MICRO WATERSHED LEVEL WATER RESOURCE MANAGEMENT BASED ON THREE YEARS RUNOFF ESTIMATION USING REMOTE SENSING AND GIS TECHNIQUES FOR SIMLAPAL BLOCK, BANKURA, W.B

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Abstract: *Water is one of the essential natural resource, without which life cannot exist. Demand of water is increasing with the increase of population. We need water for agriculture, industry, human and cattle consumption. Therefore it is very important to manage this very essential resource with sustainable manner. Hence, we need proper management and development planning to restore or recharge water where runoff is very high due to various topographical conditions. The Runoff estimation method is one of the significant RSGIS tool for prioritization of micro watershed. Soil Conservation Service Runoff Curve Number is a quantitative descriptor of the land use/land cover, soil complex characteristics of watershed and its computed direct runoff through an empirical relation that requires the rainfall and watershed co-efficient namely runoff curve number. The SCS Curve Number approach to runoff volume is typically thought of as a method for generating storm runoff for rare events and not for water quality design. The parameters were obtained with the help of Erdas, Arc GIS and MS Office. The methodology adapted from SCS method for the seasonal runoff estimation for each micro-watershed is how much prioritized. Using last three years rainfall data and estimate three years runoff than compare the three years priority level and prepared by final priority map. The results revealed that the micro watershed priorities are shows five categorizes very high, high, medium, low and very low priority.*

Keywords: *Remote Sensing, GIS, Algorithms, Arc GIS, Erdas, Ms Office*

1. Introduction:

A watershed is an ideal unit for management of natural resources that also supports land and water resource management for mitigation of the impact of natural disasters for achieving sustainable development. The significant factor for the planning and development of a watershed are its physiographic, drainage, geomorphology, soil, land use/land cover and available water resources. Remote Sensing and GIS are the most proven tools for watershed development, management and also the studies on prioritization of micro-watersheds development and management. Runoff method could be used for prioritization of micro-watersheds by studying hydrological soil group condtions and seasonal rainfall parameters of the watershed with the help of soil and land use/ land cover maps.

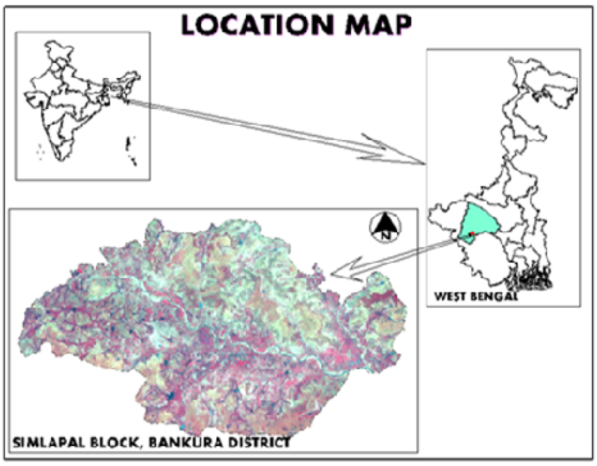
Water is one of the essential natural resource, without which life cannot exist. Demand of water is increasing with the increase of population. We need water for agriculture, industry, human and cattle consumption. Therefore it is very important to manage this very essential resource with sustainable manner. Hence, we need proper management and development planning to restore or recharge water where runoff is very high due to various topographical conditions. If proper management is planned that will not only control surface soil erosion but also recharge ground water. Remote Sensing and GIS have become proven tools for the management and development of water resources. Several studies have been carried out worldwide and they have shown excellent results. Due to advancement in satellites and sensing technology, it is possible to map finer details of the earth surface and provide scope for micro level planning and management. The study area that is taken has severe water crises during the summer season. The terrain is highly undulating with very high runoff which causes minimum recharge of ground water in spite of 1750 mm average annual rainfall. This high runoff also causes the erosion of very fertile soil.

The present study aims at water resource management for the prioritization of micro watershed based on three different years runoff estimation using Remote sensing data and GIS overlaying techniques. This study is mainly helpful for the increasing agricultural based livelihood and also to supplying the greater level of irrigation facilities.

1.1. Study Area:

The study area has been taken is a part of Silai River Basin in Simlapal block of Bankura district part of West Bengal State. It is located on 22˚59'38.84"North to 22˚50'34.42"North latitude and 86˚55'20.15" to 87˚13'06.10" East longitudes. It has an average elevation of 57mtr (187 feet's). Simlapal is a community development block is in Khatra subdivision of Bankura district in West Bengal state, and it is bounded by the Khatra block in west, Taldangra block in north, Sarenga block is south and also covered west Midnapur district in east. The geographic area of this block is 309.20 Sq Kms (119sqmile or 1144.04 hectares), "Figure 1. Location Map of Study Area".

