.38	6.59	0.72	0.65	0.58	0.75	0.67	0.60
61	15697.04	0.36	0.39	0.36	9.13	8.25	7.37	0.52	0.47	0.42	0.55	0.50	0.45
62	4360.29	0.37	0.37	0.37	9.94	8.98	8.02	0.16	0.15	0.13	0.16	0.15	0.13
63	3488.23	0.50	0.50	0.50	10.36	9.36	8.36	0.18	0.16	0.15	0.18	0.16	0.15
64	3488.23	0.39	0.39	0.46	14.52	13.11	11.71	0.20	0.18	0.16	0.20	0.18	0.16
65	2616.17	0.43	0.43	0.43	16.69	15.08	13.47	0.19	0.17	0.15	0.19	0.17	0.15
66	13080.87	0.41	0.41	0.41	8.62	7.79	6.95	0.46	0.42	0.38	0.47	0.42	0.38
67	2616.17	0.61	0.61	0.61	17.80	16.08	14.36	0.29	0.26	0.23	0.29	0.26	0.23
68	1744.11	0.51	0.52	0.51	21.23	19.18	17.13	0.19	0.17	0.15	0.19	0.17	0.16
69	3488.23	0.44	0.44	0.44	15.20	13.73	12.27	0.23	0.21	0.19	0.23	0.21	0.19
70	3488.24	0.50	0.53	0.50	13.29	12.00	10.72	0.23	0.21	0.19	0.24	0.22	0.20
71	12208.80	0.40	0.40	0.40	8.32	7.52	6.71	0.40	0.37	0.33	0.41	0.37	0.33
72	2616.17	0.31	0.31	0.36	17.97	16.24	14.50	0.14	0.13	0.12	0.15	0.13	0.12
73	6976.47	0.41	0.41	0.41	11.23	10.14	9.06	0.32	0.29	0.26	0.32	0.29	0.26
74	13080.87	0.35	0.35	0.35	10.02	9.05	8.09	0.46	0.41	0.37	0.46	0.41	0.37
75	191852.75	0.42	0.42	0.43	3.76	3.39	3.03	3.01	2.72	2.43	3.05	2.76	2.46
76	328765.84	0.37	0.38	0.37	2.66	2.40	2.14	3.20	2.89	2.59	3.28	2.96	2.64
77	107263.12	0.37	0.37	0.38	3.65	3.30	2.95	1.46	1.32	1.18	1.46	1.32	1.18
78	5232.36	0.38	0.38	0.43	8.96	8.09	7.23	0.18	0.16	0.14	0.18	0.16	0.14
79	16569.10	0.40	0.40	0.41	8.84	7.99	7.13	0.58	0.52	0.47	0.58	0.52	0.47

Table 4: Peak runoff values from watersheds of Sonaighuli hill

Bas-in ID	Watershed area (sq m)	Composite C for the year			Rainfall intensity (x10^{-5} m/s) for RP			Peak Q (m3/s) in 2011 for RP			Peak Q (m3/s) in 2015 for RP		
		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr
1	1744.12	0.54	0.57	0.60	20.10	18.16	16.22	0.19	0.17	0.15	0.20	0.18	0.16
2	9592.64	0.53	0.54	0.55	9.61	8.68	7.75	0.49	0.44	0.39	0.50	0.45	0.40
3	3488.23	0.49	0.53	0.57	14.17	12.80	11.43	0.24	0.22	0.20	0.26	0.24	0.21
4	5232.34	0.46	0.47	0.57	19.48	17.60	15.72	0.47	0.43	0.38	0.48	0.43	0.39

5	1744.12	0.64	0.64	0.64	21.23	19.18	17.13	0.24	0.21	0.19	0.24	0.21	0.19
6	13952.93	0.45	0.47	0.64	6.80	6.15	5.49	0.43	0.39	0.34	0.44	0.40	0.36
7	55811.71	0.32	0.35	0.47	5.75	5.19	4.64	1.01	0.92	0.82	1.11	1.00	0.90
8	6976.46	0.36	0.41	0.55	10.52	9.50	8.49	0.26	0.24	0.21	0.30	0.27	0.24
9	3488.23	0.49	0.49	0.49	14.79	13.36	11.93	0.25	0.23	0.20	0.25	0.23	0.20
10	2616.17	0.44	0.51	0.53	13.07	11.80	10.54	0.15	0.14	0.12	0.17	0.16	0.14
11	5232.34	0.51	0.53	0.55	10.32	9.32	8.33	0.27	0.25	0.22	0.28	0.26	0.23
12	4360.28	0.57	0.59	0.57	14.35	12.97	11.58	0.36	0.32	0.29	0.37	0.34	0.30
13	4360.29	0.38	0.42	0.44	10.83	9.79	8.74	0.18	0.16	0.15	0.20	0.18	0.16
14	39242.60	0.44	0.47	0.47	6.47	5.84	5.22	1.12	1.01	0.90	1.19	1.08	0.96
15	1744.12	0.55	0.55	0.61	26.45	23.89	21.34	0.25	0.23	0.20	0.25	0.23	0.21
16	1744.12	0.50	0.51	0.65	27.65	24.98	22.31	0.24	0.22	0.20	0.25	0.22	0.20
17	1744.12	0.51	0.51	0.51	45.79	41.37	36.95	0.41	0.37	0.33	0.41	0.37	0.33
18	42730.84	0.53	0.55	0.54	6.04	5.45	4.87	1.36	1.23	1.10	1.41	1.28	1.14
19	2616.17	0.52	0.52	0.66	17.80	16.08	14.36	0.24	0.22	0.19	0.24	0.22	0.19
20	2616.17	0.35	0.35	0.48	21.59	19.51	17.42	0.20	0.18	0.16	0.20	0.18	0.16
21	9592.63	0.41	0.42	0.46	8.91	8.05	7.19	0.35	0.32	0.28	0.36	0.32	0.29
22	8720.58	0.50	0.53	0.61	9.90	8.95	7.99	0.44	0.39	0.35	0.46	0.41	0.37
23	6104.40	0.50	0.50	0.54	10.15	9.17	8.19	0.31	0.28	0.25	0.31	0.28	0.25
24	1744.11	0.30	0.30	0.30	44.46	40.17	35.88	0.23	0.21	0.19	0.23	0.21	0.19
25	10464.70	0.32	0.32	0.53	10.05	9.08	8.11	0.33	0.30	0.27	0.34	0.30	0.27
26	7848.53	0.40	0.44	0.53	10.59	9.57	8.55	0.33	0.30	0.27	0.37	0.33	0.30
27	16569.11	0.29	0.31	0.44	9.01	8.14	7.27	0.43	0.38	0.34	0.46	0.42	0.37
28	11336.76	0.52	0.52	0.52	8.41	7.60	6.79	0.50	0.45	0.40	0.50	0.45	0.40
29	9592.64	0.44	0.46	0.47	7.96	7.19	6.42	0.34	0.30	0.27	0.35	0.32	0.28
30	2616.17	0.47	0.47	0.47	15.69	14.17	12.66	0.19	0.17	0.15	0.19	0.17	0.16
31	6976.47	0.36	0.36	0.50	10.83	9.78	8.74	0.27	0.24	0.22	0.27	0.24	0.22
32	2616.17	0.34	0.34	0.34	20.18	18.23	16.29	0.18	0.16	0.14	0.18	0.16	0.14
33	2616.17	0.55	0.55	0.55	17.41	15.73	14.05	0.25	0.23	0.20	0.25	0.23	0.20
34	6976.47	0.44	0.45	0.48	10.14	9.16	8.18	0.31	0.28	0.25	0.32	0.29	0.26
35	1744.12	0.30	0.30	0.30	16.89	15.26	13.63	0.09	0.08	0.07	0.09	0.08	0.07
36	4360.30	0.33	0.33	0.44	20.41	18.44	16.47	0.29	0.26	0.24	0.29	0.26	0.24

37	2616.17	0.33	0.33	0.33	21.59	19.51	17.42	0.19	0.17	0.15	0.19	0.17	0.15
38	2616.17	0.32	0.32	0.32	21.59	19.51	17.42	0.18	0.16	0.15	0.18	0.16	0.15
39	1744.12	0.30	0.30	0.30	21.23	19.18	17.13	0.11	0.10	0.09	0.11	0.10	0.09
40	2616.18	0.30	0.30	0.30	18.43	16.65	14.87	0.14	0.13	0.12	0.14	0.13	0.12
41	5232.34	0.51	0.51	0.55	11.41	10.30	9.20	0.30	0.27	0.24	0.30	0.27	0.24
42	10464.70	0.22	0.33	0.49	9.53	8.61	7.69	0.22	0.20	0.17	0.33	0.29	0.26
43	2616.17	0.41	0.48	0.41	16.69	15.08	13.47	0.18	0.16	0.14	0.21	0.19	0.17
44	3488.24	0.35	0.35	0.35	18.58	16.79	15.00	0.23	0.21	0.18	0.23	0.21	0.19
45	3488.24	0.37	0.37	0.41	18.78	16.97	15.15	0.24	0.22	0.20	0.24	0.22	0.20
46	4360.29	0.31	0.36	0.40	14.26	12.88	11.51	0.19	0.17	0.15	0.22	0.20	0.18
47	3488.23	0.32	0.32	0.43	13.73	12.41	11.08	0.15	0.14	0.12	0.15	0.14	0.12
48	1744.11	0.32	0.32	0.38	21.23	19.18	17.13	0.12	0.11	0.10	0.12	0.11	0.10
49	6976.46	0.47	0.47	0.48	7.37	6.66	5.95	0.24	0.22	0.20	0.24	0.22	0.20
50	1744.11	0.31	0.31	0.31	27.65	24.98	22.31	0.15	0.14	0.12	0.15	0.14	0.12
51	2616.17	0.43	0.43	0.43	18.14	16.39	14.64	0.20	0.18	0.16	0.20	0.18	0.16
52	2616.17	0.31	0.31	0.31	22.35	20.19	18.04	0.18	0.16	0.15	0.18	0.16	0.15
53	2616.17	0.27	0.27	0.27	22.12	19.98	17.85	0.16	0.14	0.13	0.16	0.14	0.13
54	1744.12	0.47	0.47	0.47	36.38	32.87	29.36	0.30	0.27	0.24	0.30	0.27	0.24
55	2616.17	0.38	0.38	0.41	17.86	16.13	14.41	0.18	0.16	0.14	0.18	0.16	0.14
56	5232.34	0.38	0.40	0.42	10.24	9.25	8.26	0.21	0.19	0.17	0.21	0.19	0.17
57	12208.82	0.43	0.43	0.43	10.70	9.67	8.64	0.56	0.51	0.45	0.56	0.51	0.45
58	4360.29	0.49	0.49	0.50	14.32	12.94	11.55	0.31	0.28	0.25	0.31	0.28	0.25
59	4360.29	0.50	0.50	0.50	13.61	12.29	10.98	0.30	0.27	0.24	0.30	0.27	0.24
60	8720.57	0.34	0.40	0.38	10.17	9.18	8.20	0.30	0.27	0.25	0.36	0.32	0.29
61	3488.24	0.51	0.51	0.51	16.39	14.81	13.23	0.29	0.26	0.24	0.29	0.26	0.24
62	5232.34	0.46	0.46	0.46	11.13	10.05	8.98	0.27	0.24	0.22	0.27	0.24	0.22
63	4360.28	0.45	0.46	0.45	15.53	14.03	12.53	0.31	0.28	0.25	0.31	0.28	0.25
64	40986.73	0.38	0.40	0.41	6.12	5.53	4.94	0.95	0.86	0.77	1.00	0.91	0.81
65	6976.46	0.39	0.40	0.39	16.20	14.63	13.07	0.44	0.40	0.35	0.45	0.41	0.36

Table 5: Peak runoff values from watersheds of Sarania hill

Bas-in ID	Watershed area (sq m)	Composite C for the year			Rainfall intensity ($x10^{-5}$ m/s) for RP			Peak Q (m3/s) in 2011 for RP			Peak Q (m3/s) in 2015 for RP		
		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr
1	31394.10	0.39	0.39	0.42	6.29	5.68	5.08	0.77	0.69	0.62	0.77	0.69	0.62
2	36626.43	0.47	0.47	0.53	6.16	5.56	4.97	1.06	0.96	0.86	1.07	0.96	0.86
3	41858.80	0.40	0.41	0.45	5.94	5.37	4.80	1.01	0.91	0.81	1.02	0.92	0.82
4	81101.38	0.45	0.46	0.48	4.54	4.10	3.66	1.67	1.51	1.35	1.68	1.52	1.36
5	1744.11	0.61	0.61	0.61	27.09	24.47	21.86	0.29	0.26	0.23	0.29	0.26	0.23
6	1744.12	0.56	0.57	0.56	25.68	23.20	20.72	0.25	0.23	0.20	0.25	0.23	0.21
7	1744.11	0.72	0.72	0.72	21.23	19.18	17.13	0.27	0.24	0.21	0.27	0.24	0.21
8	2616.17	0.43	0.46	0.44	20.78	18.77	16.77	0.23	0.21	0.19	0.25	0.22	0.20
9	14824.98	0.36	0.36	0.41	8.28	7.48	6.68	0.44	0.40	0.36	0.44	0.40	0.36
10	3488.24	0.48	0.48	0.48	17.68	15.97	14.26	0.30	0.27	0.24	0.30	0.27	0.24
11	13952.92	0.37	0.37	0.45	7.54	6.81	6.08	0.39	0.35	0.31	0.39	0.35	0.31
12	7848.52	0.41	0.42	0.41	9.86	8.91	7.96	0.32	0.29	0.26	0.33	0.29	0.26
13	2616.17	0.46	0.46	0.46	19.08	17.23	15.39	0.23	0.21	0.18	0.23	0.21	0.18
14	6976.48	0.41	0.44	0.41	9.32	8.42	7.52	0.27	0.24	0.21	0.29	0.26	0.23
15	3488.23	0.54	0.55	0.54	15.36	13.88	12.39	0.29	0.26	0.23	0.30	0.27	0.24
16	3488.23	0.47	0.47	0.47	15.45	13.96	12.47	0.26	0.23	0.21	0.26	0.23	0.21
17	27905.85	0.57	0.57	0.57	9.68	8.74	7.81	1.53	1.38	1.23	1.54	1.39	1.24
18	68892.58	0.43	0.43	0.43	5.63	5.08	4.54	1.68	1.51	1.35	1.68	1.52	1.36
19	1744.11	0.46	0.46	0.46	13.43	12.14	10.84	0.11	0.10	0.09	0.11	0.10	0.09
20	15697.04	0.59	0.59	0.59	8.42	7.61	6.79	0.78	0.70	0.63	0.78	0.70	0.63
21	2616.18	0.68	0.68	0.68	14.09	12.73	11.37	0.25	0.23	0.20	0.25	0.23	0.20
22	46219.06	0.58	0.59	0.58	5.80	5.24	4.68	1.56	1.41	1.26	1.58	1.42	1.27
23	26161.73	0.62	0.62	0.62	5.94	5.37	4.80	0.96	0.87	0.78	0.96	0.87	0.78
24	107263.12	0.50	0.51	0.50	4.66	4.21	3.76	2.52	2.27	2.03	2.55	2.30	2.06

Table 6 Peak runoff values from watersheds of Kharguli hill

Bas-in ID	Watershed area (sq m)	Composite C for the year	Rainfall intensity ($x10^{-5}$ m/s) for RP	Peak Q (m3/s) in 2011 for RP	Peak Q (m3/s) in 2015 for RP

		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr
1	17441.16	0.30	0.30	0.36	8.16	7.38	6.59	0.43	0.39	0.35	0.43	0.39	0.35
2	10464.70	0.30	0.31	0.41	9.86	8.91	7.95	0.31	0.28	0.25	0.32	0.29	0.26
3	11336.74	0.30	0.30	0.30	8.96	8.09	7.23	0.30	0.28	0.25	0.30	0.28	0.25
4	1033388.63	0.34	0.35	0.42	1.84	1.67	1.49	8.25	7.46	6.66	8.32	7.51	6.71
5	26161.73	0.36	0.36	0.37	6.18	5.58	4.99	0.58	0.52	0.46	0.58	0.52	0.46
6	10464.71	0.34	0.39	0.38	8.12	7.33	6.55	0.29	0.26	0.24	0.33	0.30	0.27
7	10464.68	0.31	0.31	0.31	7.68	6.94	6.20	0.25	0.23	0.20	0.25	0.23	0.20
8	11336.76	0.36	0.37	0.36	9.43	8.52	7.61	0.39	0.35	0.31	0.40	0.36	0.32
9	108135.17	0.28	0.29	0.41	4.57	4.13	3.69	1.40	1.26	1.13	1.41	1.28	1.14
10	11336.74	0.30	0.33	0.34	8.48	7.66	6.84	0.29	0.26	0.23	0.32	0.29	0.26
11	10464.70	0.31	0.32	0.36	6.90	6.23	5.57	0.22	0.20	0.18	0.23	0.21	0.19
12	10464.69	0.27	0.37	0.56	8.86	8.01	7.15	0.25	0.22	0.20	0.34	0.31	0.27
13	254640.91	0.30	0.32	0.32	3.06	2.76	2.47	2.35	2.12	1.90	2.47	2.23	1.99
14	11336.74	0.30	0.30	0.46	7.58	6.84	6.11	0.26	0.23	0.21	0.26	0.23	0.21
15	11336.74	0.29	0.30	0.29	6.27	5.67	5.06	0.21	0.19	0.17	0.22	0.20	0.17
16	11336.75	0.30	0.31	0.52	8.41	7.60	6.78	0.28	0.26	0.23	0.29	0.26	0.24
17	13080.87	0.30	0.31	0.34	7.65	6.91	6.17	0.30	0.27	0.25	0.31	0.28	0.25
18	13952.94	0.29	0.35	0.43	6.93	6.26	5.59	0.28	0.25	0.23	0.34	0.30	0.27
19	13952.92	0.32	0.32	0.32	6.98	6.31	5.63	0.31	0.28	0.25	0.31	0.28	0.25
20	30522.03	0.38	0.38	0.41	5.90	5.33	4.76	0.68	0.62	0.55	0.69	0.62	0.55
21	19185.27	0.29	0.29	0.33	6.76	6.11	5.46	0.38	0.34	0.31	0.38	0.35	0.31
22	148249.83	0.27	0.29	0.29	3.82	3.46	3.09	1.55	1.40	1.25	1.63	1.48	1.32
23	147377.77	0.26	0.28	0.28	4.04	3.65	3.26	1.56	1.41	1.26	1.64	1.48	1.32
24	373240.80	0.34	0.37	0.39	3.02	2.73	2.44	3.88	3.51	3.13	4.20	3.79	3.39
25	17441.14	0.27	0.28	0.33	6.86	6.20	5.54	0.33	0.30	0.27	0.34	0.31	0.27
26	13080.87	0.38	0.38	0.38	10.87	9.82	8.77	0.54	0.49	0.44	0.54	0.49	0.44
27	17441.15	0.38	0.39	0.39	8.46	7.64	6.82	0.56	0.51	0.45	0.57	0.52	0.46
28	56683.77	0.40	0.40	0.41	5.47	4.94	4.42	1.25	1.13	1.01	1.25	1.13	1.01
29	38370.53	0.26	0.26	0.33	4.79	4.33	3.87	0.48	0.43	0.39	0.48	0.43	0.39
30	12208.81	0.37	0.38	0.37	8.89	8.03	7.18	0.40	0.36	0.32	0.42	0.38	0.34
31	94182.25	0.38	0.38	0.44	4.48	4.05	3.62	1.60	1.45	1.29	1.62	1.47	1.31

