Water Resource Management Of Simlapal Micro-Watershed Using Rs- Gis Based Universal Soil Loss Equation, Bankura District, W.B, India.

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Abstract: Water is one of the essential natural resource for the very survival of life on the planet Earth. Demand for water is increasing day by day, with the ever increasing population, resulted severe water crisis. We need water for agriculture, industry, human and cattle consumption. The available water is also affected by problem of pollution and contamination. Therefore it is very important to manage this very essential resource in a sustainable manner. Hence, we need proper management and development plan to conserve, restore or recharge water, where soil loss is very high due to various topographical conditions. The USLE (Universal Soil Loss Equation) method is one of the significant RS-GIS tools for prioritization of micro watersheds. A watershed is an ideal unit for study and to implement any model of water management towards achieving sustainable development. The significant factors for the planning and development of a watershed are its physiography, drainage, geomorphology, soil, land use/land cover and available water resources. In the current study, the micro-watershed priority fixation has been adopted under USLE model using Remote Sensing data. SRTM DEM, rainfall data and soil maps have been used to derive various thematic layers. The study area (Simlapal, W.B.) was subjected to USLE model of classifying and prioritizing the micro watersheds. The study area is divided into 22 sub-watersheds with areas ranging from 25 to 30 sq. km from the drainage map. Again each sub-watershed is divided into micro-watersheds with areas ranging from 5to10 sq. km. Thus 77 micro-watersheds were delineated for the present study area, considering all the controlling factors. Based on the results the 77 micro- watersheds could be prioritized in to five ranges viz very high, high, medium, low and very low.

Key Words: USLE, Watershed, Remote Sensing and GIS

1 Introduction

Remote Sensing and GIS tools are utilized for the water resource 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 present study aims at the proper management of water resource and controlling the surface soil loss. Water resource management by prioritization of micro watershed based on USLE analysis using Remote sensing data and GIS overlaying techniques. This study is helpful for increasing the agricultural based livelihood, irrigation facilities and to find the solution of uncontrolled soil loss. A watershed is an ideal unit for management of water for land and water resources for mitigation of the impact of natural disasters for achieving sustainable development.

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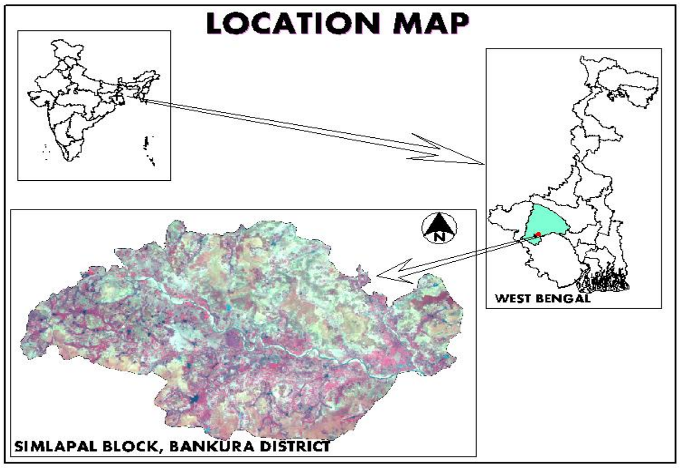
The significant factor for the planning and development of a watershed are its physiography, drainage, geomorphology, soil, land use/land cover and available water resources. Remote Sensing and GIS are the most proven tools for watershed development, management and also the studies on prioritization of micro-watersheds development and management. Soil loss is the most important factor for water resource management like irrigation and agricultural land erosion. The universal soil loss equation (USLE) has been the most widely accepted and utilized equation for analyzing soil loss caused by erosion from agricultural lands. The universal soil loss equation can be used to estimate the average rate of soil erosion for each feasible alternative combination and crop system and management practice in associated with a specified soil type, rainfall pattern and topography (Chandramohan T et al, 2002). The USLE equation is used in the present study to find out micro-watershed priority in the study area. This equation based on five factors R, K, LS, C and P. The soil loss is estimated from each micro-watershed by multiplying the maps of (R, K, LS, C and P factors) runoff map, soil erodibility map, slope map and agricultural map. These five numerical factors help to calculate the long time soil losses from micro-watersheds stream bank erosion and stream bed erosion.