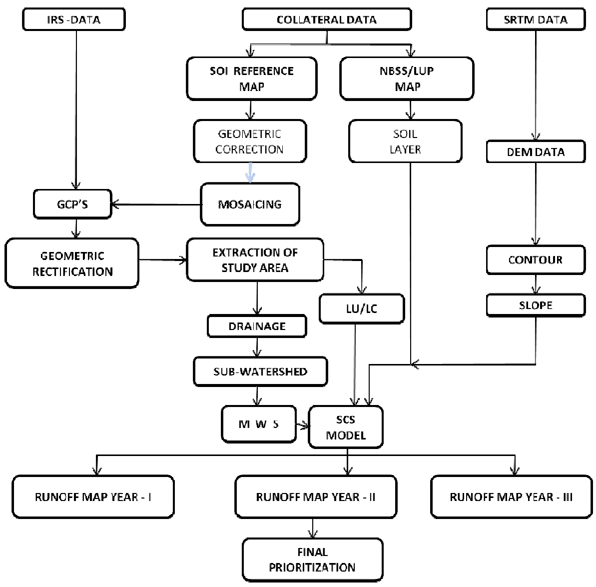
Figure 1: *Location Map of Study Area*



2. Methodology:

The methodology can be divided into two parts one is rasterization and other one is vectorization. The rasterization involves creation of mosaicking, sub-set of image, image enhancement and land use/ land cover maps etc. The vectorizations process involves creation of vector layers like; administrative boundaries (i.e. block and village boundaries), watershed boundaries, drainage layers etc. The drainage layer was digitized using Arc/Info tools. The stream ordering was given to each stream is Using Arc Info software by following Strahler (1952) Stream ordering technique. Stream order is a measure of the position of streams in the hierarchy of the tributaries, the first order stream which have no tributaries. Certain limitations were followed in vectorization of micro-watershed to maintain the physical area 5-10 Sq Kms. Supervised classification technique was used to generate the land use/land cover map. (**Fig-4) .** The study area is covered by 73J/13 & 73N/1 Survey of India topomaps on 1:50,000 scale and IRS LISS III & IV satellite imagery with 23.5 and 5 meter resolutions, which was acquired on 17th February 2003 and 21st January 2007 with path and row of 107/56 & 102/56 ware used as source data. IRS LISS-IV Data was geometrically corrected with reference to already geo-corrected IRS LISS-III Data keeping RMS Error within the range of sub-pixel and geo-referenced image generated using nearest neighborhood re-sampling method. The Lambert Conformal Conic projection was used with Everest datum for the geo-referencing. An AOI (Area of interest) layer of the study area was prepared and applied to IRS LISS-IV data for extraction of the study area. **Finally,** the study area was divided total 77 micro watersheds. The entire methodology which has been adopted in this study is explained in the flow chart (**Fig-2**).

Figure 2: *Flow Chart of Methodology*



2.1. Drainage & Watershed Delineation:

The drainage layers was digitized using Arc Info tools from FCC of LISS-IV data and then Updated using the Resourcesat(LISS-IV) data because of the high spatial resolution data with multispectral bands, and a substantial increase in the number of drainages compared to the LISS-III data. All drainage layers mainly 1st order streams will be validated to the SRTM DEM data. To generate the DEM layer which is better interpreted to drainage behavior and its patterns through visualization viewer **(Figure6)** and also validated the SOI reference maps of 1:50000 scale.

The stream ordering was given to each stream is Using Arc Info software by following Strahler (1952) Stream ordering technique. Stream order is a measure of the position of streams in the hierarchy of the tributaries, the first order stream which have no tributaries. Stream ordering technique is determination hierarchical position of a stream with in a drainage basin **(Table: 1)**.

Table 1: *Stream Ordering*

Stream Nos	Orders	Stream Nos	Orders
1+1	2	3+2	3
2+1	2	3+1	3
2+2	3	3+3	4

The drainage pattern formed the basis for divided into riverbanks, sub-watershed and micro-watershed. The texture of drainage pattern and its density not only define a geomorphic region but also indicate its cycle of erosion. The properties and pattern of a drainage basin are dependent upon a number of classes i.e. nature, distribution, features. The quantitative features of the drainage basin and its stream channel can be divided into linear aspect, aerial aspect and shape parameters.The study area was divided into 22 sub watershedshaving an area of 30 to 50 Sq kms and each sub watershed is further divided into micro-watershed having an area of 5 to 10 Sq kms or less the 5 Sqkms on the basis of drainage pattern and its texture.