32	56683.76	0.25	0.27	0.27	4.04	3.65	3.26	0.57	0.52	0.46	0.62	0.56	0.50
33	20057.34	0.43	0.43	0.44	7.18	6.49	5.80	0.62	0.56	0.50	0.62	0.56	0.50
34	19185.28	0.48	0.48	0.50	8.07	7.29	6.51	0.74	0.67	0.60	0.74	0.67	0.60
35	72380.80	0.42	0.44	0.43	4.80	4.34	3.87	1.46	1.32	1.18	1.54	1.39	1.25
36	61916.11	0.45	0.46	0.50	5.57	5.04	4.50	1.54	1.39	1.25	1.58	1.43	1.27
37	10464.70	0.58	0.58	0.61	6.76	6.11	5.45	0.41	0.37	0.33	0.41	0.37	0.33
38	629625.79	0.41	0.42	0.44	2.15	1.94	1.73	5.56	5.02	4.49	5.62	5.08	4.54
39	34882.32	0.35	0.38	0.37	6.91	6.24	5.58	0.85	0.77	0.68	0.91	0.83	0.74
40	416843.66	0.42	0.44	0.44	2.46	2.23	1.99	4.32	3.90	3.49	4.47	4.04	3.61
41	131680.75	0.42	0.43	0.43	4.13	3.73	3.33	2.28	2.06	1.84	2.36	2.13	1.91
42	24417.62	0.50	0.51	0.50	7.07	6.38	5.70	0.85	0.77	0.69	0.88	0.79	0.71
43	115111.65	0.53	0.53	0.55	4.21	3.80	3.39	2.54	2.30	2.05	2.59	2.34	2.09
44	32266.14	0.42	0.45	0.49	8.24	7.44	6.65	1.12	1.01	0.90	1.20	1.08	0.97
45	31394.08	0.41	0.41	0.43	6.76	6.11	5.46	0.88	0.79	0.71	0.88	0.79	0.71
46	51451.42	0.57	0.57	0.57	6.53	5.90	5.27	1.92	1.74	1.55	1.93	1.75	1.56
47	60172.02	0.49	0.50	0.50	4.19	3.79	3.38	1.24	1.12	1.00	1.26	1.14	1.01
48	136913.08	0.41	0.43	0.41	3.91	3.53	3.15	2.19	1.98	1.77	2.29	2.07	1.85
49	41858.78	0.47	0.49	0.47	5.32	4.81	4.30	1.04	0.94	0.84	1.10	1.00	0.89
50	175283.63	0.44	0.44	0.45	3.67	3.32	2.96	2.80	2.53	2.26	2.86	2.59	2.31
51	711599.26	0.44	0.45	0.49	2.49	2.25	2.01	7.76	7.01	6.26	7.98	7.21	6.44
52	32266.15	0.53	0.54	0.55	5.49	4.96	4.43	0.94	0.85	0.76	0.96	0.87	0.78
53	63660.23	0.53	0.54	0.54	4.87	4.40	3.93	1.63	1.47	1.31	1.67	1.51	1.35
54	19185.27	0.50	0.50	0.54	6.88	6.22	5.55	0.66	0.60	0.53	0.67	0.60	0.54
55	506665.69	0.42	0.43	0.44	2.78	2.51	2.24	5.97	5.39	4.82	6.05	5.46	4.88
56	14824.99	0.42	0.45	0.42	9.02	8.15	7.28	0.56	0.50	0.45	0.61	0.55	0.49
57	306092.30	0.40	0.41	0.43	3.27	2.95	2.64	4.04	3.65	3.26	4.15	3.75	3.35
58	92438.14	0.45	0.48	0.50	5.15	4.65	4.16	2.16	1.95	1.74	2.26	2.04	1.82
59	12208.81	0.58	0.58	0.58	7.53	6.80	6.08	0.53	0.48	0.43	0.54	0.48	0.43
60	11336.76	0.58	0.62	0.62	8.01	7.24	6.47	0.53	0.48	0.43	0.56	0.50	0.45
61	34882.32	0.65	0.66	0.66	5.46	4.93	4.40	1.24	1.12	1.00	1.26	1.14	1.02
62	17441.16	0.56	0.57	0.60	7.29	6.59	5.88	0.72	0.65	0.58	0.72	0.65	0.58
63	47091.14	0.49	0.53	0.54	5.32	4.80	4.29	1.23	1.11	0.99	1.33	1.20	1.07

64	47963.18	0.52	0.52	0.53	4.97	4.49	4.01	1.23	1.11	0.99	1.23	1.11	0.99
65	634858.11	0.51	0.52	0.52	1.87	1.69	1.51	6.05	5.47	4.88	6.20	5.60	5.00
66	85461.69	0.57	0.58	0.57	5.44	4.91	4.39	2.63	2.37	2.12	2.71	2.44	2.18
67	156970.42	0.49	0.50	0.51	3.75	3.39	3.03	2.87	2.59	2.31	2.96	2.67	2.39
68	12208.80	0.41	0.41	0.41	9.00	8.13	7.27	0.45	0.41	0.36	0.45	0.41	0.37
69	18313.22	0.47	0.48	0.47	6.31	5.70	5.09	0.54	0.49	0.43	0.56	0.51	0.45
70	16569.11	0.43	0.44	0.45	6.34	5.72	5.11	0.45	0.41	0.36	0.46	0.42	0.37
71	312196.74	0.51	0.51	0.55	2.32	2.10	1.87	3.68	3.33	2.97	3.72	3.36	3.00

Table 7: Peak runoff values from watersheds of Japorigog hill

Bas-in ID	Watershed area (sq m)	Composite C for the year			Rainfall intensity ($x10^{-5}$ m/s) for RP			Peak Q (m3/s) in 2011 for RP			Peak Q (m3/s) in 2015 for RP		
		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr
1	901707.89	0.34	0.35	0.35	2.15	1.95	1.74	9.08	8.20	7.33	9.31	8.41	7.52
2	50579.34	0.51	0.51	0.53	3.81	3.44	3.07	0.97	0.88	0.79	0.97	0.88	0.79
3	13080.87	0.56	0.56	0.56	5.80	5.24	4.68	0.43	0.39	0.35	0.43	0.39	0.35
4	226735.06	0.54	0.55	0.56	3.54	3.19	2.85	4.32	3.90	3.49	4.42	3.99	3.56
5	162202.77	0.47	0.48	0.53	4.14	3.74	3.34	3.16	2.86	2.55	3.21	2.90	2.59
6	581662.59	0.33	0.34	0.37	1.95	1.76	1.57	3.78	3.42	3.05	3.91	3.54	3.16
7	23545.57	0.43	0.44	0.45	7.21	6.51	5.82	0.73	0.66	0.59	0.75	0.68	0.60
8	123832.23	0.36	0.38	0.40	3.95	3.57	3.19	1.77	1.60	1.43	1.84	1.66	1.48
9	589511.15	0.40	0.41	0.48	2.19	1.98	1.77	5.20	4.70	4.20	5.35	4.83	4.32
10	259873.25	0.44	0.44	0.49	3.19	2.88	2.57	3.64	3.29	2.94	3.67	3.31	2.96
11	17441.17	0.60	0.60	0.63	6.86	6.20	5.54	0.72	0.65	0.58	0.72	0.65	0.58
12	58427.88	0.69	0.70	0.69	4.81	4.34	3.88	1.95	1.76	1.57	1.96	1.77	1.58
13	170923.36	0.46	0.46	0.56	2.97	2.68	2.39	2.32	2.09	1.87	2.32	2.09	1.87
14	16569.11	0.54	0.54	0.59	8.69	7.85	7.02	0.78	0.71	0.63	0.78	0.71	0.63
15	28777.90	0.39	0.39	0.40	6.82	6.17	5.51	0.76	0.69	0.61	0.76	0.69	0.62
16	18313.22	0.48	0.48	0.62	8.04	7.26	6.48	0.71	0.64	0.57	0.71	0.64	0.57
17	55811.69	0.43	0.46	0.51	4.98	4.50	4.02	1.21	1.09	0.97	1.27	1.15	1.03
18	215398.30	0.36	0.37	0.40	3.75	3.39	3.03	2.89	2.61	2.33	3.00	2.71	2.42
19	36626.42	0.67	0.67	0.67	5.74	5.19	4.63	1.40	1.27	1.13	1.41	1.28	1.14

20	12208.81	0.50	0.50	0.54	8.70	7.86	7.02	0.53	0.48	0.43	0.53	0.48	0.43
21	18313.22	0.47	0.47	0.52	7.95	7.19	6.42	0.68	0.61	0.55	0.68	0.61	0.55
22	60172.01	0.65	0.65	0.65	4.47	4.04	3.61	1.74	1.57	1.40	1.74	1.57	1.40
23	15697.04	0.59	0.59	0.59	7.15	6.46	5.77	0.66	0.60	0.54	0.66	0.60	0.54
24	104646.96	0.36	0.36	0.39	5.81	5.25	4.69	2.18	1.97	1.76	2.19	1.98	1.77
25	14824.98	0.58	0.58	0.58	8.59	7.76	6.93	0.74	0.67	0.60	0.74	0.67	0.60
26	334870.22	0.57	0.57	0.57	2.85	2.57	2.30	5.43	4.90	4.38	5.45	4.93	4.40
27	12208.81	0.45	0.47	0.48	9.73	8.79	7.85	0.53	0.48	0.43	0.56	0.51	0.45
28	40114.67	0.40	0.40	0.41	6.51	5.88	5.26	1.05	0.95	0.85	1.05	0.95	0.85
29	20929.39	0.50	0.50	0.54	7.53	6.80	6.08	0.79	0.71	0.63	0.79	0.72	0.64
30	1394420.59	0.44	0.45	0.48	1.79	1.62	1.45	19.70	17.80	15.90	19.70	17.80	15.90
31	81101.39	0.38	0.39	0.46	5.53	5.00	4.47	1.72	1.56	1.39	1.75	1.58	1.41
32	85461.68	0.40	0.40	0.40	4.22	3.81	3.40	1.44	1.30	1.16	1.45	1.31	1.17
33	497945.04	0.34	0.35	0.37	3.01	2.72	2.43	5.12	4.63	4.13	5.28	4.77	4.26
34	31394.08	0.41	0.41	0.41	5.09	4.60	4.11	0.66	0.60	0.53	0.66	0.60	0.53
35	166563.06	0.29	0.29	0.29	3.32	3.00	2.68	1.60	1.44	1.29	1.61	1.45	1.30
36	16569.10	0.37	0.38	0.37	6.10	5.52	4.93	0.37	0.33	0.30	0.39	0.35	0.31
37	151738.11	0.44	0.44	0.50	4.62	4.17	3.72	3.09	2.79	2.49	3.09	2.79	2.50
38	18313.22	0.41	0.42	0.45	5.20	4.69	4.19	0.39	0.35	0.31	0.40	0.36	0.32
39	72380.80	0.42	0.42	0.42	4.31	3.90	3.48	1.30	1.17	1.05	1.32	1.20	1.07
40	27033.80	0.40	0.40	0.43	5.29	4.78	4.27	0.57	0.52	0.46	0.57	0.52	0.46
41	160458.66	0.42	0.42	0.42	3.60	3.25	2.90	2.40	2.17	1.94	2.40	2.17	1.94
42	69764.63	0.39	0.40	0.40	5.09	4.60	4.11	1.39	1.25	1.12	1.41	1.28	1.14
43	34010.26	0.51	0.51	0.51	5.56	5.03	4.49	0.97	0.88	0.78	0.97	0.88	0.78
44	119471.95	0.37	0.38	0.39	4.14	3.74	3.34	1.83	1.66	1.48	1.90	1.72	1.53
45	426436.30	0.25	0.25	0.28	2.99	2.70	2.41	3.25	2.93	2.62	3.25	2.93	2.62
46	20057.34	0.41	0.42	0.49	6.67	6.03	5.38	0.55	0.50	0.44	0.56	0.50	0.45
47	12208.82	0.41	0.41	0.49	6.93	6.26	5.59	0.34	0.31	0.28	0.35	0.31	0.28
48	14824.98	0.35	0.35	0.51	6.63	5.99	5.35	0.35	0.31	0.28	0.35	0.31	0.28
49	16569.10	0.43	0.43	0.48	8.80	7.95	7.10	0.63	0.57	0.51	0.63	0.57	0.51
50	675844.88	0.39	0.41	0.42	2.63	2.38	2.12	7.01	6.33	5.66	7.31	6.60	5.90
51	1284541.30	0.36	0.36	0.39	1.89	1.71	1.52	14.00	12.65	11.30	14.07	12.71	11.35

52	19185.25	0.34	0.35	0.34	7.77	7.02	6.27	0.51	0.46	0.41	0.52	0.47	0.42
53	90694.03	0.54	0.54	0.56	5.32	4.80	4.29	2.59	2.34	2.09	2.62	2.37	2.11
54	13952.93	0.50	0.51	0.53	8.18	7.39	6.60	0.57	0.52	0.46	0.59	0.53	0.47
55	61916.12	0.43	0.43	0.48	5.54	5.01	4.47	1.48	1.34	1.20	1.49	1.35	1.20
56	158714.54	0.48	0.49	0.50	3.41	3.09	2.76	2.59	2.34	2.09	2.67	2.41	2.15
57	76741.10	0.52	0.53	0.56	4.85	4.38	3.91	1.94	1.75	1.57	1.99	1.80	1.60
58	268593.85	0.46	0.48	0.48	3.35	3.03	2.71	4.11	3.71	3.32	4.28	3.87	3.45
59	17441.15	0.53	0.53	0.56	5.50	4.97	4.44	0.50	0.46	0.41	0.51	0.46	0.41
60	25289.67	0.42	0.43	0.42	5.55	5.01	4.48	0.60	0.54	0.48	0.60	0.54	0.48
61	236327.68	0.51	0.52	0.52	2.65	2.39	2.14	3.16	2.86	2.55	3.23	2.91	2.60
62	51451.44	0.54	0.54	0.54	5.17	4.67	4.17	1.43	1.29	1.15	1.45	1.31	1.17
63	11336.76	0.56	0.56	0.56	6.45	5.83	5.20	0.41	0.37	0.33	0.41	0.37	0.33
64	1787718.64	0.35	0.36	0.37	1.71	1.55	1.38	19.20	17.34	15.49	19.20	17.34	15.49
65	157842.48	0.51	0.52	0.53	4.04	3.65	3.26	3.24	2.92	2.61	3.31	2.99	2.67

Table 8: Peak runoff values from watersheds of Burhagosain hill

Bas-in ID	**Watershed area (sqm)**	**Composite C for the year**			**Rainfall intensity ($x10^{-5}$ m/s) for RP**			**Peak Q (m3/s) in 2011 for RP**			**Peak Q (m3/s) in 2015 for RP**		
		2011	**2015**	**2025**	**100 yr**	**50 yr**	**25 yr**	**100 yr**	**50 yr**	**25 yr**	**100 yr**	**50 yr**	**25 yr**
1	6976.47	0.39	0.43	0.47	9.05	8.18	7.31	0.24	0.22	0.20	0.27	0.25	0.22
2	2616.17	0.30	0.32	0.30	17.55	15.86	14.17	0.14	0.12	0.11	0.15	0.13	0.12
3	142145.44	0.26	0.27	0.29	4.09	3.70	3.30	1.53	1.38	1.24	1.58	1.42	1.27
4	102902.84	0.27	0.28	0.29	4.41	3.99	3.56	1.22	1.10	0.99	1.26	1.13	1.01
5	117727.82	0.28	0.29	0.32	4.29	3.87	3.46	1.43	1.29	1.15	1.46	1.32	1.18
6	23545.56	0.34	0.36	0.35	6.35	5.74	5.12	0.50	0.46	0.41	0.53	0.48	0.43
7	22673.52	0.28	0.29	0.28	6.16	5.56	4.97	0.38	0.35	0.31	0.41	0.37	0.33
8	48835.23	0.41	0.43	0.43	6.31	5.70	5.09	1.25	1.13	1.01	1.33	1.20	1.07
9	1744.12	0.34	0.34	0.34	10.69	9.65	8.62	0.06	0.06	0.05	0.06	0.06	0.05
10	2616.18	0.34	0.34	0.34	21.15	19.10	17.06	0.19	0.17	0.15	0.19	0.17	0.15
11	1744.11	0.28	0.28	0.28	20.59	18.60	16.61	0.10	0.09	0.08	0.10	0.09	0.08
12	1744.11	0.30	0.30	0.30	53.82	48.62	43.43	0.28	0.25	0.23	0.28	0.25	0.23

13	2616.18	0.30	0.30	0.30	20.50	18.52	16.55	0.16	0.15	0.13	0.16	0.15	0.13
14	16569.09	0.30	0.31	0.30	7.80	7.05	6.30	0.38	0.35	0.31	0.40	0.36	0.32
15	83717.56	0.39	0.42	0.49	4.58	4.14	3.69	1.50	1.36	1.21	1.60	1.44	1.29
16	40114.65	0.42	0.44	0.51	5.53	5.00	4.46	0.93	0.84	0.75	0.97	0.88	0.79
17	53195.53	0.34	0.36	0.41	5.70	5.15	4.60	1.02	0.92	0.82	1.08	0.98	0.87
18	8720.58	0.35	0.45	0.72	11.52	10.40	9.29	0.36	0.32	0.29	0.45	0.41	0.37
19	20057.34	0.36	0.39	0.44	6.24	5.63	5.03	0.45	0.41	0.37	0.49	0.44	0.39
20	190980.67	0.27	0.27	0.27	3.54	3.19	2.85	1.82	1.65	1.47	1.82	1.65	1.47
21	3488.23	0.46	0.46	0.46	15.15	13.69	12.23	0.24	0.22	0.19	0.24	0.22	0.20
22	118599.88	0.46	0.46	0.47	4.07	3.68	3.28	2.20	1.99	1.77	2.24	2.02	1.81
23	9592.63	0.35	0.35	0.39	5.08	4.59	4.10	0.17	0.15	0.14	0.17	0.15	0.14
24	425564.26	0.25	0.26	0.27	2.47	2.23	1.99	2.67	2.42	2.16	2.72	2.46	2.19
25	347951.09	0.34	0.35	0.34	3.44	3.11	2.78	4.07	3.68	3.29	4.13	3.73	3.33
26	660147.88	0.30	0.30	0.30	2.58	2.33	2.08	5.04	4.56	4.07	5.06	4.57	4.09
27	1279308.91	0.27	0.27	0.30	1.65	1.49	1.33	7.94	7.17	6.41	7.99	7.22	6.45
28	8720.58	0.18	0.18	0.18	9.85	8.90	7.95	0.15	0.14	0.12	0.16	0.14	0.13
29	5232.34	0.29	0.29	0.34	9.29	8.39	7.50	0.14	0.13	0.11	0.14	0.13	0.11
30	48835.25	0.27	0.27	0.41	5.23	4.72	4.22	0.68	0.61	0.55	0.69	0.62	0.56
31	38370.54	0.41	0.43	0.46	4.42	4.00	3.57	0.70	0.63	0.56	0.73	0.66	0.59
32	33138.22	0.31	0.31	0.31	5.13	4.63	4.14	0.53	0.48	0.43	0.53	0.48	0.43
33	85461.68	0.40	0.40	0.46	4.15	3.75	3.35	1.41	1.28	1.14	1.42	1.29	1.15
34	1744.12	0.39	0.39	0.39	16.25	14.68	13.11	0.11	0.10	0.09	0.11	0.10	0.09
35	13952.93	0.36	0.36	0.36	7.48	6.76	6.04	0.38	0.34	0.31	0.38	0.34	0.31