2 Study Area

The study area geographically extended from 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 57mtr (187 feet's). This block is covered by 73J/13 and 73N/1 Survey of India reference maps on 1:50,000 scale. Bankura district lies on the western part of West Bengal having 7.75% of state's geographical area and 3.98% of states demographic profile. This block consists of rural areas with seven gram punchayats (Bikrampur, Dubrajpur, Parsola , Lakshmisagar, Machatora, Mondalgram, and Simlapal) covered 203 villages, two police stations and three headquarters. Area of this block is 309.20 sqkms (119sqmile or 1144.04 hectares).

Figure 1: Location Map of Study Area



3 METHODOLOGY

The major portion of land is covered by the forest area and undulating terrain and due to this reason the soil type varies from fine loamy with sandy. The total area is covered with six types of soils (fine loamy, coarse loamy, fine loamy sandy, gravelly loamy, fine and loamy soils). The soil conditions depict the agricultural productivity and irrigable lands. The soil factor is considered to be the most effective factor for water and land resource managements. Due to this reason we are applying the USLE factor to manage the water resources. 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 vectorization 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. (Fig-3). Certain limitations were followed in vectorization of micro-watershed to maintain the physical area 5-10 Sqkms. Supervised classification technique was used to generate the land use/land cover map (Fig-4). The study area is expand by 73J/13 and 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. That the study area was divided total 77 micro watersheds. The entire methodology which has been adopted in this study is given in the flow chart (Fig-2).