Figure 3: *Drainage Network Map of Study Area*

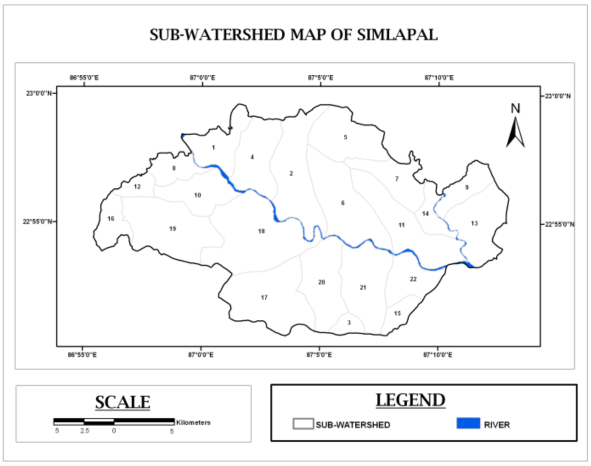


Figure 5: *Micro Watershed Map of Study Area*

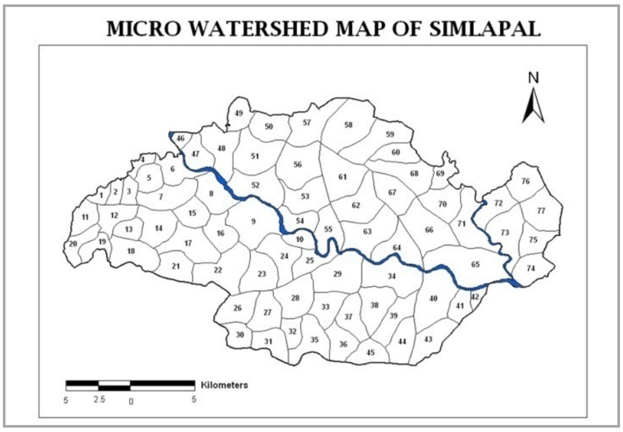


Figure 6: *Micro Watershed, Sub Watershed and Drainage map of Study Area*

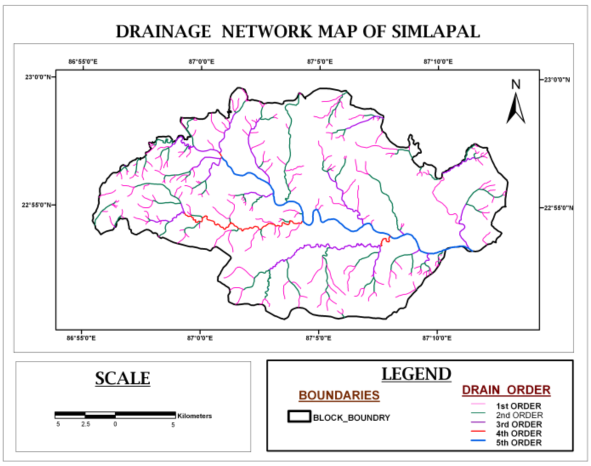
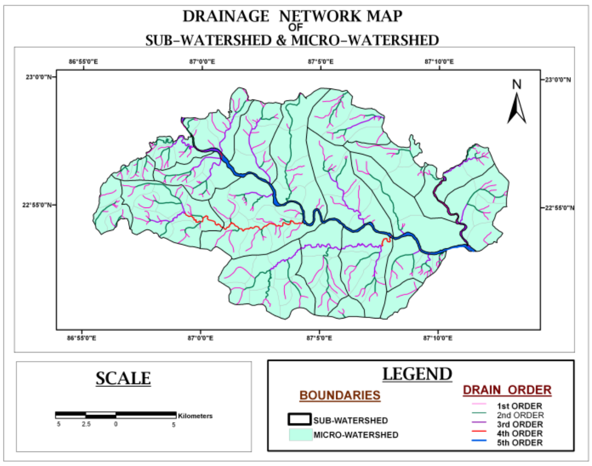


Figure 4: *Sub Watershed Map of Study Area*



Total study area was divided 22 sub-watersheds in three river banks, 77 micro- watersheds in out of 22 sub-watersheds. The drainage network, micro watershed and sub-watershed details are given in below **Figures 3,4,5,6**.