Table 9: Peak runoff values from watersheds of Khanapara and Koinadhara hill

Bas-in ID	Watershed area (sq m)	Composite C for the year			Rainfall intensity ($x10^{-5}$ m/s) for RP			Peak Q (m3/s) in 2011 for RP			Peak Q (m3/s) in 2015 for RP		
		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr
1	1918527.39	0.33	0.34	0.44	1.55	1.40	1.25	16.78	15.16	13.54	16.92	15.29	13.65
2	4441390.87	0.26	0.27	0.30	1.22	1.10	0.98	29.08	26.27	23.47	29.33	26.50	23.67
3	1846146.59	0.33	0.33	0.40	1.69	1.53	1.37	14.80	13.37	11.94	15.10	13.64	12.18
4	445621.57	0.37	0.37	0.39	1.97	1.78	1.59	3.29	2.97	2.66	3.29	2.97	2.66

5	6377359.42	0.32	0.32	0.34	0.95	0.86	0.77	59.40	53.66	47.94	59.56	53.80	48.06
6	6982567.57	0.35	0.35	0.36	1.12	1.01	0.90	77.18	69.73	62.29	78.78	71.17	63.57
7	3385328.73	0.27	0.27	0.28	1.67	1.51	1.34	30.62	27.66	24.71	30.91	27.92	24.94

Table 10: Peak runoff values from watersheds of Garbhanga hill

Bas-in ID	Watershed area (sq m)	Composite C for the year			Rainfall intensity ($x10^{-5}$ m/s) for RP			Peak Q (m3/s) in 2011 for RP			Peak Q (m3/s) in 2015 for RP		
		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr
1	7,21,99,417.51	0.248	0.249	0.251	3.09	2.79	2.49	769	695	621	776	701	626

Table 11: Peak runoff values from watersheds of Kamakhya hill

Bas-in ID	Watershed area (sq m)	Composite C for the year			Rainfall intensity ($x10^{-5}$ m/s) for RP			Peak Q (m3/s) in 2011 for RP			Peak Q (m3/s) in 2015 for RP		
		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr
1	6104.42	0.04	0.04	0.04	2.73	2.46	2.20	0.01	0.01	0.01	0.01	0.01	0.01
2	338358.46	0.19	0.19	0.22	2.48	2.24	2.00	1.55	1.40	1.25	1.55	1.40	1.25
3	6104.42	0.06	0.06	0.09	6.49	5.86	5.24	0.02	0.02	0.02	0.02	0.02	0.02
4	6104.40	0.07	0.07	0.10	6.38	5.76	5.15	0.03	0.02	0.02	0.03	0.02	0.02
5	6104.40	0.10	0.10	0.17	6.12	5.53	4.94	0.04	0.03	0.03	0.04	0.03	0.03
6	6104.40	0.13	0.13	0.29	7.13	6.44	5.75	0.06	0.05	0.05	0.06	0.05	0.05
7	6976.46	0.10	0.10	0.13	5.81	5.25	4.69	0.04	0.04	0.03	0.04	0.04	0.03
8	18313.22	0.18	0.18	0.36	4.59	4.14	3.70	0.15	0.13	0.12	0.15	0.13	0.12
9	8720.58	0.16	0.16	0.36	6.40	5.78	5.16	0.09	0.08	0.07	0.09	0.08	0.07
10	47963.21	0.22	0.22	0.26	3.36	3.04	2.72	0.36	0.32	0.29	0.36	0.32	0.29
11	12208.80	0.20	0.20	0.32	7.09	6.40	5.72	0.17	0.16	0.14	0.17	0.16	0.14
12	13952.93	0.20	0.20	0.39	5.69	5.14	4.59	0.16	0.14	0.13	0.16	0.14	0.13
13	132552.79	0.23	0.23	0.31	2.63	2.38	2.12	0.79	0.71	0.63	0.79	0.71	0.63
14	6104.42	0.02	0.02	0.02	2.80	2.53	2.26	0.00	0.00	0.00	0.00	0.00	0.00
15	6104.40	0.07	0.07	0.07	2.70	2.44	2.18	0.01	0.01	0.01	0.01	0.01	0.01
16	6104.40	0.07	0.07	0.08	5.89	5.32	4.75	0.02	0.02	0.02	0.02	0.02	0.02
17	6104.40	0.06	0.06	0.10	5.96	5.38	4.81	0.02	0.02	0.02	0.02	0.02	0.02

18	6104.40	0.05	0.05	0.08	6.05	5.47	4.89	0.02	0.02	0.02	0.02	0.02	0.02
19	6104.42	0.04	0.04	0.04	6.51	5.88	5.25	0.02	0.01	0.01	0.02	0.01	0.01
20	6104.40	0.10	0.10	0.18	6.71	6.06	5.42	0.04	0.04	0.03	0.04	0.04	0.03
21	6104.40	0.15	0.15	0.19	5.77	5.22	4.66	0.05	0.05	0.04	0.05	0.05	0.04
22	6104.41	0.24	0.24	0.24	7.21	6.51	5.82	0.10	0.09	0.08	0.10	0.09	0.08
23	6104.42	0.13	0.13	0.13	5.73	5.17	4.62	0.04	0.04	0.04	0.04	0.04	0.04
24	6976.47	0.32	0.32	0.32	5.46	4.93	4.40	0.12	0.11	0.10	0.12	0.11	0.10
25	634858.11	0.17	0.17	0.21	1.20	1.08	0.96	1.30	1.17	1.05	1.32	1.19	1.07
26	6104.40	0.37	0.37	0.49	8.33	7.53	6.72	0.19	0.17	0.15	0.19	0.17	0.15
27	6104.41	0.37	0.37	0.39	6.37	5.75	5.14	0.14	0.13	0.12	0.14	0.13	0.12
28	51451.40	0.24	0.24	0.27	2.93	2.65	2.36	0.36	0.32	0.29	0.36	0.33	0.29
29	383705.48	0.45	0.45	0.47	1.90	1.71	1.53	3.24	2.93	2.61	3.29	2.97	2.66
30	20057.33	0.19	0.19	0.22	3.21	2.90	2.59	0.12	0.11	0.10	0.12	0.11	0.10
31	12208.82	0.20	0.20	0.20	4.08	3.69	3.29	0.10	0.09	0.08	0.10	0.09	0.08
32	14824.98	0.20	0.23	0.20	3.67	3.31	2.96	0.11	0.10	0.09	0.12	0.11	0.10
33	80229.33	0.32	0.32	0.35	2.98	2.69	2.40	0.75	0.68	0.61	0.76	0.69	0.62
34	23545.56	0.17	0.17	0.19	2.95	2.66	2.38	0.12	0.11	0.10	0.12	0.11	0.10
35	20057.32	0.50	0.50	0.51	5.46	4.93	4.40	0.55	0.49	0.44	0.55	0.49	0.44
36	7848.52	0.47	0.47	0.49	6.82	6.16	5.50	0.25	0.23	0.20	0.25	0.23	0.20
37	9592.63	0.44	0.44	0.50	5.89	5.32	4.75	0.25	0.22	0.20	0.25	0.23	0.20
38	15697.04	0.41	0.41	0.45	5.42	4.90	4.38	0.35	0.32	0.28	0.35	0.32	0.28
39	6976.46	0.41	0.41	0.41	5.72	5.17	4.61	0.16	0.15	0.13	0.16	0.15	0.13
40	38370.55	0.41	0.41	0.42	4.37	3.95	3.53	0.68	0.62	0.55	0.69	0.62	0.56
41	8720.60	0.45	0.45	0.45	5.34	4.82	4.31	0.21	0.19	0.17	0.21	0.19	0.17
42	6104.40	0.58	0.58	0.62	9.92	8.96	8.00	0.35	0.32	0.28	0.35	0.32	0.28
43	36626.45	0.43	0.43	0.43	3.04	2.75	2.45	0.48	0.43	0.38	0.48	0.43	0.39
44	125576.31	0.35	0.35	0.35	3.01	2.72	2.43	1.33	1.20	1.07	1.34	1.21	1.08
45	6104.40	0.59	0.61	0.59	8.91	8.05	7.19	0.32	0.29	0.26	0.33	0.30	0.27
46	6104.41	0.55	0.55	0.55	6.42	5.80	5.18	0.21	0.19	0.17	0.21	0.19	0.17
47	470000.00	0.43	0.43	0.43	1.12	1.01	0.90	11.11	10.03	8.96	11.32	10.22	9.13

48	247664.45	0.42	0.43	0.43	2.17	1.96	1.75	2.26	2.04	1.82	2.29	2.07	1.85
49	6104.41	0.62	0.65	0.62	8.86	8.01	7.15	0.34	0.30	0.27	0.35	0.32	0.28
50	6104.40	0.31	0.32	0.31	7.50	6.77	6.05	0.14	0.13	0.12	0.14	0.13	0.12
51	35754.38	0.43	0.47	0.43	3.88	3.51	3.13	0.60	0.54	0.49	0.66	0.59	0.53
52	28777.92	0.38	0.42	0.38	4.15	3.75	3.35	0.45	0.41	0.37	0.50	0.45	0.41
53	7848.51	0.38	0.38	0.38	5.73	5.18	4.62	0.17	0.16	0.14	0.17	0.16	0.14
54	6976.46	0.43	0.43	0.43	6.32	5.71	5.10	0.19	0.17	0.15	0.19	0.17	0.15
55	14824.98	0.43	0.45	0.43	5.55	5.01	4.48	0.36	0.32	0.29	0.37	0.34	0.30
56	45347.01	0.47	0.47	0.47	3.68	3.33	2.97	0.79	0.71	0.64	0.79	0.71	0.64
57	8720.58	0.47	0.47	0.47	5.30	4.79	4.28	0.22	0.20	0.17	0.22	0.20	0.17
58	224990.95	0.53	0.53	0.53	1.26	1.14	1.02	1.49	1.35	1.21	1.49	1.35	1.21
59	84589.62	0.51	0.52	0.51	3.19	2.88	2.57	1.39	1.25	1.12	1.39	1.26	1.12
60	37498.49	0.54	0.54	0.54	4.02	3.63	3.25	0.81	0.73	0.65	0.82	0.74	0.66
61	397658.41	0.48	0.49	0.48	1.38	1.24	1.11	2.60	2.35	2.10	2.67	2.41	2.15
62	299115.86	0.56	0.57	0.57	1.58	1.43	1.27	2.67	2.41	2.15	2.70	2.44	2.18
63	212782.13	0.53	0.53	0.53	1.77	1.60	1.43	1.99	1.79	1.60	1.99	1.80	1.61

Table 12: Peak runoff values from watersheds of Kahilipara hill

Bas-in ID	Watershed area (sq m)	Composite C for the year			Rainfall intensity ($x10^{-5}$ m/s) for RP			Peak Q (m3/s) in 2011 for RP			Peak Q (m3/s) in 2015 for RP		
		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr
1	95926.38	0.54	0.54	0.55	4.97	4.49	4.01	2.57	2.32	2.07	2.58	2.33	2.09
2	232839.48	0.46	0.46	0.47	3.43	3.10	2.77	3.66	3.30	2.95	3.66	3.31	2.96
3	347079.03	0.38	0.38	0.42	3.59	3.24	2.90	4.70	4.25	3.80	4.78	4.32	3.86
4	348823.14	0.40	0.41	0.44	3.32	3.00	2.68	4.67	4.22	3.77	4.74	4.28	3.82
5	268593.84	0.36	0.36	0.38	3.65	3.29	2.94	3.55	3.21	2.87	3.56	3.22	2.87
6	61916.10	0.45	0.45	0.51	4.68	4.23	3.78	1.30	1.17	1.05	1.31	1.18	1.05
7	102902.81	0.52	0.52	0.54	4.10	3.70	3.31	2.18	1.97	1.76	2.20	1.99	1.78
8	79357.27	0.49	0.49	0.57	5.05	4.56	4.08	1.95	1.76	1.58	1.95	1.76	1.58
9	34010.25	0.47	0.47	0.49	5.90	5.33	4.76	0.94	0.85	0.76	0.94	0.85	0.76
10	170923.36	0.44	0.44	0.51	4.92	4.45	3.97	3.68	3.33	2.97	3.73	3.37	3.01

11	24417.62	0.60	0.60	0.63	5.46	4.93	4.41	0.80	0.72	0.64	0.80	0.72	0.64
12	420331.91	0.32	0.34	0.34	3.44	3.11	2.77	4.69	4.24	3.79	4.92	4.45	3.97
13	47963.20	0.59	0.59	0.60	5.03	4.54	4.06	1.42	1.28	1.14	1.42	1.28	1.14
14	64532.29	0.58	0.61	0.63	5.68	5.13	4.58	2.14	1.93	1.73	2.23	2.01	1.80
15	104646.95	0.46	0.46	0.48	4.58	4.14	3.70	2.22	2.00	1.79	2.22	2.01	1.79
16	96798.42	0.43	0.45	0.47	3.90	3.52	3.14	1.63	1.47	1.32	1.68	1.52	1.35
17	34010.25	0.58	0.58	0.62	4.76	4.30	3.84	0.93	0.84	0.75	0.94	0.85	0.76
18	167435.12	0.40	0.41	0.41	3.48	3.14	2.81	2.34	2.12	1.89	2.39	2.16	1.93
19	132552.81	0.51	0.52	0.54	4.06	3.67	3.27	2.77	2.50	2.23	2.78	2.51	2.25
20	105518.99	0.55	0.55	0.58	4.27	3.86	3.45	2.47	2.23	1.99	2.47	2.23	2.00
21	244176.23	0.51	0.51	0.51	3.48	3.14	2.81	4.35	3.93	3.51	4.36	3.94	3.52
22	115983.69	0.47	0.48	0.50	5.51	4.98	4.45	2.99	2.70	2.41	3.05	2.75	2.46
23	102030.76	0.50	0.51	0.53	4.33	3.91	3.50	2.23	2.01	1.80	2.25	2.04	1.82
24	129936.63	0.37	0.38	0.39	3.96	3.58	3.19	1.92	1.73	1.55	1.94	1.76	1.57
25	11336.76	0.45	0.45	0.45	6.05	5.47	4.88	0.31	0.28	0.25	0.31	0.28	0.25
26	61044.06	0.56	0.57	0.59	4.78	4.32	3.86	1.65	1.49	1.33	1.66	1.50	1.34
27	67148.46	0.57	0.57	0.57	4.99	4.51	4.03	1.91	1.72	1.54	1.91	1.72	1.54
28	74124.92	0.44	0.45	0.46	5.19	4.68	4.18	1.68	1.51	1.35	1.72	1.56	1.39
29	23545.56	0.66	0.66	0.66	7.71	6.97	6.22	1.21	1.09	0.97	1.21	1.09	0.97
30	68892.57	0.58	0.59	0.61	5.44	4.91	4.39	2.18	1.97	1.76	2.20	1.98	1.77
31	497073.00	0.41	0.42	0.45	2.25	2.03	1.82	4.62	4.17	3.73	4.67	4.22	3.77
32	16569.11	0.60	0.61	0.60	6.20	5.60	5.01	0.62	0.56	0.50	0.62	0.56	0.50
33	22673.51	0.57	0.57	0.57	5.99	5.41	4.83	0.77	0.70	0.62	0.77	0.70	0.62
34	24417.62	0.62	0.63	0.63	6.54	5.91	5.28	0.98	0.89	0.79	1.01	0.91	0.82
35	131680.73	0.47	0.48	0.49	4.21	3.80	3.40	2.62	2.37	2.11	2.65	2.39	2.14
36	1796439.27	0.41	0.42	0.45	1.89	1.71	1.53	13.88	17.87	15.96	20.31	18.35	16.39
37	186620.38	0.57	0.58	0.58	3.53	3.19	2.85	3.76	3.39	3.03	3.79	3.42	3.06
38	195340.96	0.61	0.61	0.61	3.57	3.22	2.88	4.26	3.85	3.44	4.28	3.87	3.45
39	344462.87	0.54	0.55	0.54	2.85	2.58	2.30	5.29	4.78	4.27	5.37	4.85	4.33
40	1108385.57	0.33	0.34	0.39	2.23	2.02	1.80	8.23	9.30	8.31	10.57	9.55	8.53
41	205805.66	0.41	0.42	0.44	3.21	2.90	2.59	2.74	2.47	2.21	2.79	2.52	2.25
42	42730.85	0.51	0.51	0.53	5.57	5.03	4.50	1.20	1.09	0.97	1.20	1.09	0.97

43	86333.74	0.48	0.48	0.49	4.32	3.90	3.49	1.80	1.63	1.45	1.81	1.63	1.46
44	43602.89	0.49	0.49	0.51	4.70	4.25	3.79	1.01	0.91	0.81	1.01	0.92	0.82
45	248536.48	0.46	0.46	0.47	3.42	3.09	2.76	3.93	3.55	3.17	3.94	3.56	3.18
46	42730.83	0.58	0.58	0.58	5.86	5.29	4.73	1.44	1.30	1.16	1.45	1.31	1.17
47	20057.32	0.65	0.65	0.65	6.61	5.97	5.33	0.86	0.78	0.69	0.87	0.78	0.70
48	20057.34	0.58	0.58	0.58	6.53	5.90	5.27	0.75	0.68	0.61	0.76	0.68	0.61

Table 13: Peak runoff values from watersheds of Betkuchi hill

Bas-in ID	Watershed area (sq m)	Composite C for the year			Rainfall intensity ($x10^{-5}$ m/s) for RP			Peak Q (m3/s) in 2011 for RP			Peak Q (m3/s) in 2015 for RP		
		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr
1	153482.20	0.47	0.47	0.48	3.50	3.16	2.83	2.53	2.29	2.04	2.55	2.30	2.05
2	53195.53	0.46	0.48	0.50	4.54	4.10	3.66	1.12	1.01	0.90	1.17	1.06	0.94
3	9592.63	0.36	0.40	0.44	9.54	8.62	7.70	0.33	0.30	0.26	0.37	0.33	0.30
4	6976.47	0.45	0.46	0.52	10.59	9.57	8.54	0.33	0.30	0.27	0.34	0.31	0.28
5	10464.69	0.36	0.37	0.45	7.53	6.80	6.07	0.29	0.26	0.23	0.29	0.26	0.24
6	4360.29	0.37	0.39	0.45	11.76	10.63	9.49	0.19	0.17	0.15	0.20	0.18	0.16
7	4360.30	0.27	0.29	0.34	13.21	11.93	10.66	0.16	0.14	0.13	0.16	0.15	0.13
8	6104.40	0.33	0.41	0.39	12.54	11.33	10.12	0.26	0.23	0.21	0.32	0.29	0.26
9	4360.29	0.34	0.38	0.34	11.10	10.03	8.96	0.17	0.15	0.13	0.18	0.16	0.15
10	8720.59	0.30	0.32	0.44	11.54	10.43	9.31	0.30	0.27	0.24	0.32	0.29	0.26
11	136913.09	0.40	0.40	0.41	4.62	4.17	3.73	2.50	2.26	2.02	2.53	2.28	2.04
12	1744.11	0.50	0.53	0.50	24.72	22.33	19.95	0.21	0.19	0.17	0.23	0.21	0.18
13	34882.32	0.42	0.42	0.42	5.88	5.31	4.75	0.86	0.77	0.69	0.86	0.78	0.70
14	49707.29	0.42	0.43	0.43	6.08	5.50	4.91	1.28	1.16	1.04	1.29	1.17	1.04
15	73252.86	0.24	0.24	0.26	5.55	5.02	4.48	0.98	0.88	0.79	0.98	0.89	0.79
16	34010.26	0.15	0.16	0.16	6.64	6.00	5.36	0.34	0.31	0.28	0.37	0.34	0.30