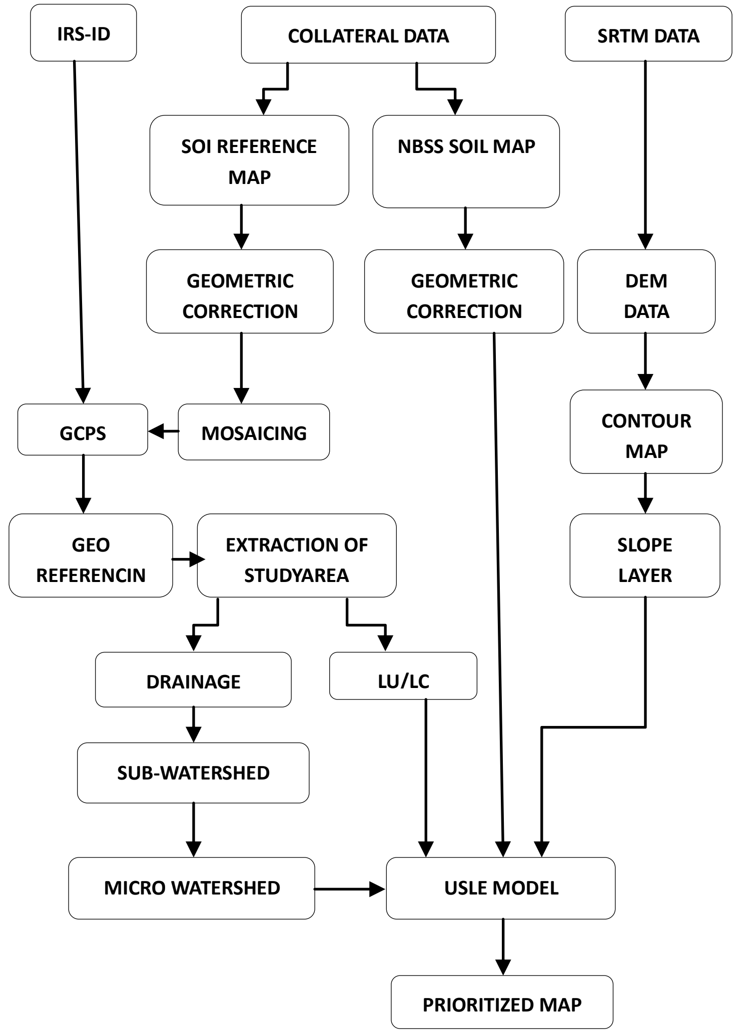


Figure 2: Flow Chart of Methodology

3.1 Drainage & Watershed Delineation:

The drainage layers have 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 on substantial increase in the number of drainages observed to the LISS-III data. All drainage layers mainly 1st order streams are validated to the SRTM DEM data. To generate the DEM layer which is better interpreted to drainage behavior and its patterns through visualization viewer **(Fig 6)** and also validated the SOI reference maps of 1:50000 scale. The stream order was given to each stream using Arc Info software by following Strahler (1952) stream ordering technique. Stream ordering technique is determination hierarchical position of a stream with in a drainage basin **(Table: 1)**.

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

Table 1: Stream Ordering

The drainage pattern formed the basis for division 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 watersheds having an area of 30 to 50 sq. km and each sub watershed is further divided into micro-watershed having an area of 5 to 10 sq. km or less the 5 sq. km on the basis of drainage pattern and its texture.

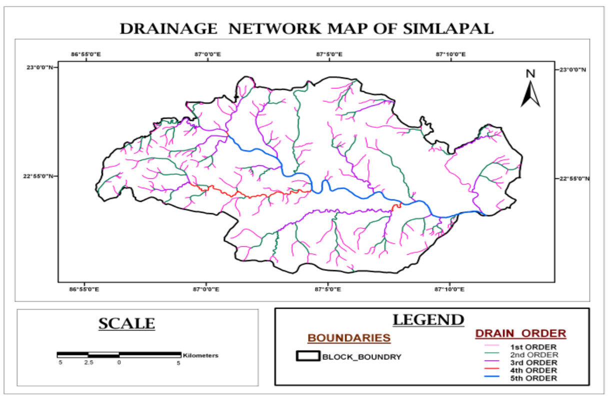


Figure 3: Drainage Network Map of Study Area

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.