2.2.1. Runoff Estimation Method Using CN method:

The SCS curve number approach to runoff volume is typically thought of as a method for generating storm runoff for rare events and not for water quality design. As typically utilized with the assumption of average AMC's (Anti Moisture Condition) that will be appropriately analyzed to study the moisture condition of each micro-watershed. SCS (Soil Conservation Service) is to be used with GIS to estimate the runoff from each Micro-Watershed. The CN method is also known as hydrological soil cover complex method. It is widely used for runoff estimation of Micro-Watershed. SCS CN model carried on some parameters namely hydrological soil groups, daily rainfall data, land use/land cover features. Soil Conservation Service (USDA, 1985) Curve Number method is a well accept tool in hydrology, which uses a land condition factor called the Curve Number. This curve number is taken based some important properties of catchments namely soil type, land use, surface condition, and antecedent moisture conditions, and also some desirable curve number in suitable land use/land cover features of Indian conditions.

Soil Conservation Service Runoff Curve Number is a quantitative descriptor of the land use/land cover, soil complex characteristics of watershed and its computed direct runoff through an empirical relation that requires the rainfall and watershed co-efficient namely runoff curve number. The SCS Curve Number approach to runoff volume is typically thought of as a method for generating storm runoff for rare events and not for water quality design. The volume of runoff is expressed as:

$$\boldsymbol{VQ} = \frac{(\boldsymbol{P} - \boldsymbol{0.3S})^2}{(\boldsymbol{P} + \boldsymbol{0.7S})}$$

Where, **VQ** is volume of runoff and P is Accumulated rainfall and S is potential maximum relation of water by the soil.

2.2.2. Data Used & Methodology:

The SCS curve number approach to runoff volume is typically thought of as a method for generating storm runoff for rare events and not for water quality design. As typically utilized with the assumption of average AMC's (Anti Moisture Condition) that will be appropriately analyzed to study the moisture condition of each micro-watershed. SCS (Soil Conservation Service) is to be used with GIS to estimate the runoff from each Micro-Watershed. The CN method is also known as hydrological soil cover complex method. It is widely used for runoff estimation of Micro-Watershed.

Table 2: *Input data*

Data Type	Details	Source
SOI Ref Map	1:50,000	RRSC - East
Soil Map	1:5,00,000	NBSS LUP
SRTM DEM DATA	90 Mtr	SRTM SITE
SATELLITE DATA	Liss III & IV	RRSC – East
Rainfall Data	2007,2008,2009	Metrological Dpt

2.2.3. Land Use & Land Cover Classification:

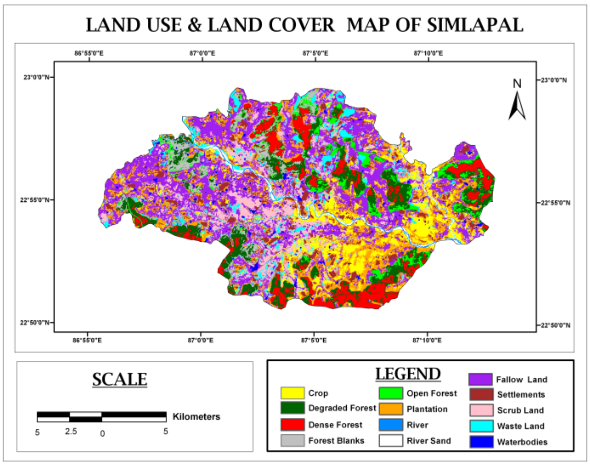
A NDVI (Normalized Difference Vegetation Index) indices was performed to derive the class in the forest area and water-bodies. As all the LISS – IV scenes were acquired in the different time interval hence, each was separately used for NDVI and then desired classes were sliced while clubbing other classes. Final NDVI map was overlaid on the classified image to represent the classes which were not considered during the supervised classification. A supervised classification technique was adopted with maximum likelihood algorithm. Due care was taken in generating the signature sets for the desired classes and where validated with the error of omission and error of commission. Wherever, overlapping of signatures was found, new sets of signatures were generated to improve the classification of LISS -IV image. Basic visual and digital interpretation parameters were followed like; tone, texture, shape, size, pattern, location and association for the recognition of objects and their tonal boundaries. Further refinement was carried out in the classified image with filtering and recoding of few classes. The final classified output image was assigned 13 classes (**Table – 3**).

Table 3: *Land Use/Land Cover Categories*

Code	LU/LC	CODE	LU/LC
1	Agriculture	8	Blank forest
2	Plantation	9	Degraded forest
3	Fallow	10	Dense forest
4	Scrub land	11	River
5	Wasteland	12	Sand Deposition
6	Water bodies	13	Settlement
7	Open forest		

Validation was performed with respect to SOI reference maps and other collateral data. Overall good accuracy of 90 – 95 % was achieved (**Figure - 7**).