Table 14: Peak runoff values from watersheds of Chunsali hill

Bas-in ID	Watershed area (sq m)	Composite C for the year			Rainfall intensity ($x10^{-5}$ m/s) for RP			Peak Q (m3/s) in 2011 for RP			Peak Q (m3/s) in 2015 for RP		
		2011	2015	2025	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr	100 yr	50 yr	25 yr

1	135168.96	0.12	0.12	0.18	3.02	2.72	2.43	0.50	0.45	0.40	0.50	0.45	0.40
2	923509.33	0.20	0.21	0.26	2.53	2.28	2.04	5.67	5.12	4.58	5.83	5.27	4.70
3	197957.14	0.22	0.22	0.24	3.04	2.74	2.45	1.31	1.18	1.05	1.31	1.19	1.06
4	782235.93	0.19	0.20	0.26	2.24	2.02	1.81	3.39	3.06	2.74	3.45	3.12	2.78
5	268593.83	0.28	0.29	0.30	3.12	2.82	2.52	2.32	2.09	1.87	2.43	2.19	1.96
6	256385.00	0.21	0.21	0.21	3.58	3.23	2.89	1.90	1.71	1.53	1.90	1.71	1.53
7	1854867.15	0.23	0.24	0.30	1.90	1.72	1.53	11.98	10.83	9.67	12.02	10.86	9.70
8	89821.98	0.25	0.27	0.44	6.04	5.46	4.88	1.38	1.24	1.11	1.44	1.30	1.16
9	201445.36	0.36	0.38	0.36	3.60	3.25	2.90	2.63	2.38	2.12	2.79	2.52	2.25
10	1025540.09	0.24	0.25	0.27	2.17	1.96	1.75	6.27	5.67	5.06	6.43	5.81	5.19
11	200573.31	0.31	0.34	0.31	4.09	3.70	3.30	2.56	2.32	2.07	2.76	2.49	2.23
12	80229.33	0.21	0.21	0.28	5.59	5.05	4.51	0.92	0.83	0.74	0.95	0.86	0.76
13	140401.32	0.33	0.34	0.34	4.01	3.62	3.24	1.87	1.69	1.51	1.91	1.72	1.54
14	2033639.04	0.34	0.36	0.35	1.79	1.62	1.45	20.92	18.90	16.88	21.91	19.79	17.68
15	258129.16	0.54	0.54	0.55	2.95	2.66	2.38	4.11	3.71	3.31	4.11	3.72	3.32
16	243304.16	0.38	0.38	0.40	4.55	4.11	3.67	4.18	3.77	3.37	4.19	3.79	3.39
17	103774.89	0.57	0.58	0.58	3.12	2.82	2.52	1.85	1.67	1.49	1.87	1.69	1.51
18	125576.33	0.49	0.51	0.57	3.61	3.26	2.91	2.21	1.99	1.78	2.30	2.07	1.85
19	91566.07	0.54	0.54	0.55	3.91	3.53	3.15	1.95	1.76	1.57	1.95	1.76	1.57
20	166563.05	0.32	0.33	0.32	3.96	3.58	3.20	2.14	1.93	1.73	2.17	1.96	1.75
21	115983.70	0.32	0.33	0.33	4.59	4.15	3.70	1.70	1.54	1.37	1.75	1.58	1.41
22	158714.54	0.34	0.35	0.34	3.90	3.53	3.15	2.11	1.91	1.71	2.18	1.97	1.76
23	102902.83	0.33	0.34	0.36	5.10	4.61	4.12	1.75	1.58	1.41	1.78	1.61	1.44
24	447365.68	0.34	0.35	0.40	2.84	2.57	2.29	4.32	3.90	3.49	4.42	3.99	3.57
25	349695.21	0.29	0.30	0.32	2.57	2.32	2.07	2.63	2.37	2.12	2.65	2.39	2.14
26	94182.25	0.38	0.38	0.41	4.42	3.99	3.56	1.58	1.43	1.27	1.59	1.44	1.28
27	119471.93	0.31	0.32	0.32	4.12	3.72	3.33	1.54	1.39	1.24	1.60	1.44	1.29

Fig. 18 and Fig. 19 show the sum of peak runoffs with respect to 25 year return period and average increase in peak runoff in 2015 coming from watersheds of individual hills of Guwahati city. It is found that in contrast to the highest runoff generation, Garbhanga hill (Hill ID 10) is having the least increment in peak runoff among all the hills from 2011 to 2015. This is because only 2% area of Garbhanga hill watershed is lying under GMCA and urban settlement has been increased in that portion only. LULC change in the remaining part of the watershed is very little from 2011 to 2015. From 2011 to 2015 there is an average 2% increase in peak runoff from watersheds of hills of Guwahati city. Based on the amount of peak runoff generated, the watersheds of hills of Guwahati city are categorised in 8 classes. These are shown in Table 15. Accordingly Fig. 20 shows watershed wise peak runoff class maps of hills of Guwahati city for the year 2015. These will also help to identify the watersheds of hills requiring watershed management plan in order to minimize peak runoff. From these watershed class maps, it is clear that most areas of hills of Guwahati city are the parts of watersheds of Class III. Class IV and Class V watersheds are also there, but in limited cases. It is found that small watersheds of hills of Guwahati city are mainly belonging to Class I and II. On the contrary, number of Class VIII watershed is only one. That is the Garbhanga hill watershed having the largest drainage area.

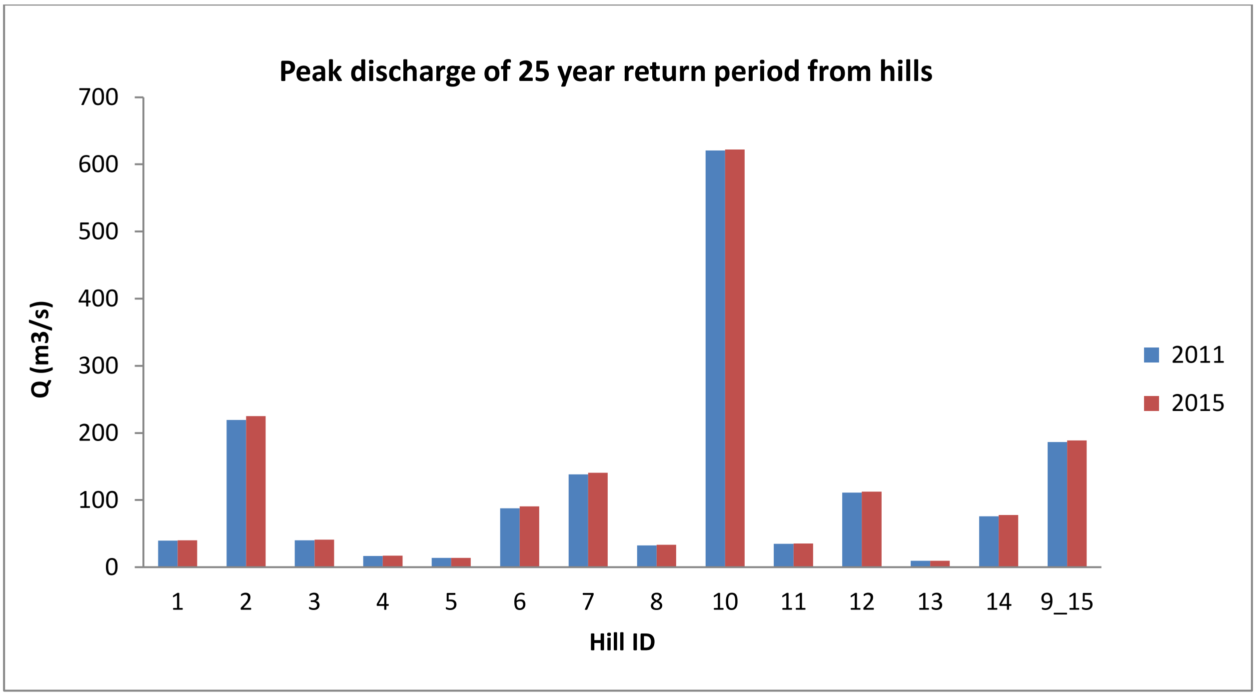


Fig. 18: Peak runoffs of 25 year return period coming from the hills of Guwahati city for the years 2011 and 2015

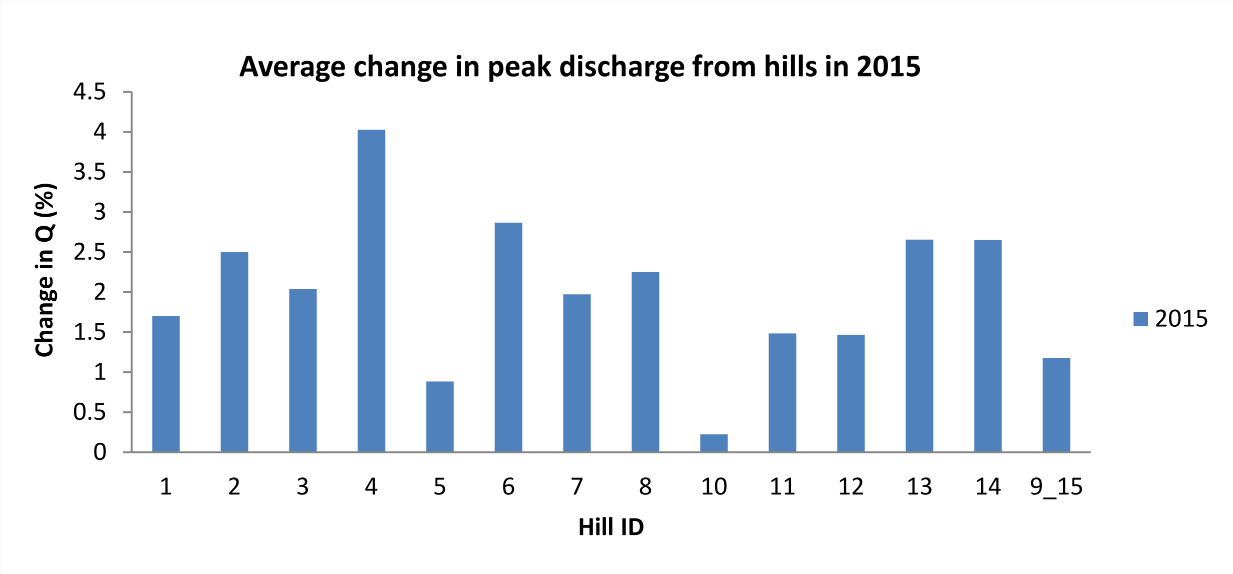
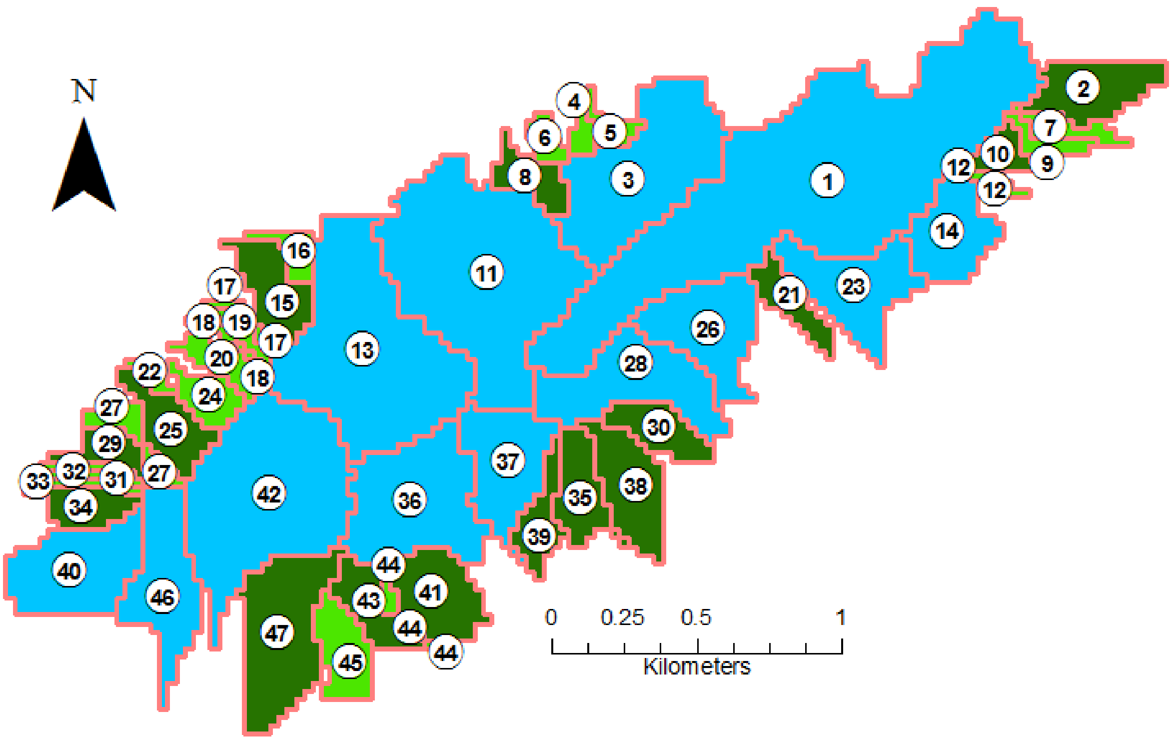


Fig. 19: Average increase in peak runoff values from 15 hills of Guwahati city in 2015 with respect to those in 2011

Table 15: Classification of watersheds of hills of Guwahati city based on peak runoff generation

Peak Runoff (m^3/s)	**Class of watersheds**	**Assigned colour in map**
0-0.5	Class I	
0.5-1	Class II	
1-5	Class III	
5-15	Class IV	
15-30	Class V	
30-50	Class VI	
50-80	Class VII	
>80	Class VIII	



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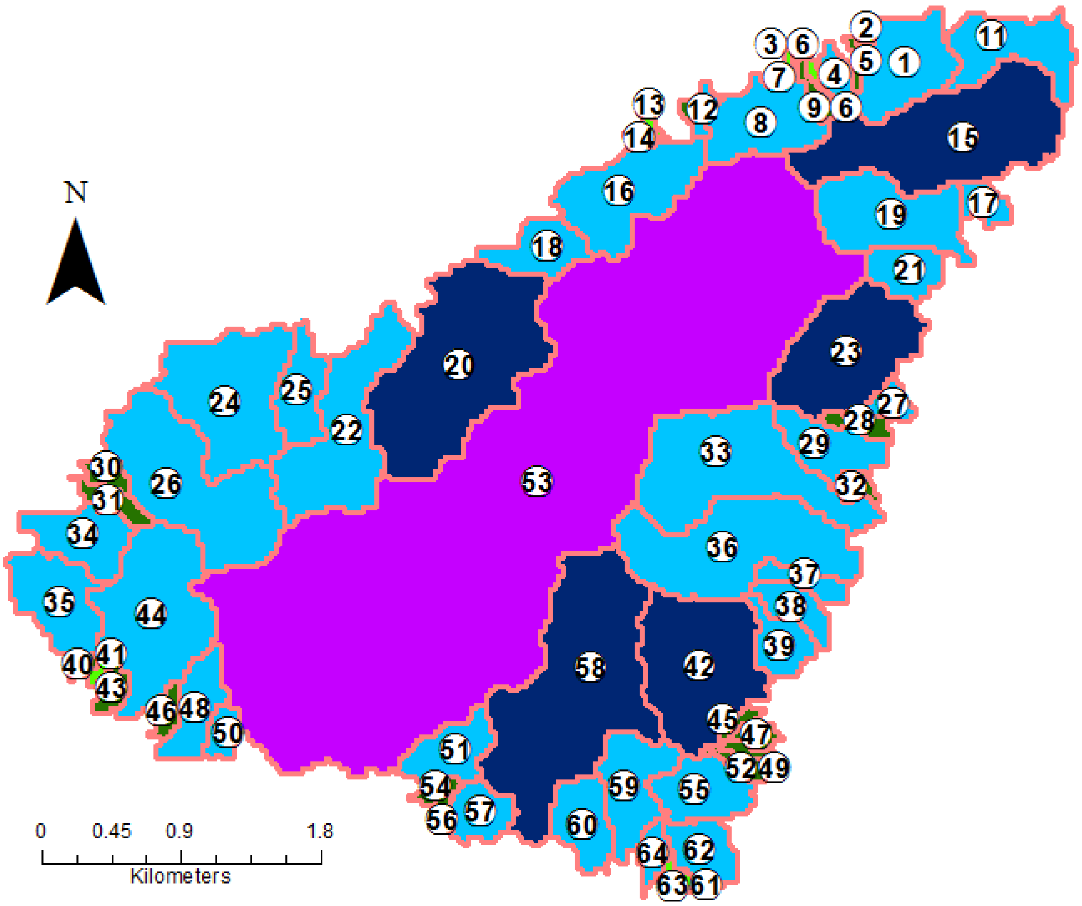

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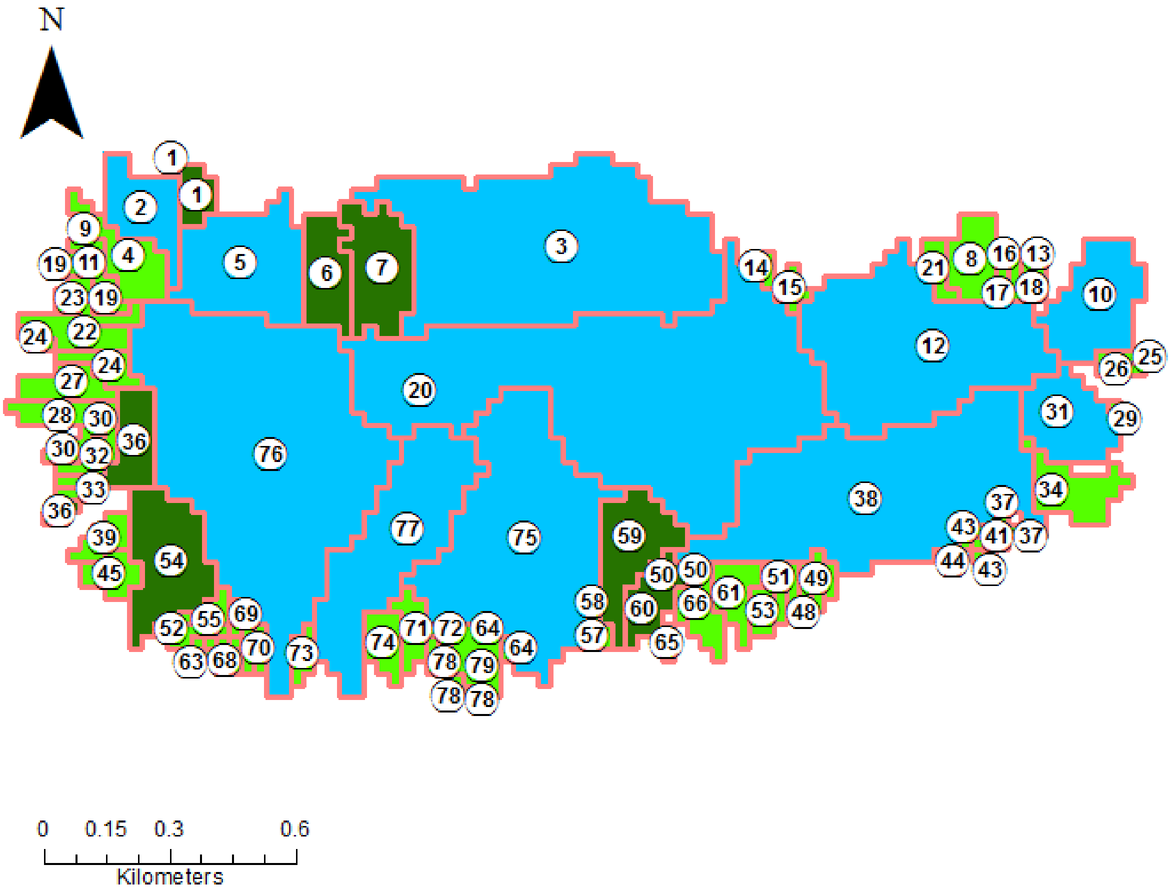