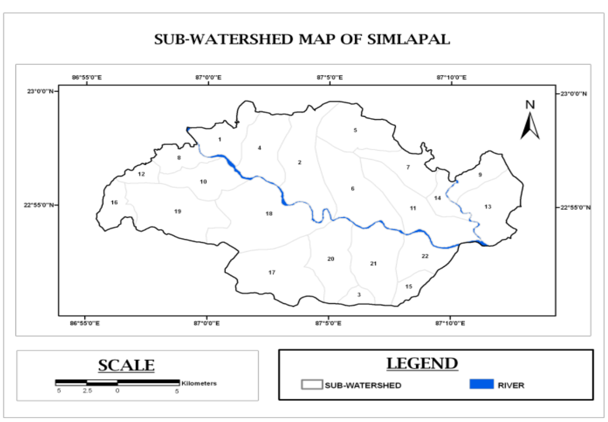


Figure 4: Sub Watershed Map of Study Area

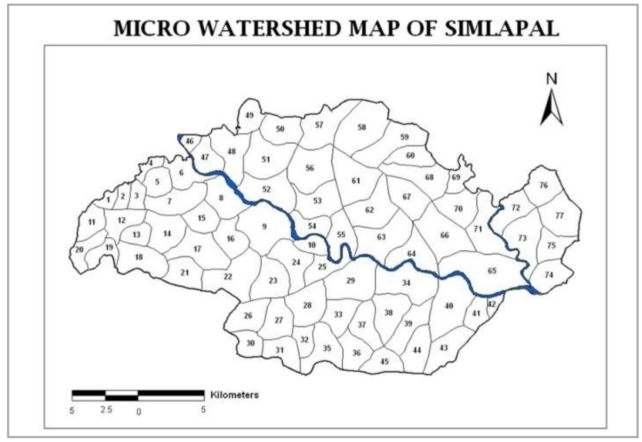


Figure 5: Micro Watershed Map of Study Area

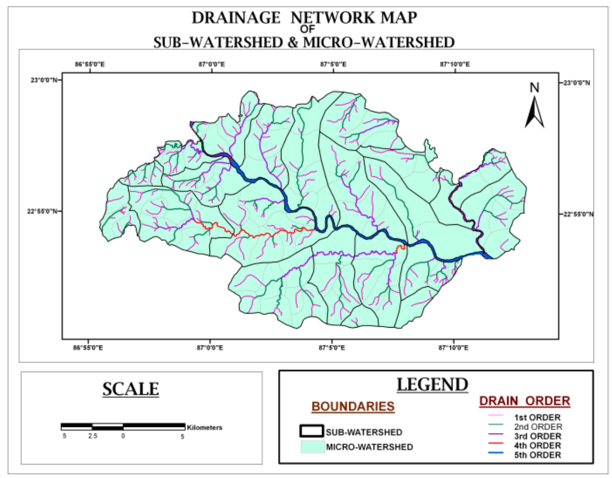


Figure 6: Micro Watershed, Sub Watershed and Drainage map of Study Are

3.2 Land Use and Land Cover Planning:

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

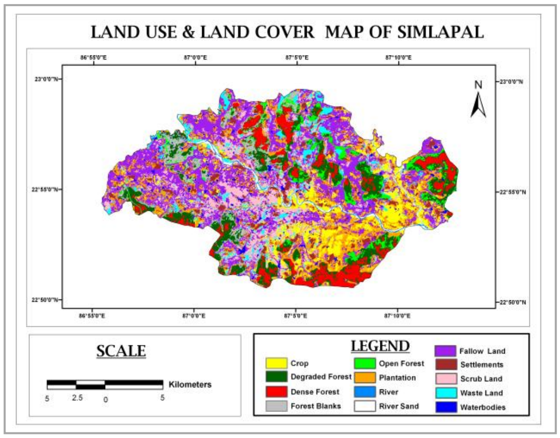


Figure 7: Land use land cover classification Map

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

Table 2: Land use Land cover classification scheme

3.3 SOILS:
The major portion of land is covered with the forest and undulating terrain and due to this reason the soil type varies from fine loamy to sandy. The total area is covered with six types of soils (fine loamy, coarse loamy, fine loamy sandy, gravelly loamy, fine and loamy soils).

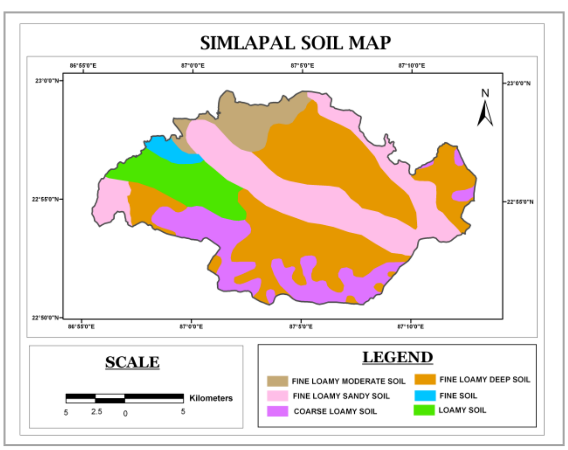


Figure 8: Soil Map

3.4 SLOPE:
Slope is one of the important parameter for water resource and watershed management. This is the main factor for calculation of universal soil loss equation. Slope can be classified into a few categories. Using guidelines of All India Soil and Land Use Survey the slope categories are nearly level to very steep sloping based on the steepness.