Figure 7: *Land Use/Land Cover Classification Map of Study Area*



2.2.4. Defining Hydrological Soil Groups:

A soil and its moisture condition are very important in runoff estimation and universal soil loss model for prioritization of micro watershed and water resource management and land resource management. Soil properties influence the relationship between rainfall and runoff by affecting the rate of infiltration. NRCS divides soils into four hydrologic soil groups based on infiltration rates (Groups A,B.C and D). The hydrologic groups can be derived by soil texture and soil taxonomic conditions.

Group A: *Well drained*
Group B: *Moderate to well drain*
Group C: *Poor to Moderate drained*
Group D: *Poorly drained*

Group A: Group A soils have a low runoff potential due to high infiltration rates even when saturated (0.30 in/hr to 0.45 in/hr or 7.6 mm/hr to 11.4 mm/hr). These soils primarily consist of deep sands, deep loess, and aggregated silts.

Group B: Group B soils have a moderately low runoff potential due to moderate infiltration rates when saturated (0.15 in/hr to 0.30 in/hr or 3.8 mm/hr to 7.6 mm/hr). These soils primarily consist of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures (shallow loess, sandy loam).

Group C: Group C soils have a moderately high runoff potential due to slow infiltration rates (0.05 in/hr to 0.5 in/hr or 1.3 mm/hr to 3.8 mm/hr if saturated). These soils primarily consist of soils in which a layer near the surface impedes the downward movement of water or soils with moderately fine to fine texture such as clay loams, shallow sandy loams, soils low in organic content, and soils usually high in clay.

Group D: Group D soils have a high runoff potential due to very slow infiltration rates (less than 0.05 in./hr or 1.3 mm/hr if saturated). These soils primarily consist of clays with high swelling potential, soils with permanently high water tables, soils with a clay pan or clay layer at or near the surface, shallow soils over nearly impervious parent material such as soils that swell significantly when wet or heavy plastic clays or certain saline soils.

The soil map of the study area was digitally converted and geo-referenced with respect to study area. Different soil groups were derived in GIS environment and later they were merged in 3 classes (A, B and D) according to their taxonomy and hydrological parameters, land use classes. **Figure- 8 and 9.**

Figure 8: *Soil Map of Study Area*

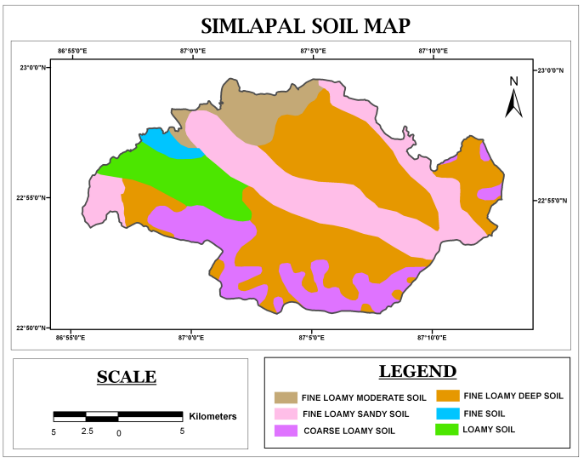
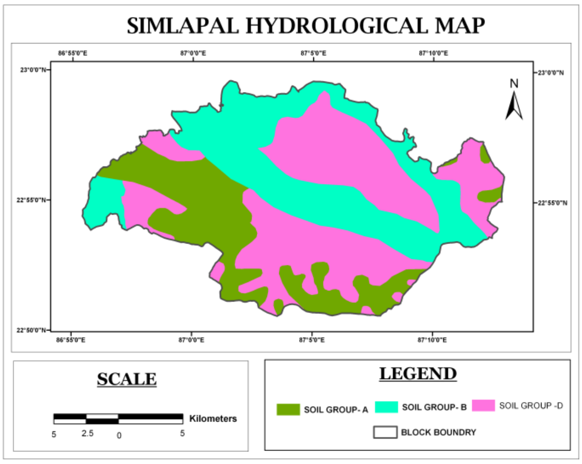


Figure 8: *Hydrological Map of Study Area*



2.2.5. Antecedent moisture condition:

Water content present in the soil at a given time. The AMC value is intended to reflect the effect of infiltration on both the volume and rate of runoff. AMC is an indicator of watershed wetness and availability of soil moisture storage during the rain. The soil conservation service developed three antecedent soil-moisture conditions and named as AMC-I, AMC-II, AMC-III. **Table 4** gives seasonal rainfall and dormant rainfall limits, soil conditions for these three antecedent soil moisture conditions. The AMC condition I curve number is dry condition in can be denoted to CN-I, AMC condition II curve number is normal condition in can be denoted to CN-II, AMC condition III curve number is dry condition in can be denoted to CN-III, AMC depends the submission of previous five days rainfall then apply the which storm date goes to condition I, II, III. The average curve number Antecedent moisture condition II approaches to: (USDA,1985)

$$\mathrm{CN(CN-II)} = \frac{\sum(\mathrm{Ai} * \mathrm{CNi})}{\sum \mathrm{Ai}} \quad (Equation - 1)$$

The CN values were documented for the case of AMC-II. The each micro-watershed computed curve number of Indian conditions suitable land use/land cover and analyzed curve number is derived **Table 5**.