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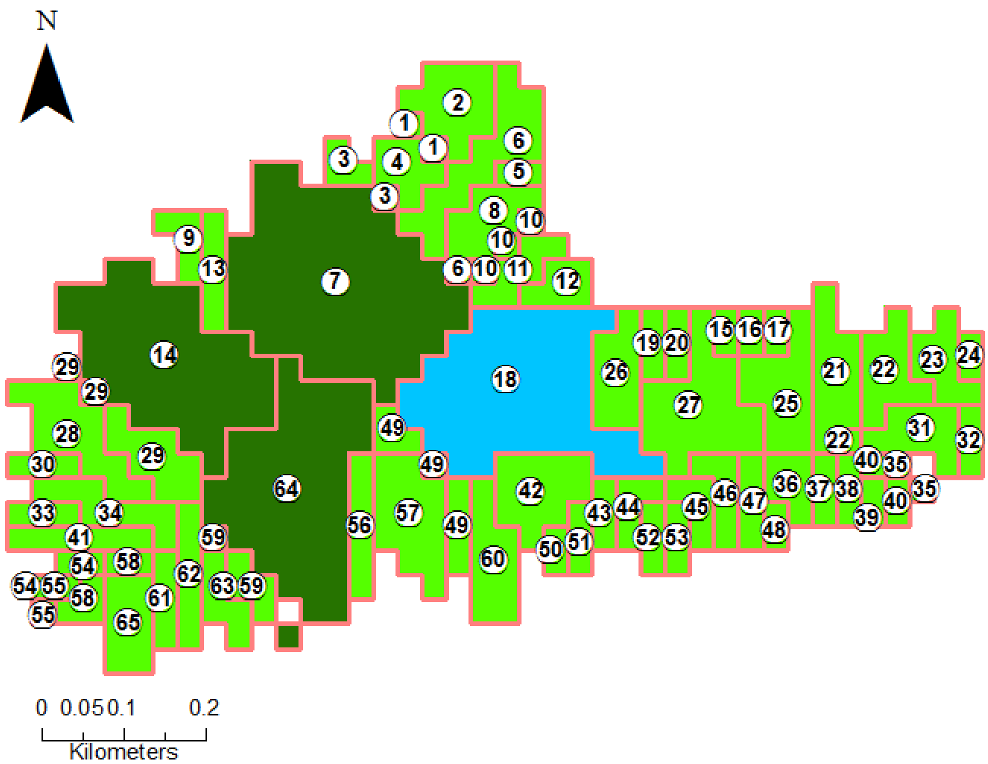

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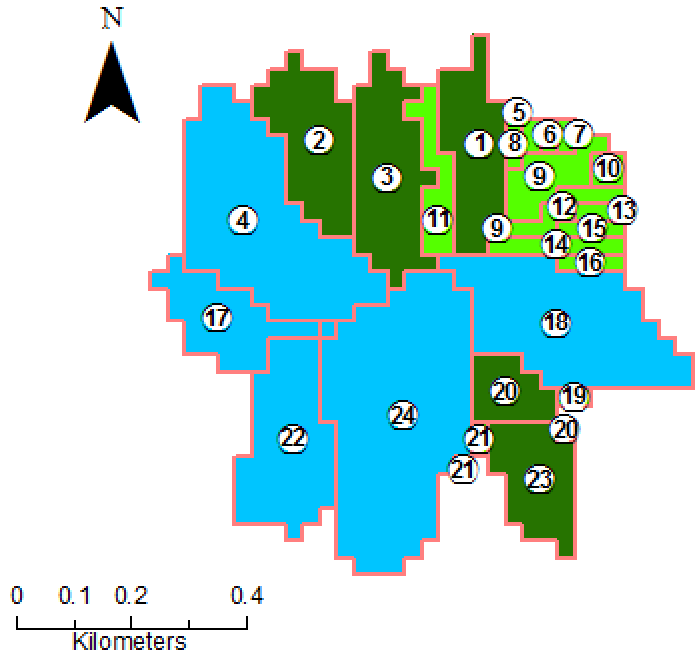

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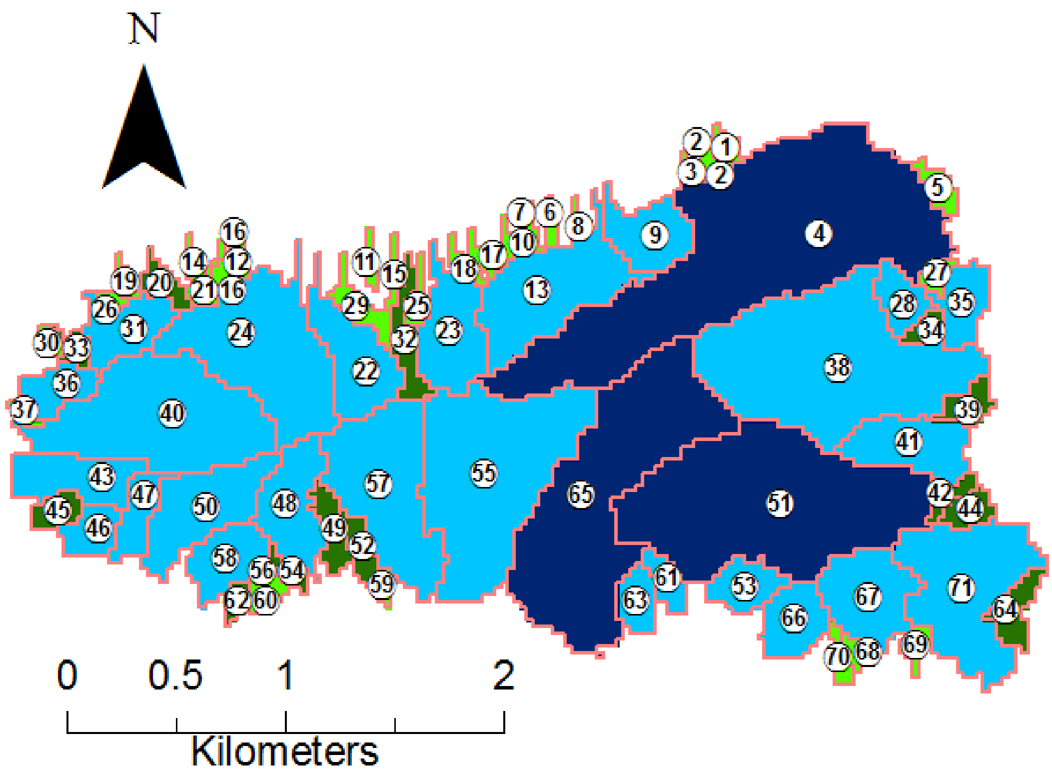

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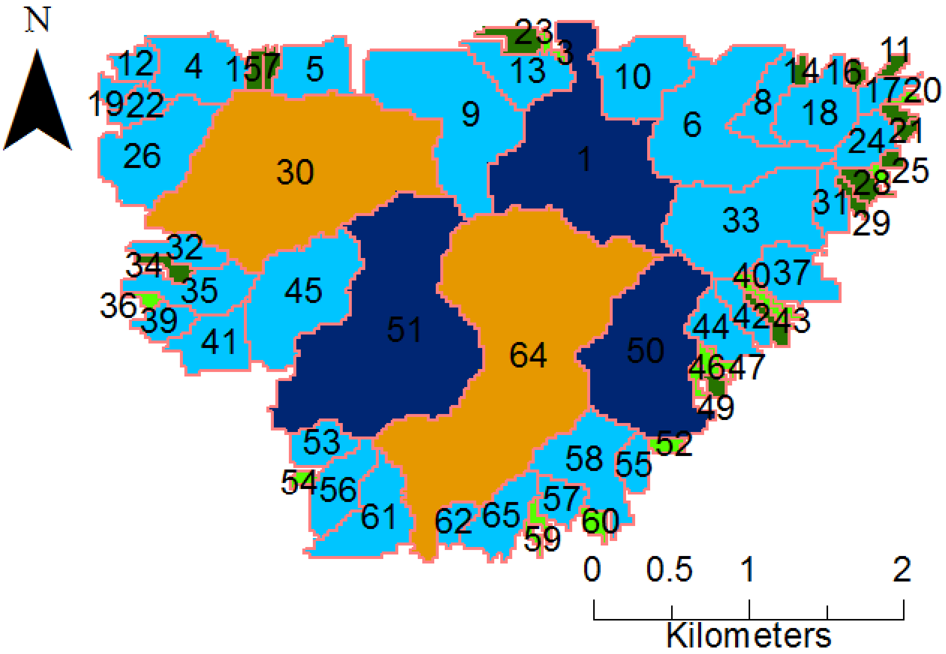

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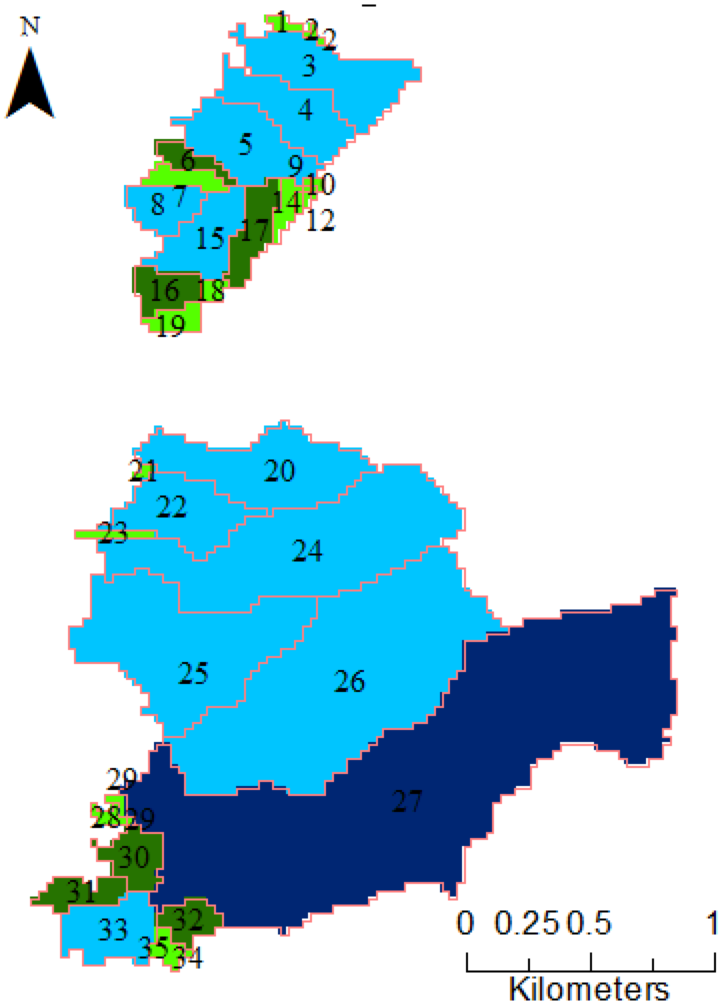

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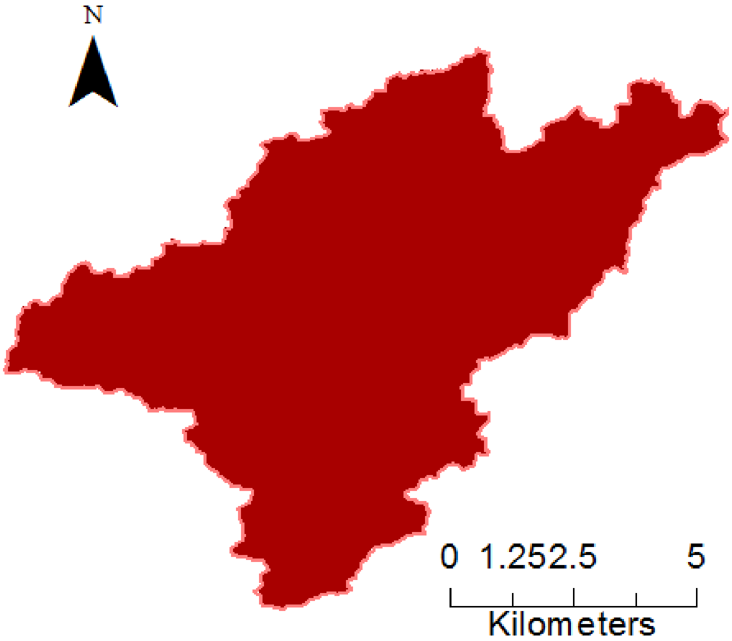

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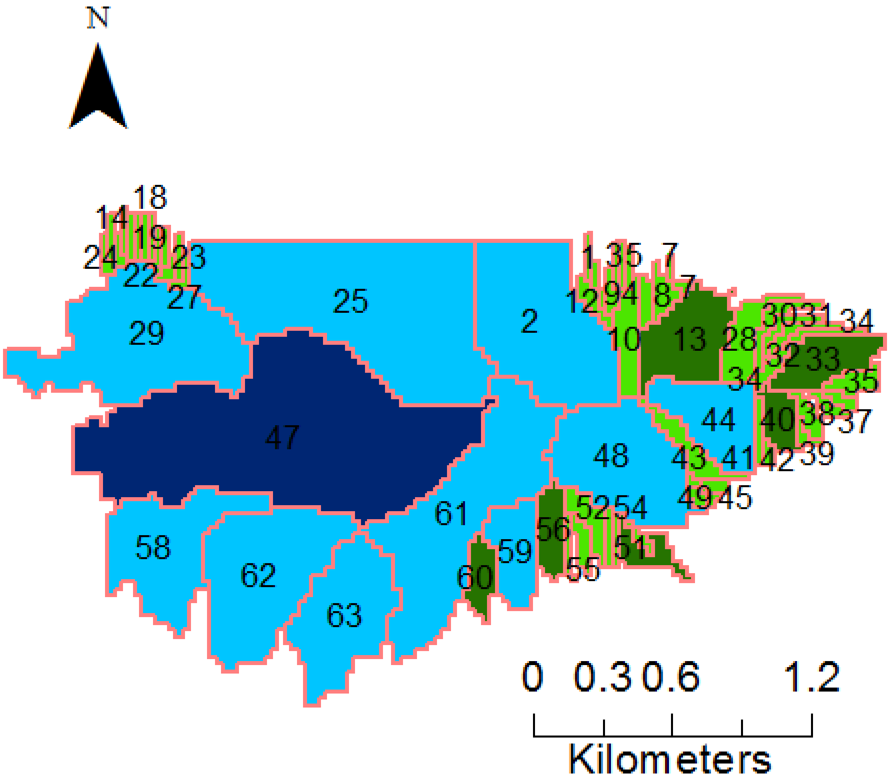

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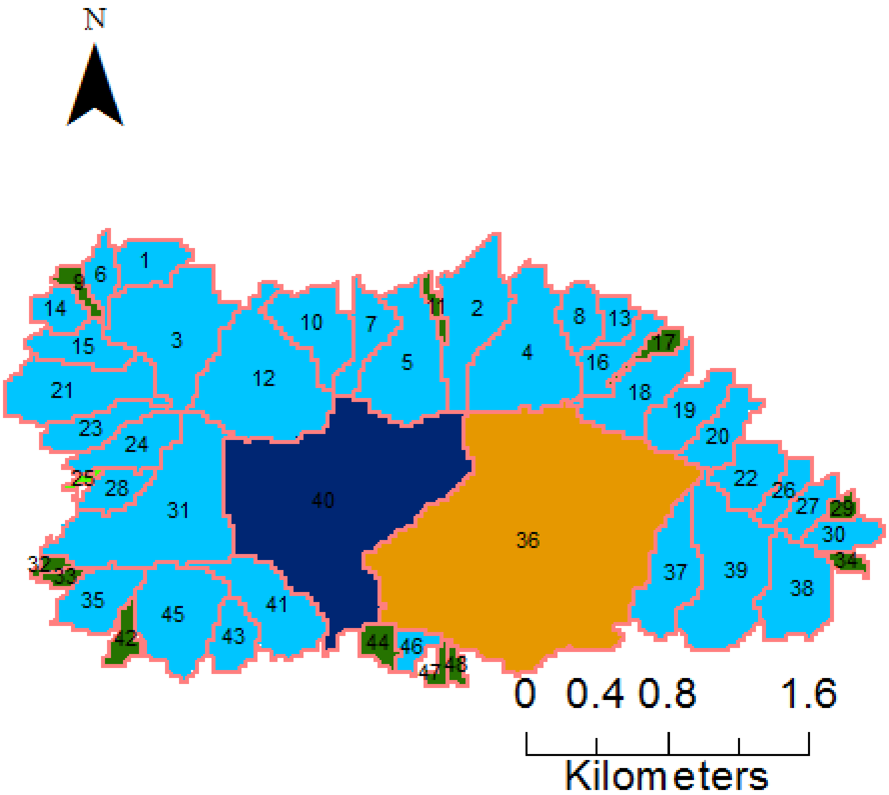