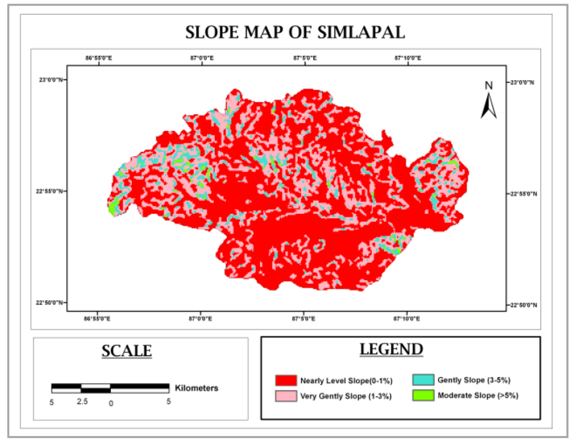


Figure 9: Slope Map

The slope categories are nearly level is 0-1%, very gently sloping is 1-3%, gently sloping is 3-5%, moderate sloping is 5-10%, strongly sloping is 10-15%, moderate steep to steep sloping is 10-15% and steep sloping is greater than 35%. The steeper slopes can be further sub divided as per local need especially in hilly areas. The slope map prepared using SRTM DEM data (90 meters resolution, path and row is 54/08). Extraction of the study area from DEM image has been done by using Arc GIS software generating the contour map and demand slope by taking grid format.

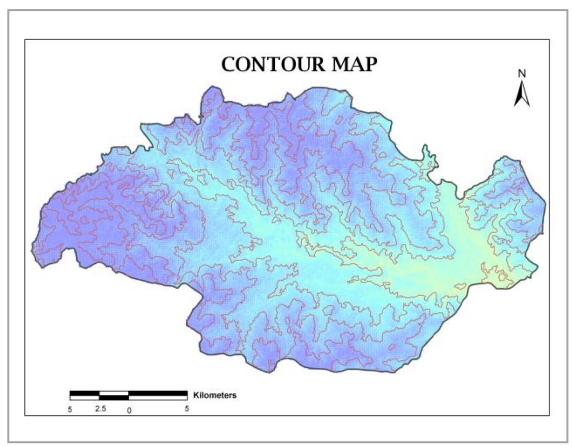


Figure 10: Contour Map

3.5 UNIVERSAL SOIL LOSS EQUATION MODEL:
The universal soil loss equation can be used to estimate the average rate of soil erosion for each feasible alternative combination of crop system and management practices in association with a specified soil type, rainfall pattern, and topography (smith, 1965). The average annual soil loss is tons/ hectare (A) is calculated using.

$$A=R*K*LS*C*P \quad ---------- \quad (1)$$

Where, A is the average annual soil loss in tons./ha, R is a rainfall factor, K is a Soil erodibility factor, LS is a slope length and steepness factor, C is a cropping factor and P is a conservation practice factor. Computation of these factors can be done easily and efficiently using geographic information system with various data layers representing watershed boundary, slope, rainfall distribution, land use and management practices and soils.

3.5.1 R- FACTOR:
R factor is expressed as rainfall and runoff factor. The R-factor was calculated using the average annual and seasonal rainfall of four rain gauge stations. The following equation was used to estimate the annual and seasonal R factor (Chandramohan .T et.al, 2002).

RAINFALL

Annual - Ra = 79+0.363*P ---------- (2)

Seasonal- Ra = 50+0.389*p ---------- (3)

Where, p is rainfall in mm.

OR

RUNOFF

VQ= (P-0.3S) ²/ (P+0.7S) ---------- (4)

3.5.2 K- FACTOR:
K is soil erodibility factor, Soil erodibility namo graph was used for determining **K**-factor based on Particles size. For example: attribute table was prepared using these values of different soil types:

Soil type	**Soil texture**	**Organic matter (%)**	**Soil structure**	**Rate of permeability**	**K-Factor**
	% Sand (0.1-2m)	% silt+ Very Fine			
Clay loamy	27	51	1.5	Coarse	Moderate
Sandy Loamy	35	54	1.5	Granular	Moderate to Rapid
Clay	15	47	2.5	Very Fine	Very slow

Table 3: K-Factor

The soil erodibility map was prepared using the soil map and K factor Table. (soil and water conservation engineering, (Suresh, 1997)

3.5.3 LS- FACTOR:
It is the length and steepness of slope factor. Formula is given by Dilip Kumar.

LS= 0.4*S+40 ---------- (5)

Where, L is slope length, S=slope gradient.