Table 4: Antecedent Moisture Conditions for determining the value of CN

Antecedent Condition	Description	Growing Season	Dormant Season
AMC - I DRY	soils are dry but not to the wilting point, and when satisfactory plowing	Less than 1.4 in. or 35 mm	Less than 0.05 in. or 12 mm
AMC - II AVERAGE	The average case for annual floods	1.4 in. to 2 in. or 35 to 53 mm	0.5 to 1 in. or 12 to 28 mm
AMC - III WET	When a heavy rainfall, or light rainfall and low temperatures	Over 2 in. or 53mm	Over 1 in. or 28 mm

The Antecedent moisture condition I &III , adjust the CN-II from the following equation 2 & 3 , expressed as:

$$\mathrm{CN-I} = \frac{(4.2 * \mathrm{CN-II})}{10 - 0.058 * \mathrm{CN-II}} \quad (Equation - 2)$$

$$\mathrm{CN-III} = \frac{(23 * \mathrm{CN-II})}{10 + 0.13 * \mathrm{CN-II}} \quad (Equation - 3)$$

2.2.6. Estimation of S:

The parameter S depends upon characteristics of the Soil-Vegetation-Land(SVL) complex and antecedent soil moisture condition in a watershed. S is related to the curve number. The Soil Conservation Service expressed S as:

$$\mathrm{S} = \frac{25400}{\mathrm{CN}} - 254 \quad (Equation - 4)$$

The equation 4 is valid only for $\mathbf{P \geq 0.2S}$ otherwise volume of runoff $\mathbf{VQ = 0}$ where **P** is rainfall and **S** is watershed storage. If **P** is greater than **0.2S** than calculate the volume of runoff of each micro-watershed otherwise the volume of runoff is always zero.

2.2.7. Runoff Estimation:

Using the hydrological soil groups A,B and D ,land use classes to create the curve number. Based on the land use classes and hydrological groups and CN are using in above equation-1, the composite and average curve number was found. This composite CN is the value of AMC-II, Using this CN is above equation 2 & 3 then determine the CN from AMC-II and AMC-III. The values of curve number for the all three antecedent moisture condition are listed in **Table-5.**

Table 5: *Hydrological Soil Group Curve Numbers*

LU/LC Classes	Curve Number(CN)		
	HSG - A	HSG -B	HSG - D
Agriculture	55	69	83
Plantation	39	61	83
Fallow	59	70	81
Scrub land	77	86	94
Wasteland	45	66	83
Water bodies	94	94	94
Open Forest	19	40	63
Forests Blank	64	71	85
Degraded Forest	15	30	48
Dense Forest	36	58	80
River	94	94	94
Sand Deposition	96	96	96
Settlement’s	59	74	86

To calculate the runoff estimation of each micro-watershed by applying the hydrological equation.

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

The equation depends on the one variable P and one parameter S. where P is the value of rainfall and S is the Watershed storage.

3. Results & Discussion:

The result of runoff estimation in three years is given below:

Based on 2007 rainfall the calculation of VQ values are arranged in order of priority into five categories as, thus 4 micro-watershed out of 77, were given very high priority (≥514), 5 MWS were given high priority (≥406<514), 14 MWS fall under medium priority (≥297<406), 31 MWS fall under low category (≥189<297) and remaining 23 MWS falling very low priorities (≤189).

Based on 2008 rainfall the calculation of VQ values are arranged in order of priority into five categories as, thus 2 micro-watershed out of 77, were given very high priority (≥235), 5 MWS were given high priority (≥177<235), 11 MWS fall under medium priority (≥119<177), 32 MWS fall under low category (≥61<119) and remaining 27 MWS falling very low priorities (≤61).