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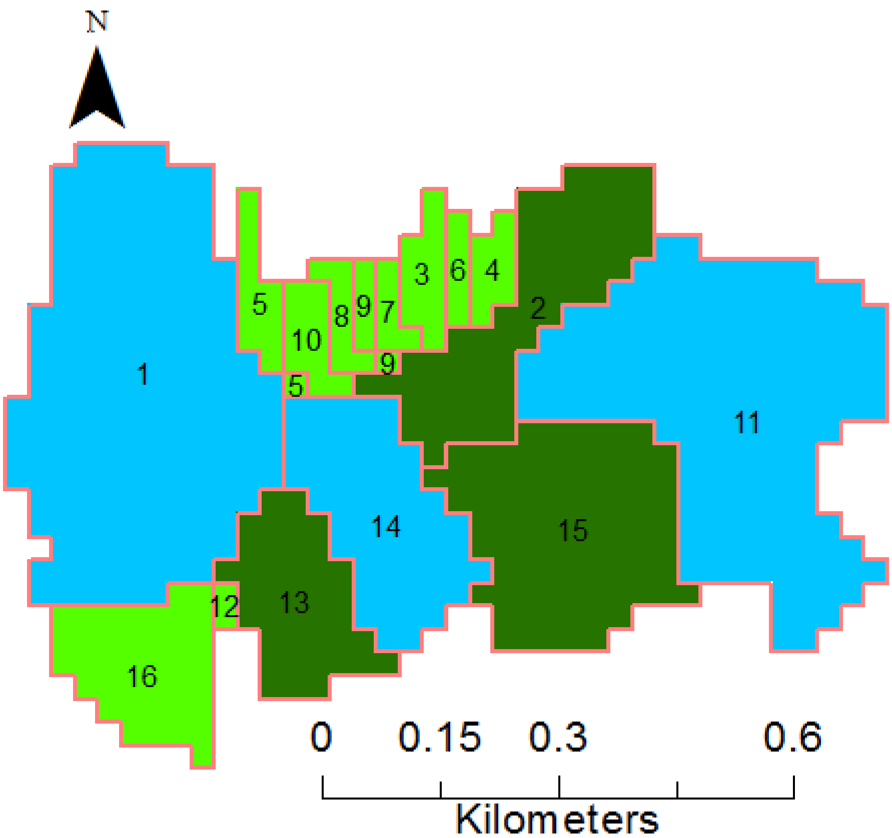

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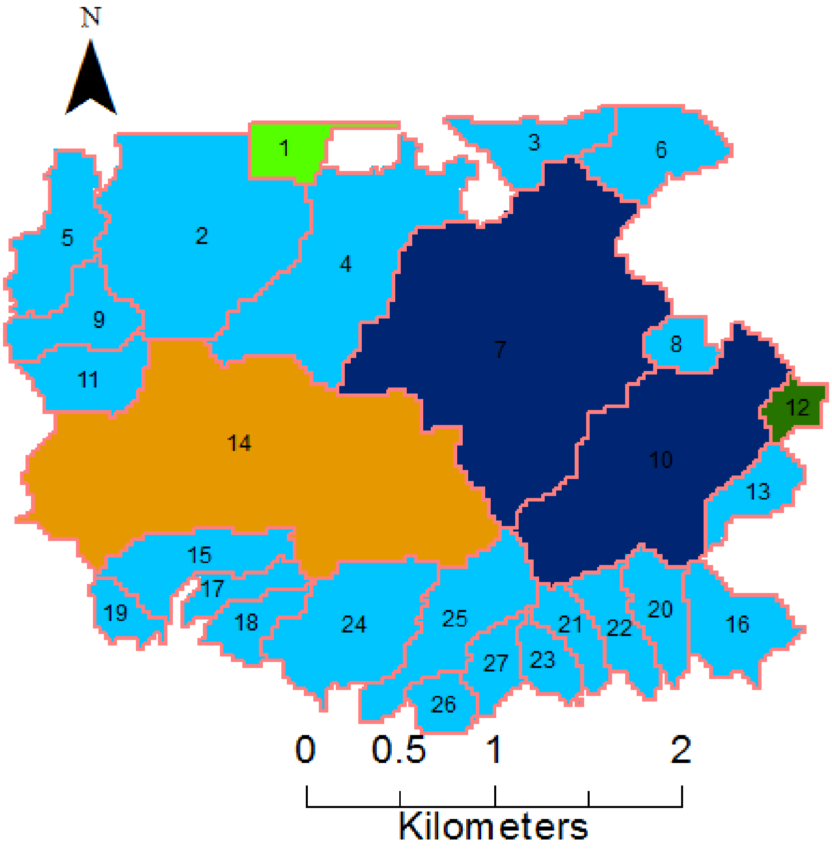

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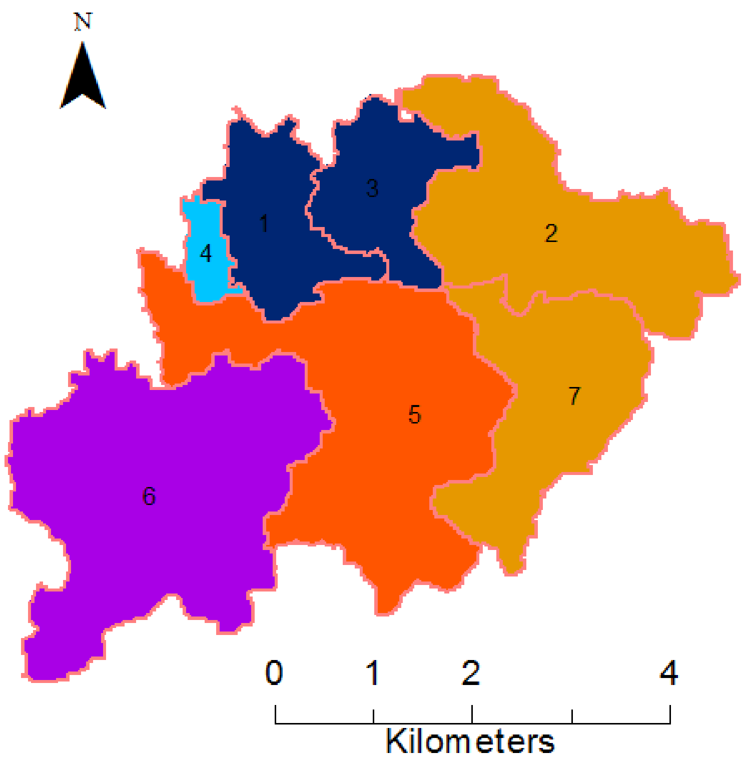


Hill ID: 9 and 15 (Combined)

Fig. 20: Watershed wise peak runoff class maps of hills of Guwahati city (: Watershed boundary)

3. Soil loss calculation from hills of Guwahati city

3.1 INTRODUCTION TO RUSLE

For this purpose 'Revised Universal Soil Loss Equation' (RUSLE), one of the most widely used empirical soil loss estimation model has been used. The basic equation of RUSLE model is expressed as-

A=R*K*LS*C*P

Where, A is the average annual soil loss per unit area (tons/ha^{-1}); R is the rainfall-runoff erosivity factor (MJ mm ha^{-1} h^{-1}year^{-1}); K is the soil erodibility factor (ton h MJ^{-1} mm^{-1}); L is the slope length factor; S is the slope steepness factor; C is the cover and management factor; P is the support and conservation practices factor. Sarma et al. (2005) conducted a study on the rainfall erosivity factor R for Guwahati city and found it as 9259 MJ.mm ha^{-1} h^{-1}year$^{-1.}$ However, by using 2 years of hourly rainfall data recorded in the period 2003-2004 the R factor value for Guwahati city is found as 4631.14 MJ mm ha^{-1} h^{-1} year^{-1}. That means R factor given by Sarma et al. (2005) is two times the R factor calculated by using 2 years of hourly rainfall data. The maximum value of daily rainfall recorded in the period 2003-2004 is 90.25 mm which is almost equal to daily rainfall with 2 years of return period (92 mm) obtained from frequency analysis of 43 years of daily rainfall data of Guwahati city. On the other hand, it is found that daily rainfall with 50 years return period is 183 mm which is approximately two times of 90.25 mm. Therefore, on this basis, if we consider the R factor value equal to 4631.14 MJ mm ha^{-1} h^{-1} year^{-1}as a value with 2 year return period, R factor value equal to 9259 MJ.mm ha^{-1} h^{-1}year^{-1} can be taken as a 50 year return period value. K factor value has been taken based on the soil type of the watershed obtained from soil map of Guwahati city available in Assam Remote Sensing Application Centre (ARSAC). The slope length and slope steepness factor LS is derived with the help of DEM by using ArcGIS software. On the other hand, the cover management factor for the various land cover is considered based on available literature (Sarma 2011; Gelagay and Minale 2016) and are given in Table 16. The P factor value is taken as 1 since no support practices are found in the watershed.

Table 16: RUSLE cover management factor values for different land cover.

Land cover	C factor
Bare soil	1
Forest	0.01
Scrub land	0.014
Marshy land	0
Water bodies	0
Urban settlement	0.4

3.2 HILL CUT FACTOR

One important point is that through field survey done in this watershed it is found that there exist several steep hill cuts done by the inhabiting people in the hill. The average slope of the 100 numbers of hill cuts surveyed in the watershed is 70^{0} which are quite steep. Out of the total area of these hill cuts, average 1% area is protected by retaining wall, 39% area are covered by grass, trees or creepers and the remaining 60% area are exposed or bared. Due to the steep gradient, these hill cuts are rarely visible in the ortho rectified satellite image resulting in under estimation of soil loss. So in order to take account of these steep hill cut, a new factor called "hill cut factor" (H_f) has been introduced here. This hill cut factor is employed to the cover management factor of urban settlement area of hill. Mathematical expression of the "Hill cut factor is-

$$H_f = \frac{sin\theta}{sin\beta cos\theta - cos\beta sin\theta}$$

Where, θ= average slope of the hill

β= Average slope of hill cut

This hill cut factor is employed to the cover management factor of urban settlement area of hill and it can be expressed as-

$$C_{hu} = \frac{a}{100} * C_1 + \frac{b}{100} * C_2 + \frac{c}{100} * C_3 * H_f + C_g$$

where C_{hu} is the cover management factor of urban settlement area of hill and C_g is the general cover management factor for urban settlement=0.4.

3.3 SEDIMENT LOSS CALCULATION

Finally, raster map of all the factors of RUSLE are prepared and multiplied in ArcGIS software. Maps of soil loss rate (in ton ha^{-1} $year^{-1}$) are obtained for all the hills with respect to the two rainfall erosivity factors. An average rate of soil loss is calculated for every watershed of hills of Guwahati city by taking the arithmetic mean of the pixels values of all the raster maps of soil loss rate. Hill wise average rate (t ha^{-1} $year^{-1}$) and total amount of soil loss (t $year^{-1}$) from watersheds for the years 2011 and 2015 are given respectively in Table 17 and Table 18 for both R factors. Fig. 21 and Fig. 22 show hill wise average rate (t ha^{-1} $year^{-1}$) and total amount of soil loss (t $year^{-1}$) from watersheds for the years 2011 and 2015 for both R factor value 9259 MJ mm ha^{-1} $h^{-1}year^{-1}$. It is observed that in response to the highest amount of areas covered by watershed of Garbhanga hill (Hill ID 10), it is producing the highest amount of soil loss among all the 15 hills of Guwahati city. Next to this, combined watersheds of Khanapara and Koinadhara hills (Combined Hill ID 9_15) and Fatasil hill (Hill ID 2) are producing the highest amount of soil loss. From 2011 to 2015 there is an average 5.34% increase in soil loss from the hills of Guwahati city.

Table 17: Hill wise average rate (t ha^{-1} $year^{-1}$) of soil loss from watersheds for the years 2011 and 2015.

Hill ID	Hills	R=9259 (50 year RP)		R=4631.14 (2 year RP)	
		2011	2015	2011	2015

		Average soil loss rate (t ha-1 year-1)	Average soil loss rate (t ha-1 year-1)	Average soil loss rate (t ha-1 year-1)	Average soil loss rate (t ha-1 year-1)
1	University	75.29	83.00	37.659	41.513
2	Fatasil	287.75	296.57	143.93	148.34
3	Kalapahar	195.69	205.76	97.879	102.92
4	Sonaighuli	280.06	291.78	140.08	145.94
5	Sarania	344.62	360.39	172.37	180.26
6	Kharguli	184.17	203.00	92.117	101.54
7	Japorigog	236.12	247.37	118.1	123.73
8	Burhagosain	150.56	160.74	75.305	80.397
10	Garbhanga	135.930	136.465	67.989	68.257
11	Kamakhya	244.28	254.20	122.18	127.15
12	Kahilipara	326.92	335.10	163.52	167.61
13	Betkuchi	191.52	219.19	95.794	109.64
14	Chunsali	121.37	133.37	60.709	66.71
9+ 15	Khanapara+ Koinadhara	196.08	205.33	98.073	102.7

Table 18: Hill wise total soil loss (t year^{-1}) from watersheds for the years 2011 and 2015.

Hill ID	Hills	R=9259 (50 yr RP)		R=4631.14 (2 yr RP)	
		2011	2015	2011	2015
		Total soil loss (t/yr)	Total soil loss (t/yr)	Total soil loss (t/yr)	Total soil loss (t/yr)
1	University	32273	34450	16142	17231
2	Fatasil	529033	568722	264610	284462
3	Kalapahar	55976	58471	27998	29246
4	Sonaighuli	17009	18072	8508	9039
5	Sarania	24426	25166	12217	12587
6	Kharguli	229099	244577	114590	122332
7	Japorigog	327721	352859	163919	176492
8	Burhagosain	84872	89205	42451	44618
10	Garbhanga	981409	985271	490878	492810
11	Kamakhya	150329	156760	75191	78408
12	Kahilipara	309098	320278	154604	160196
13	Betkuchi	13509	13904	6757	6954
14	Chunsali	128687	143941	64366	71996
9+ 15	Khanapara+ Koinadhara	648633	675837	324431	338038

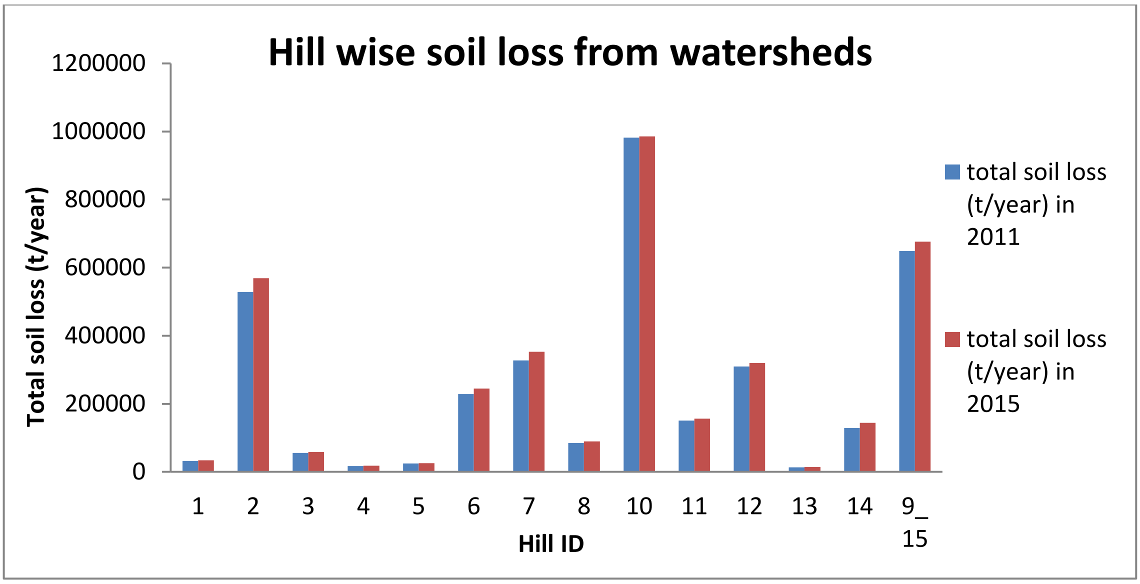


Fig. 21: Total soil loss from watersheds of hills for R=9259 MJ mm ha^{-1} h^{-1} $year^{-1}$

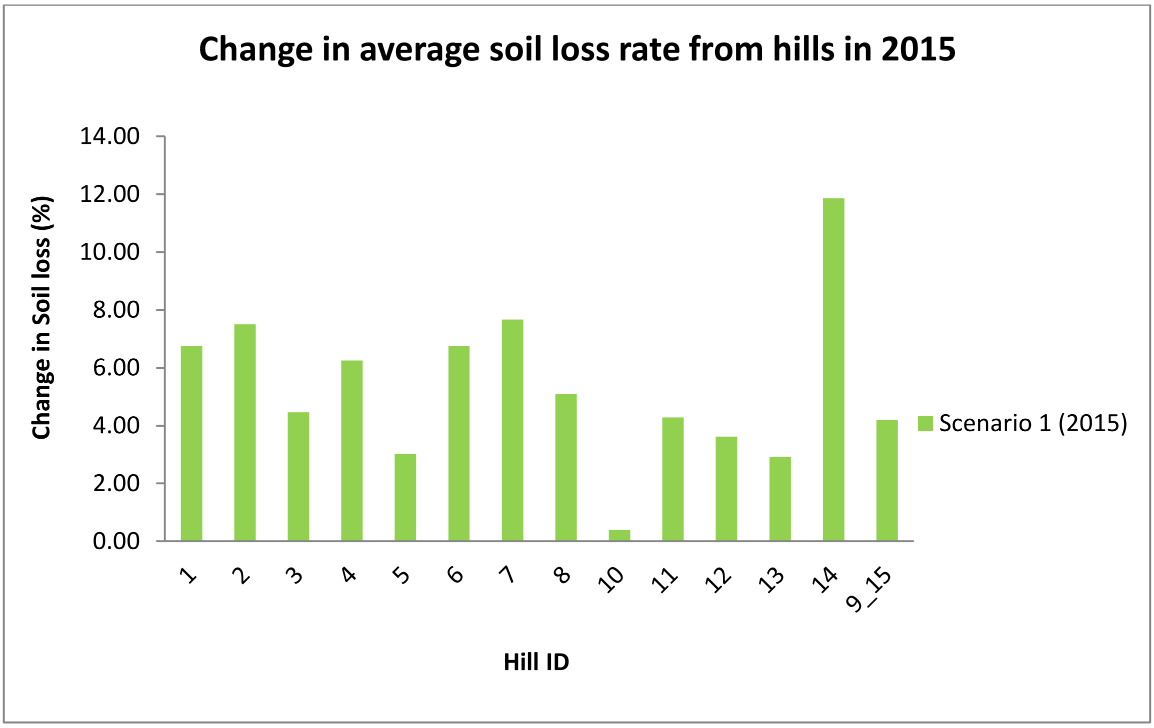


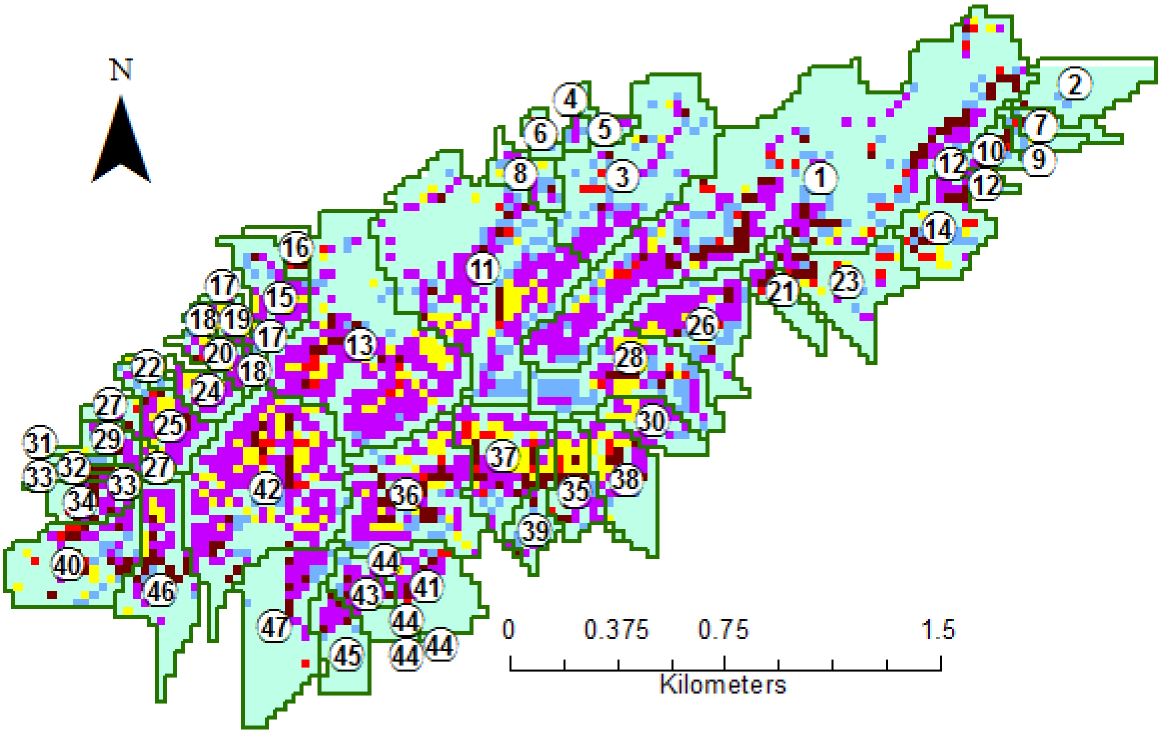
Fig. 22: Change in average rate of soil loss from hills in 2015 with respect to those in 2011

As per the soil loss classes given by Irvem et al. (2007), every pixel of the raster map of soil loss rate of watersheds of hills of Guwahati city in 2015 (for R=9259) has been classified. Table 29 shows soil loss class and the resulted soil loss risk maps have been shown in Fig. 23.