If slope steepness up to 21% the USLE formal for estimating the slope length and slope steepness was used

SL= (L/72.6)*(65.4*sin(S)+4.56*Sin(S)+0.065) ---------- (6)

Where, L is the slope length factor, S is steepness in %. Calculate "L" based on S: The slope map was generated in SRTM-Dem by applying the steepness (%), and again it generate the Dem to contour map. Then calculate the slope length. It can be expressed as

L = no of contours length/contour distance ---------- (7)

The value of topographic factor (LS) can also be calculated by using the following formula, given by smith and Wischmer (1962).

LS=√L/10(0.76*0.53s+0.076s² ---------- (8)

3.5.4 C- FACTOR:
The **C** is the cropping management factor. Is the ratio of soil loss from a field with specified cropping. In the simple meaning **C** factor can be derived crop/vegetation and management factor. It is used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil loss. The **C** factor is a ratio comparing the soil loss from land under a specific crop and management system to the corresponding loss from continuously fallow and tilled land. The suitable crop and soil factors are given agricultural handbook. **C** factor, however, provides relative numbers for the different cropping and tillage systems; thereby helping you weigh the merits of each system. (Table-4)

Crop Type	**Factor**
Grain Corn	0.40
Silage Corn, Beans & Canola	0.50
Cereals (Spring & Winter)	0.35
Seasonal Horticultural Crops	0.50
Fruit Trees	0.10
Hay and Pasture	0.02

Table 4: C-Factor

3.5.5 P- FACTOR:
The **P** factor is expressed as the management practice factor. It reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. The **P** factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. The most commonly used supporting cropland practices are cross slope cultivation, contour farming and strip-cropping so that's why **P** factor value will be assumed always "1". The 1 is the constant value of **P** factor from all conditions.

Support Practice	**P Factor**
Up & Down Slope	1.0
Cross Slope	0.75
Contour farming	0.50
Strip cropping, cross slope	0.37
Strip cropping, contour	0.25

Table 5: P-Factor

4 RESULTS & DISCUSSIONS:

The micro-watershed areas were computed using slope, soil erodibility, runoff, crop obtained by overlaying the thematic inputs. These all factors were used in estimating the average annual soil loss for each micro-watershed. Incorporation of USLE values of a micro-watershed would determine quantitative priority value of that micro-watershed. The micro-watershed would arrange in the descending order of the USLE "**A**" values and graded in order of priority into five categories, as Very High (≥17.57), High (≥13.50 <17.57), Medium (≥9.40 <13.50), Low (≥5.35 <9.40), Very Low (≤5.35).

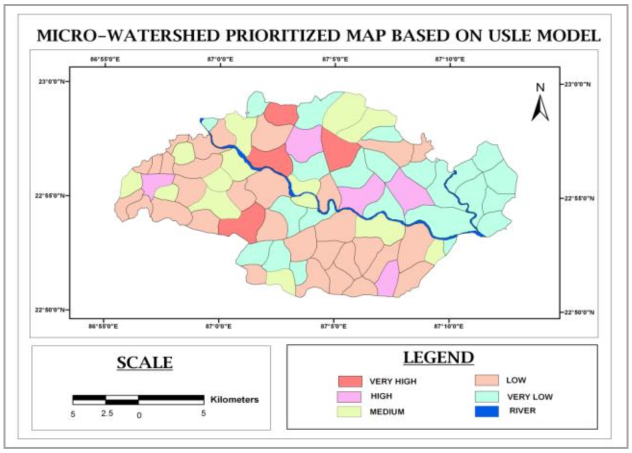


Figure 11: Final Priority Map for Water Resource Management

Thus, seven micro-watershed out of 77, were given very high priority, as they have very high **"A"** soil loss values, nine micro-watersheds were given high priority, with high A values, twelve micro-watershed fall under medium priority having moderate soil loss, twenty one micro-watershed fall under low with low soil loss and the remaining twenty eight micro-watershed were given very low "**A"** values**.** The priority obtained from USLE values were shown in **(Table: 6&7),** and micro-watershed prioritized map using USLE model were shown in **Figure: 11.**