Based on 2009 rainfall the calculation of VQ values are arranged in order of priority into five categories as, thus 4 micro-watershed out of 77, were given very high priority (≥347), 4 MWS were given high priority (≥268<347), 15 MWS fall under medium priority (≥189<268), 34 MWS fall under low category (≥110<189) and remaining 20 MWS falling very low priorities (≤110). **(Table 6, Table 7)**

Figure 9: *Runoff Map Year - I*

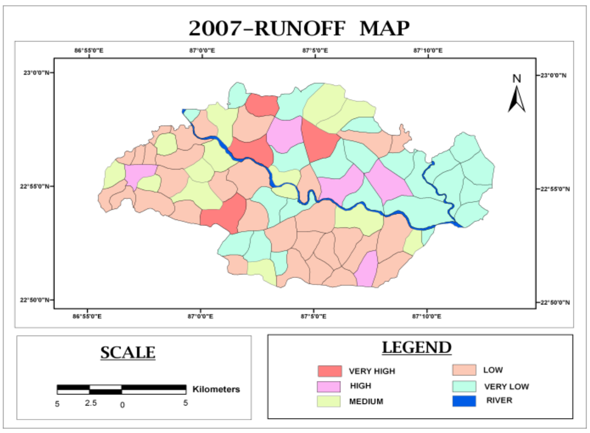


Figure 10: *Runoff Map Year - II*

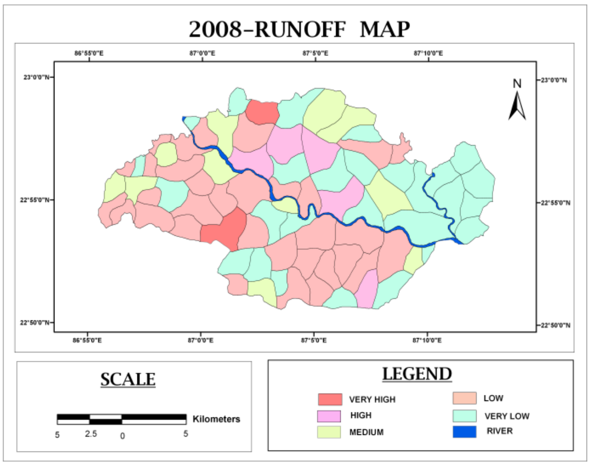


Figure 10: *Runoff Map Year - III*

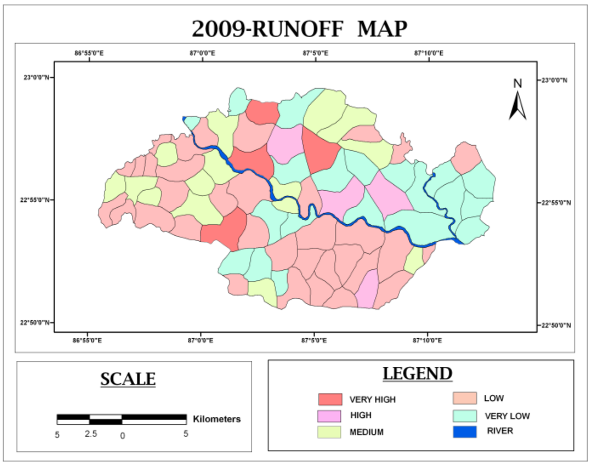
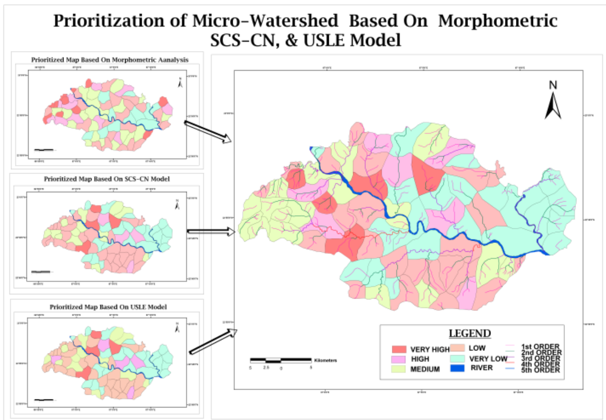


Figure 11: *Runoff Estimation of Three Different Years*



3. Acknowledgements:

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Table 7: *PRIORITIZATION OF MICRO-WATERSHED BASEDON THREE YEARS SEASONAL RUNOFF*