Table 1: Classes of soil loss rates (Irvem et al. 2007)

Soil loss rate (t ha^{-1} yr^{-1})	Class	Assigned colour in map	Average area (%)

<5	**Very low**		44.36
5-12	**Low**		5.46
12-50	**Moderate**		23.58
50-100	**Severe**		9.08
100-200	**Very severe**		4.27
>200	**Extremely severe**		13.25



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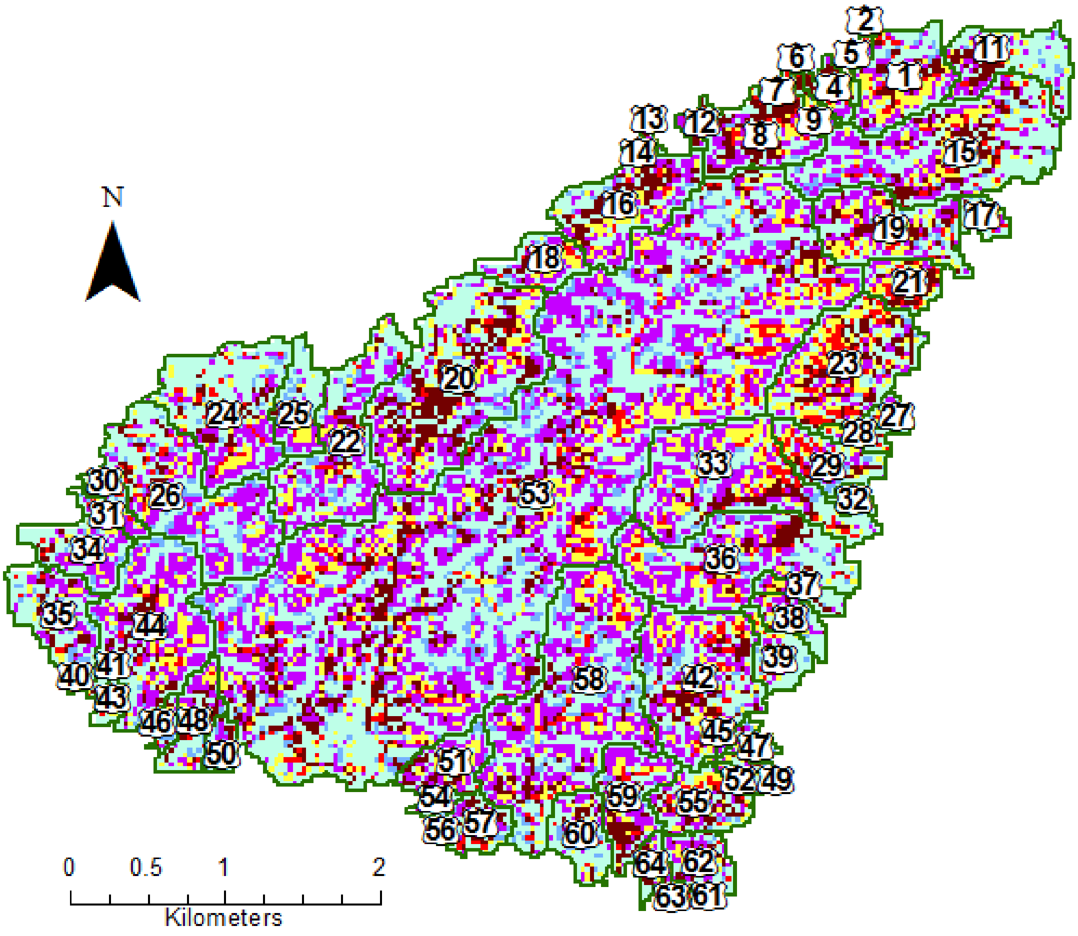

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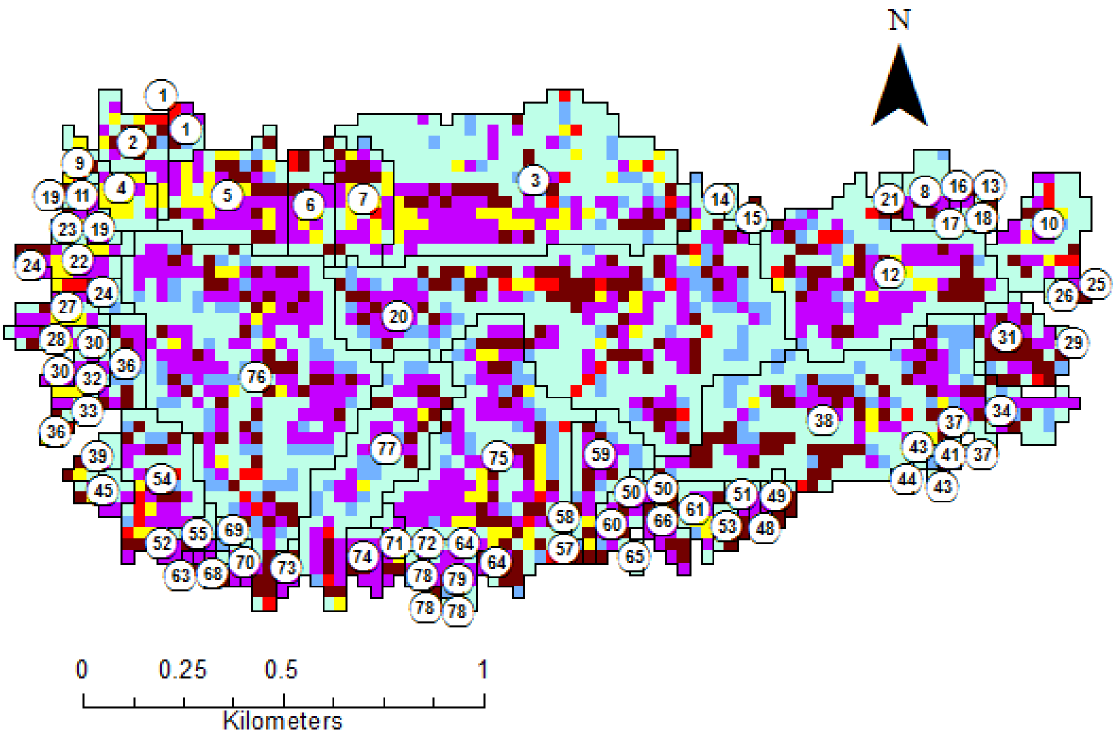

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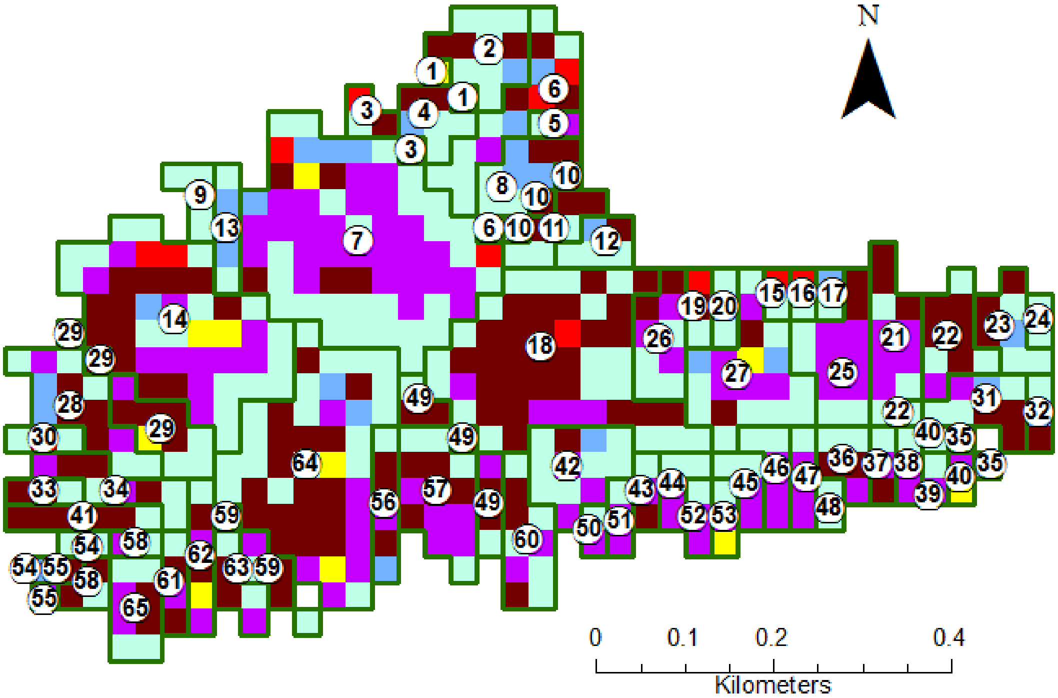

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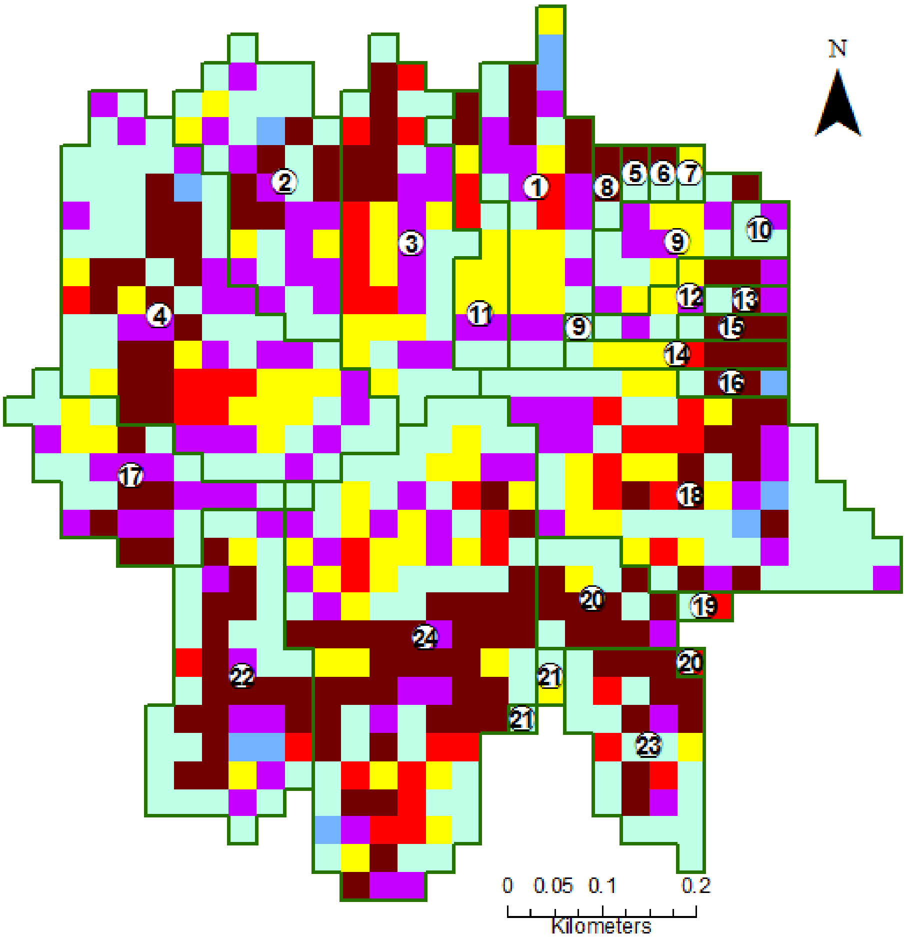

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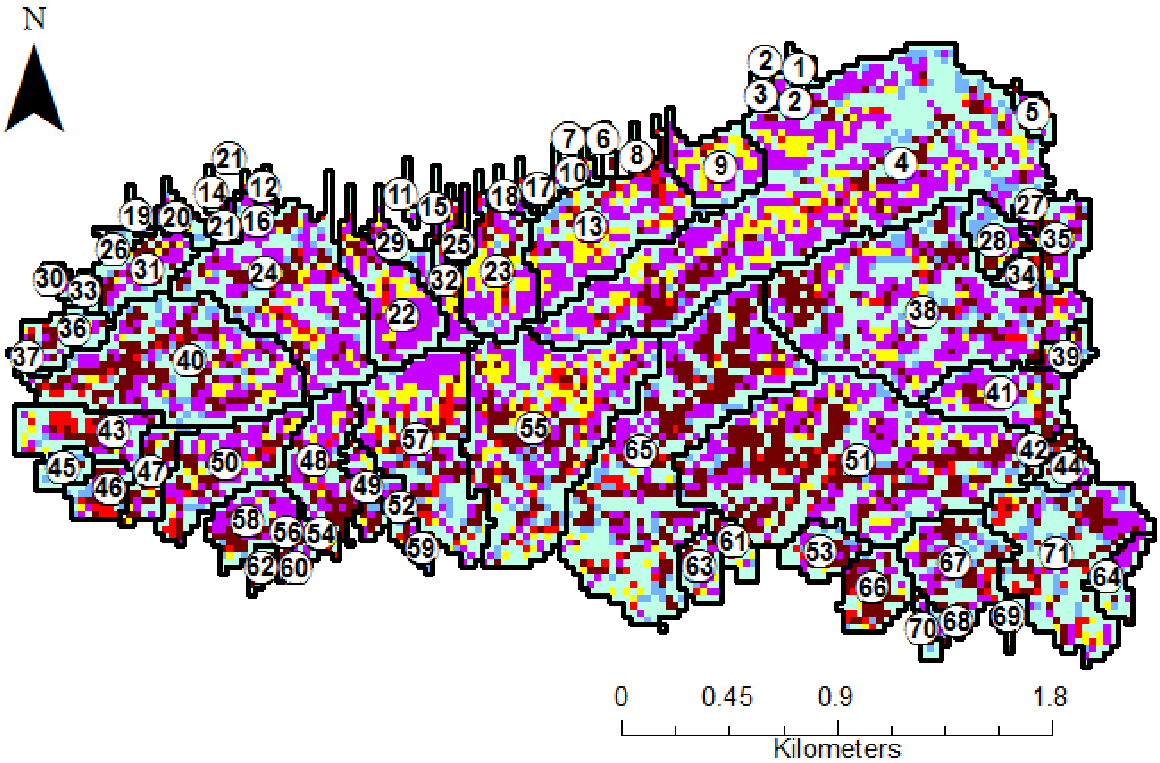

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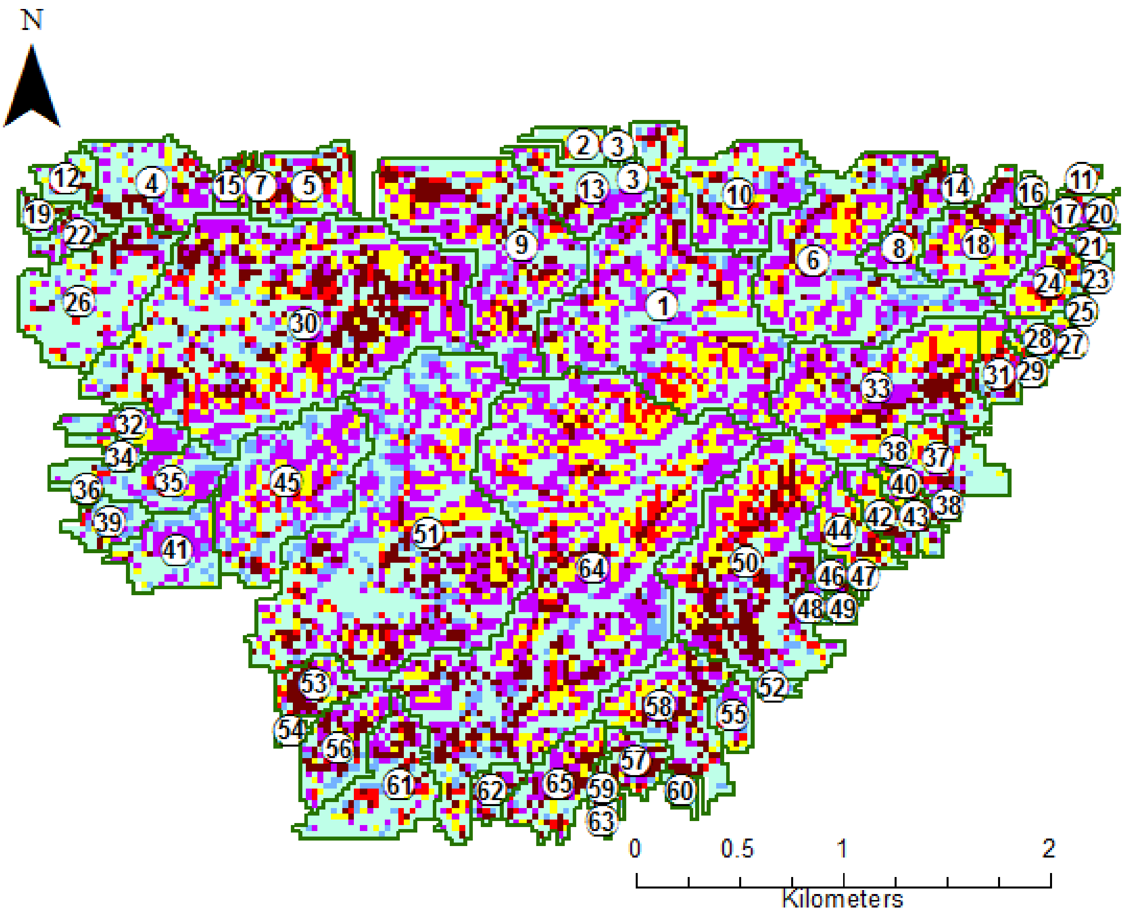