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MWS	RFACTOR(MM)	RFACTOR(M)	SLOPE LENGTH	LS	KFACTOR	CFACTOR	PFACTOR	A
MWS1	145.245	0.145	30	52	0.11	0.4	0.5	8.640
MWS2	135.764	0.136	50	60	0.11	0.4	0.5	10.753
MWS3	174.220	0.174	30	52	0.11	0.4	0.5	10.364
MWS4	142.693	0.143	20	48	0.11	0.4	0.5	7.233
MWS5	226.378	0.226	60	64	0.11	0.4	0.5	20.399
MWS6	168.513	0.169	50	60	0.11	0.4	0.5	13.346
MWS7	151.076	0.151	90	76	0.11	0.4	0.5	19.198
MWS8	265.769	0.266	10	44	0.11	0.4	0.5	11.320
MWS9	177.796	0.178	20	48	0.11	0.4	0.5	9.012
MWS10	215.569	0.216	0	40	0.11	0.4	0.5	7.588
MWS11	254.408	0.254	10	44	0.11	0.4	0.5	10.836
MWS12	267.958	0.268	30	52	0.11	0.4	0.5	15.940
MWS13	193.934	0.194	30	52	0.11	0.4	0.5	11.537
MWS14	137.328	0.137	50	60	0.11	0.4	0.5	10.876
MWS15	190.163	0.190	70	68	0.11	0.4	0.5	19.345
MWS16	171.788	0.172	20	48	0.11	0.4	0.5	8.708
MWS17	198.457	0.198	40	56	0.11	0.4	0.5	13.692
MWS18	142.667	0.143	50	60	0.11	0.4	0.5	11.299
MWS19	178.178	0.178	30	52	0.11	0.4	0.5	10.599
MWS20	158.748	0.159	50	60	0.11	0.4	0.5	12.573
MWS21	142.667	0.143	10	44	0.11	0.4	0.5	6.076
MWS22	426.947	0.427	20	48	0.11	0.4	0.5	21.641
MWS23	151.044	0.151	30	52	0.11	0.4	0.5	8.985
MWS24	101.853	0.102	0	40	0.04	0.4	0.5	1.304
MWS25	99.824	0.100	0	40	0.04	0.4	0.5	1.278
MWS26	97.068	0.097	10	44	0.04	0.4	0.5	1.503
MWS27	99.934	0.100	30	52	0.04	0.4	0.5	2.162
MWS28	158.554	0.159	10	44	0.11	0.4	0.5	6.753
MWS29	140.827	0.141	0	40	0.11	0.4	0.5	4.957
MWS30	153.483	0.153	20	48	0.11	0.4	0.5	7.780
MWS31	215.533	0.216	20	48	0.11	0.4	0.5	10.925
MWS32	84.552	0.085	20	48	0.11	0.4	0.5	4.286
MWS33	171.474	0.171	10	44	0.11	0.4	0.5	7.303
MWS34	189.330	0.189	20	48	0.04	0.4	0.5	3.490