PRIORITY	Runoff 2007	Runoff 2008	Runoff 2009	Based on 3 years Runoff
Very High	22,50, 52,61	22,50	22,50,52,61	22,50,52,61
High	12,44,56, 63,66,	44,52,56,61,63	44,56,63,66	44,56,63,66
Medium	5,8,10,11,13,15,17,31,34,41,48,54,58,59	5,8,10,11,12,31,41,48,58,59,66,	5,8,10,11,12,13,15,17,31,41,48,54,58,59,68	5,8,10,11,12,13,15,17,31,41,48,54,58,59
Low	1,2,3,4,6,7,9,14,16,18,19,20,21,23,28,29,30,33,35,36,37,38,39,40,43,45,47,51,55,68,69	1,3,4,6,7,9,13,15,16,17,18,19,20,21,23,28,29,30,33,34,35,36,37,38,39,40,47,51,54,55,68,69,	1,2,3,4,6,7,9,14,16,18,19,20,21,23,28,29,30,33,34,35,36,37,38,39,40,42,43,45,47,51,55,60,69,76	1,2,3,4,6,7,9,14,16,18,19,20,21,23,28,29,30,33,34,35,36,37,38,39,40,43,45,47,51,55,68,69
Very Low	24,25,26,27,32,42,46,49,53,57,60,62,64,65,67,70,71,72,73,74,75,76,77,	2,14,24,25,26,27,32,42,43,45,46,49,53,57,60,62,64,65,67,70,71,72,73,74,75,76,77,	24,25,26,27,32,46,49,53,57,62,64,65,67,70,71,72,73,74,75,77	24,25,26,27,32,42,46,49,53,57,60,62,64,65,67,70,71,72,73,74,75,76,77

__Table 6:__ Runoff Estimation Values of Three Different Years

MWS	RUNOFF			MWS	RUNOFF		
	2007	2008	2009		2007	2008	2009
1	228.757424	70.0617351	145.24477	40	279.0162203	95.1699041	178.178248
2	210.2459787	55.2475589	135.764267	41	327.155152	119.732192	210.862499
3	273.3205871	92.4415226	174.220235	42	188.3732761	43.0773604	114.412552
4	222.7434212	64.0794906	142.693129	43	212.8372664	59.0178937	134.966588
5	347.8776517	130.275032	226.377677	44	506.2833144	212.574283	341.555399
6	264.9143039	88.3170547	168.513001	45	216.0619332	60.5870091	138.98248
7	235.8733898	72.7836603	151.076139	46	177.3920299	37.4629692	107.452861
8	384.3537398	152.216365	265.76938	47	273.6550681	92.6574999	174.567256
9	278.298629	94.9764803	177.795828	48	374.8914779	146.824015	248.721454
10	333.5444325	122.932666	215.569475	49	147.7725767	19.787855	89.0484738
11	382.7505801	152.321063	254.408317	50	604.9712134	271.759929	415.179315
12	407.2743935	165.66224	267.958144	51	244.1428796	76.8099649	155.967642
13	303.7561713	108.453383	193.93405	52	520.0878907	219.117351	352.155194
14	213.3224642	59.1843442	137.32804	53	141.5939302	15.5200531	79.3179161
15	299.3913298	105.804336	190.163081	54	298.628728	105.986222	190.142026
16	270.1509136	90.5478331	171.788382	55	218.5051047	62.0348807	140.783937
17	310.4196396	111.190213	198.45736	56	507.5979766	212.687854	341.730571
18	221.7407331	63.8925361	142.667183	57	82.76016492	3.05763508	32.99071
19	279.0162203	95.1699041	178.178248	58	328.2011429	120.033363	211.534737
20	248.402498	79.0497089	158.748431	59	344.1666522	124.985136	220.826618
21	221.7407331	63.8925361	142.667183	60	182.695658	40.620205	111.495079
22	623.2349943	291.733595	426.947102	61	537.3427592	229.3912	364.67714
23	236.1266146	72.7836603	151.043746	62	162.3414342	25.9041129	94.3505519
24	169.9819488	31.5000073	101.853055	63	492.8043069	206.160379	329.326047
25	167.5045565	29.7905498	99.823793	64	123.66127	11.0154947	71.7880279
26	161.6011339	28.0828584	97.0679217	65	180.7204559	39.3782336	110.140033
27	164.30685	29.6717596	99.9338538	66	424.8793026	173.735275	281.750297
28	247.8138896	78.8495291	158.554069	67	161.5561851	25.1296873	93.6577766
29	218.6625328	62.2113952	140.827008	68	296.8228837	105.839613	189.697389
30	240.5876829	74.8435331	153.483361	69	286.6045075	97.6110541	182.669399
31	333.0039211	122.988464	215.5326	70	141.7398479	15.45459	79.4028318
32	146.0704158	18.6569953	84.5515732	71	110.236288	7.71947342	56.34189
33	269.1956296	90.4387674	171.474467	72	161.4669894	25.2302447	93.5109024
34	297.9698589	105.894746	189.330015	73	99.29437395	8.43993397	41.2522588
35	239.791333	74.6692121	153.373976	74	151.7637125	20.2649444	86.6917024
36	265.5082239	88.2128948	168.486145	75	113.5818301	8.37479452	59.2572848
37	286.6045075	97.6110541	182.669399	76	188.2053266	42.9110866	114.421811
38	256.8133636	86.116129	164.25142	77	80.76101618	3.2817456	31.4027219
39	256.4882305	85.9491166	163.988705				