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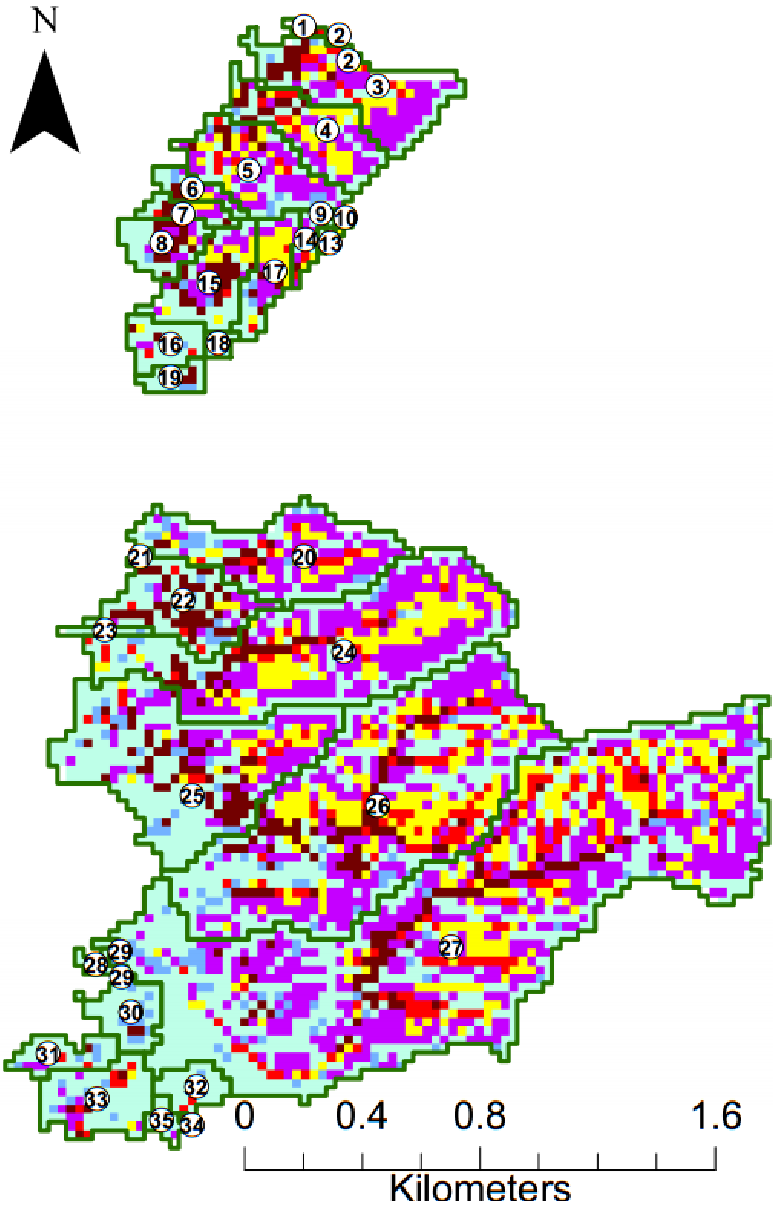
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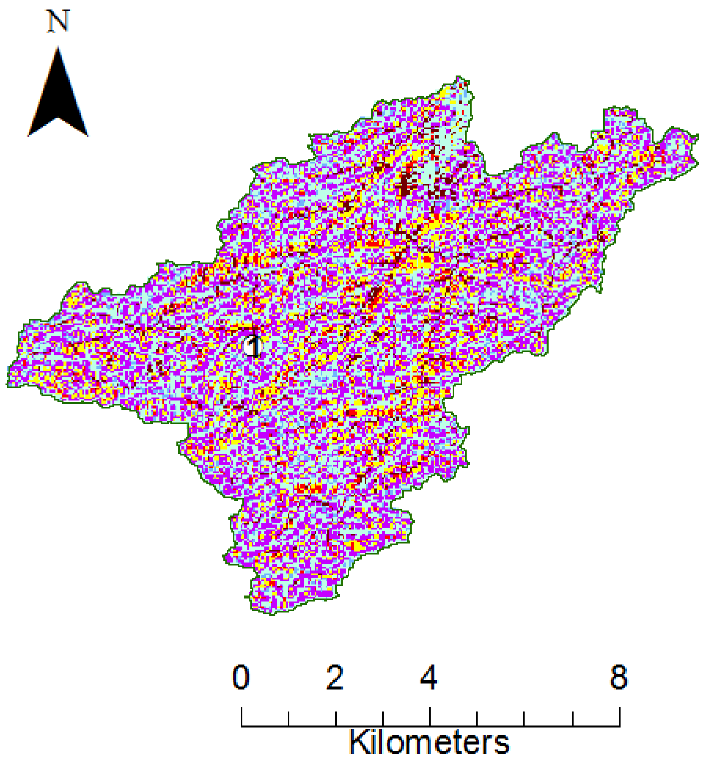

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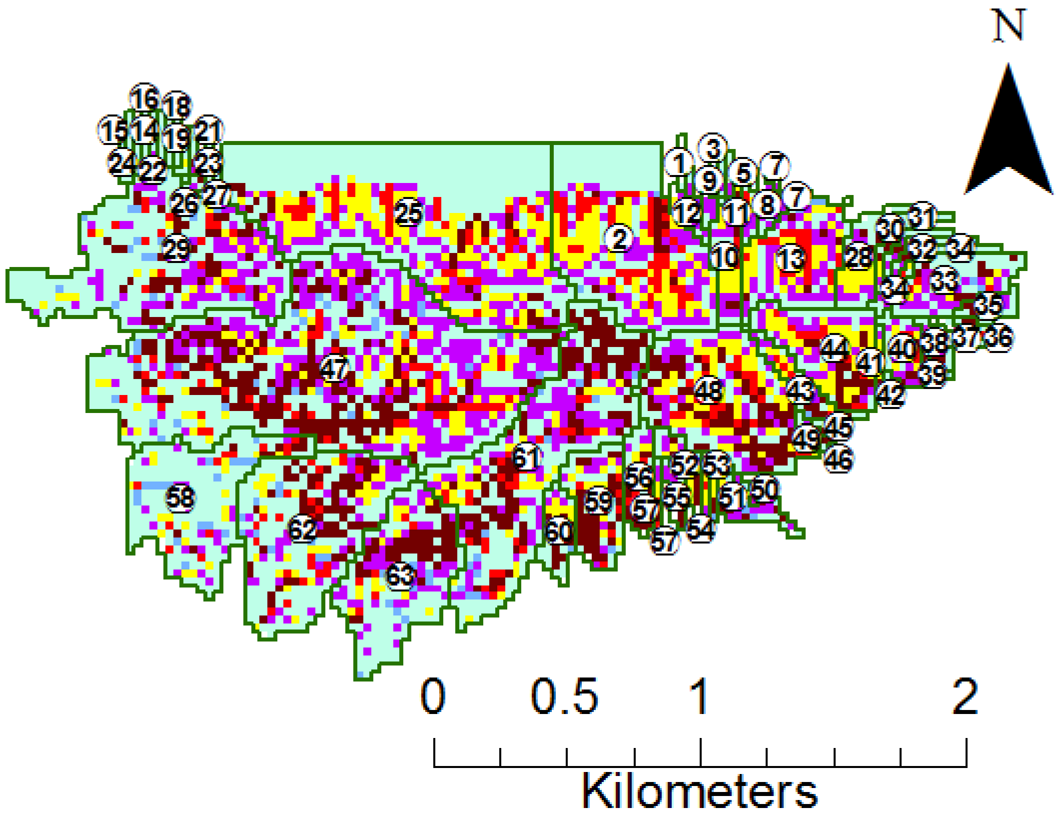
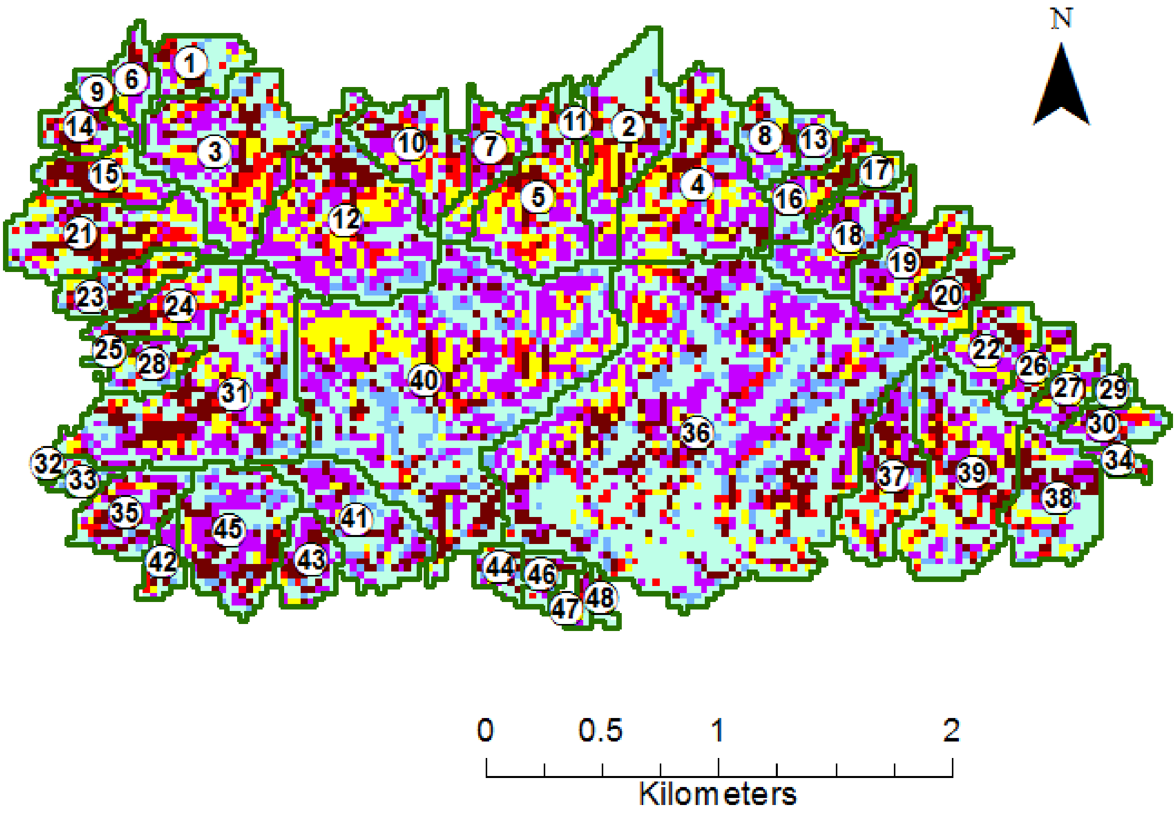


Hill ID: 11



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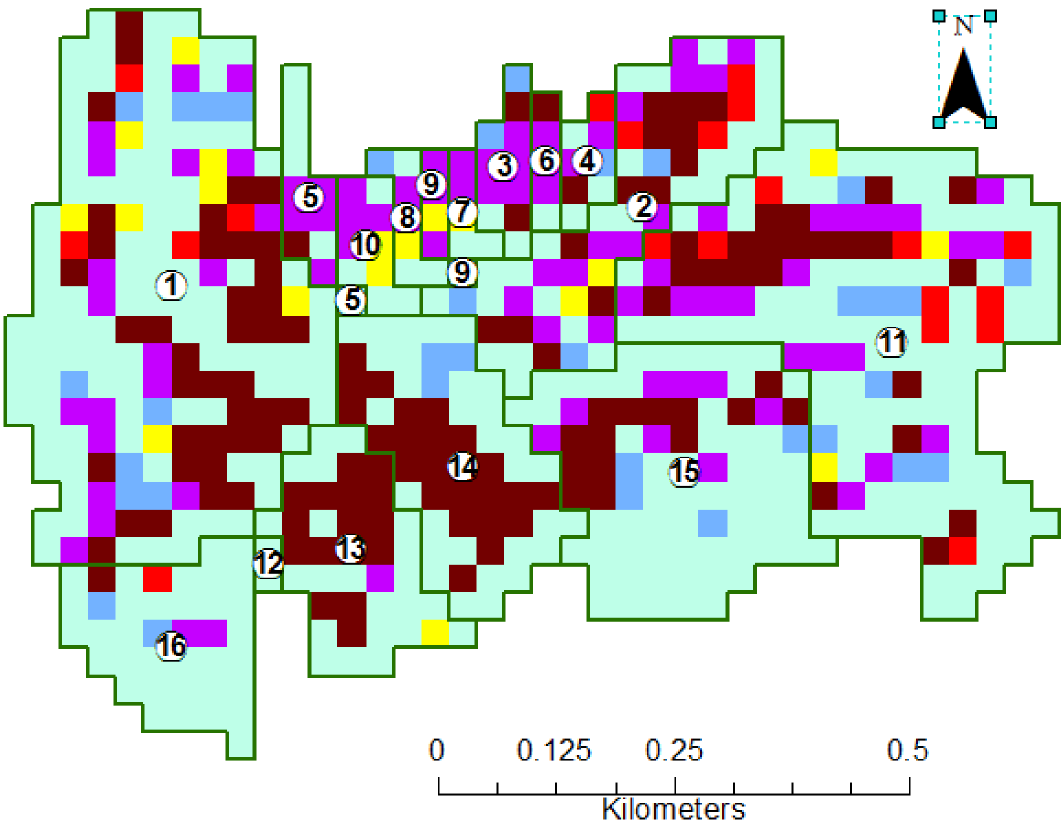

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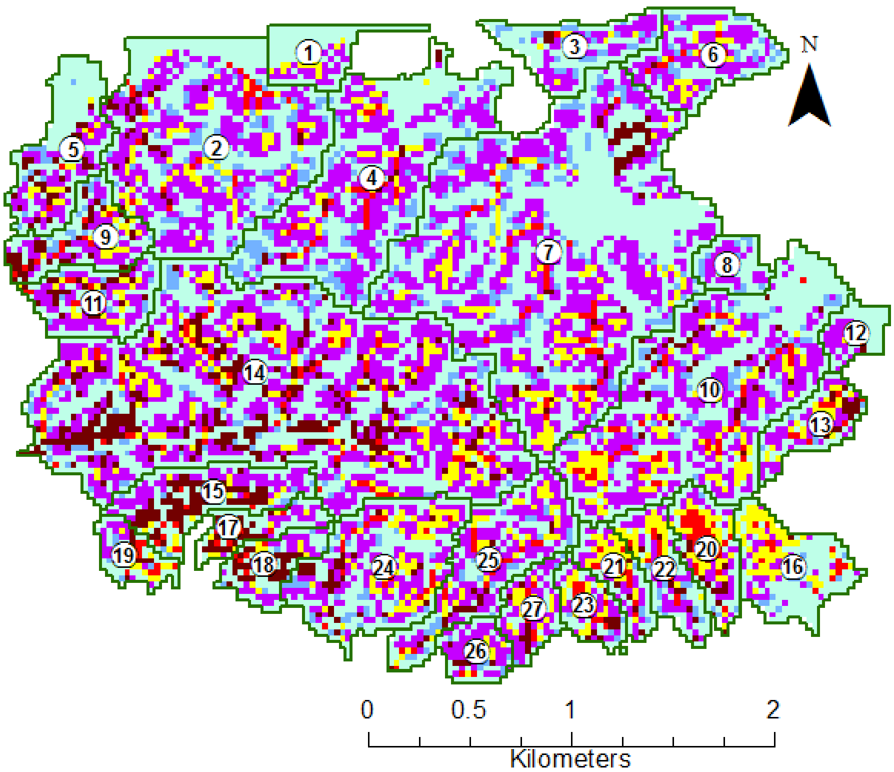

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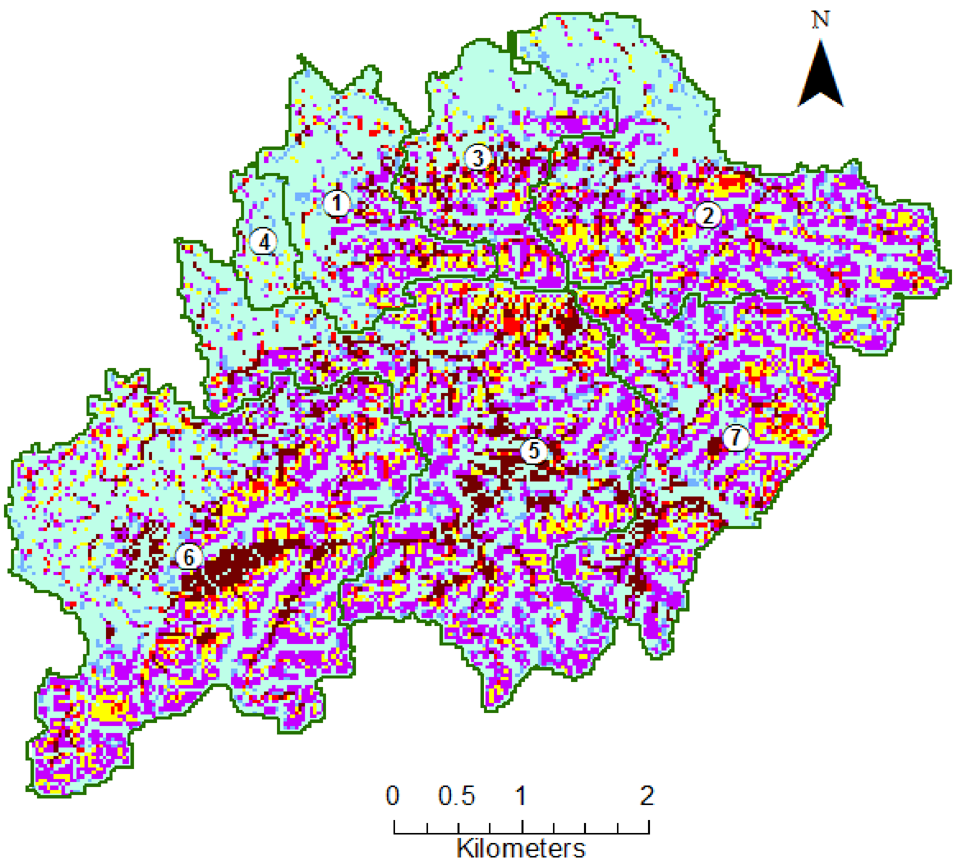

Hill ID: 9 and 15 (combined)

Fig. 23: Soil loss vulnerability maps for watersheds of hills of Guwahati city in 2015 for both R factor values. (: Watershed boundary)

4. SUMMARY AND CONCLUSION

1. Considering need of management requirement hills of Guwahati have been delineated into 612 watersheds.

2. Peak discharge has been calculated using Rational Method for the year 2011 and 2015 for return period of 100 years, 50 years and 25 years. Considering farther development in the hill and considering impact of climate change use of 25 year return period is recommended. However, it depends on economic consideration. For any clarification in this regards, for practical implementation of any project, we may be contacted.

3. Sediment loss from the catchment has been calculated for 2 values of Rainfall Erosivity factor (R). One represents high return period in the order of 50 years and another for a return period in the order of 2 years. For practical purpose 2 year return period value can be used.

4. As the hill slopes are very steep and distance to foot hill is very less, delivery factor has not been considered for this estimation of sediment loss.

5. For convenience of practical application, watersheds are divided into some classes based on degree of degradation.

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