MWS35	153.374	0.153	20	48	0.11	0.4	0.5	7.774
MWS36	168.486	0.168	30	52	0.11	0.4	0.5	10.023
MWS37	182.669	0.183	20	48	0.11	0.4	0.5	9.259
MWS38	164.251	0.164	10	44	0.11	0.4	0.5	6.996
MWS39	163.989	0.164	10	44	0.04	0.4	0.5	2.540
MWS40	178.178	0.178	50	60	0.11	0.4	0.5	14.112
MWS41	210.862	0.211	20	48	0.04	0.4	0.5	3.887
MWS42	114.413	0.114	20	48	0.11	0.4	0.5	5.799
MWS43	134.967	0.135	10	44	0.11	0.4	0.5	5.748
MWS44	341.555	0.342	20	48	0.11	0.4	0.5	17.313
MWS45	138.982	0.139	20	48	0.04	0.4	0.5	2.562
MWS46	107.453	0.107	10	44	0.07	0.4	0.5	2.912
MWS47	174.567	0.175	10	44	0.07	0.4	0.5	4.731
MWS48	248.721	0.249	40	56	0.11	0.4	0.5	17.160
MWS49	89.048	0.089	50	60	0.11	0.4	0.5	7.053
MWS50	415.179	0.415	70	68	0.04	0.4	0.5	15.358
MWS51	155.968	0.156	30	52	0.07	0.4	0.5	5.904
MWS52	352.155	0.352	30	52	0.11	0.4	0.5	20.949
MWS53	79.318	0.079	30	52	0.04	0.4	0.5	1.716
MWS54	190.142	0.190	0	40	0.11	0.4	0.5	6.693
MWS55	140.784	0.141	20	48	0.04	0.4	0.5	2.595
MWS56	341.731	0.342	20	48	0.11	0.4	0.5	17.322
MWS57	32.991	0.033	50	60	0.11	0.4	0.5	2.613
MWS58	211.535	0.212	60	64	0.11	0.4	0.5	19.062
MWS59	220.827	0.221	50	60	0.11	0.4	0.5	17.489
MWS60	111.495	0.111	10	44	0.11	0.4	0.5	4.749
MWS61	364.677	0.365	50	60	0.07	0.4	0.5	18.380
MWS62	94.351	0.094	20	48	0.11	0.4	0.5	4.782
MWS63	329.326	0.329	20	48	0.11	0.4	0.5	16.693
MWS64	71.788	0.072	30	52	0.11	0.4	0.5	4.271
MWS65	110.140	0.110	30	52	0.07	0.4	0.5	4.169
MWS66	281.750	0.282	10	44	0.07	0.4	0.5	7.637
MWS67	93.658	0.094	20	48	0.07	0.4	0.5	3.021
MWS68	189.697	0.190	10	44	0.07	0.4	0.5	5.142
MWS69	182.669	0.183	30	52	0.07	0.4	0.5	6.915
MWS70	79.403	0.079	30	52	0.07	0.4	0.5	3.006
MWS71	56.342	0.056	20	48	0.07	0.4	0.5	1.817
MWS72	93.511	0.094	10	44	0.07	0.4	0.5	2.535
MWS73	41.252	0.041	20	48	0.07	0.4	0.5	1.331
MWS74	86.692	0.087	10	44	0.07	0.4	0.5	2.350

MWS75	59.257	0.059	30	52	0.07	0.4	0.5	2.243
MWS76	114.422	0.114	80	72	0.07	0.4	0.5	8.304
MWS77	31.403	0.031	60	64	0.07	0.4	0.5	1.801

Table 6: Estimating of Soil Loss

PRIORITY Fixation	PRIORITY VALUES	Micro-Watershed No
Very High (≥17.57)	1	5,7,15,22,52,58,61
High (≥13.50 <17.57)	2	12,17,40,44,48,50,56,59,63
Medium(≥9.40 <13.50)	3	2,3,6,8,11,13,14,18,19,20,31,36
Low (≥5.35 <9.40)	4	1,4,9,10,16,21,23,28,30,33,35,37,38,42,43,49,51,54,66, 69,76
Very Low(≤5.35)	5	24,25,26,27,29,32,34,39,41,45,46,47,53,55,57,60,62,64, 65,67,68,70,71,72,73,74,75,77

Table 7: Micro-Watershed Based on USLE Model