IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 4, Issue 3 Ver. I (May. - Jun. 2016), PP 36-49
www.iosrjournals.org

Watershed Prioritization Based On Geo-Morphometry And Land Use Parameters – An Approach To Watershed Development Using Remote Sensing And GIS, Neora Watershed, Darjeeling And Jalpaiguri Districts, West Bengal, India

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Abstract: *Watershed prioritization has gained immense importance in natural resource management, especially in the context of watershed restoration and integrated watershed development. Here, morphometric parameters and land use-land cover analysis has been considered as basic elements and applied to prioritization of sub-watersheds. The quantitative analysis of morphometric parameters and land use-land cover is found to be of immense utility in watershed prioritization for water balance, runoff coefficient facts, runoff concentration, soil and water conservation and natural resources management at micro level. The present work is an attempt to carry out a detailed study of linear, relief and shape aspects of morphometric parameters and present land use-land cover analysis in thirteen sub-watersheds of Neora River and their prioritization for overall and holistic management. Neora watershed is registered between 26°40'N to 27°10'N latitudes and 88°40'E to 88°50'E longitudes and covers an area of approximately 295 sq.km. The prioritization was carried out by assigning ranks to the individual indicators and a compound value (Cp) was calculated. Watersheds with highest Cp were of low priority while those with lowest Cp were of high priority. The results obtained from morphometric parameters and land use/ land cover analysis were correlated to find out the common sub-watershed priority falling under each priority. High priority indicates that those watersheds are susceptible to greater degree of erosion and application of soil conservation measures and need to manage immediately.*

Keywords: *Sub-Watershed, Morphometric Analysis, Land Use/ land Cover, Prioritization.*

I. Introduction

Integrated watershed development of any region is an effective procedural measure for the conservation and development of natural as well as cultural resources. Watershed is a significant and independent *'Geographical Unit'* for the study of holistic development as well. Morphometric parameters of a watershed provide a quantitative description of the drainage system which is an important aspect of the characterization of watershed. The influence of drainage morphometry is very significant role to understand the landform process, soil physical properties and erosional characteristics. Thus morphometric analysis is a significant tool for prioritization of sub-watershed development and natural resource management. Land use / land cover analysis is essential component of development index for land and water resource management. Watershed prioritization has been performed based on ranking of different sub-watersheds of a watershed according to the order in which they have to taken for treatment and soil conservation measures. The resource development programs are generally applied on watershed basis and thus prioritization is required for proper planning and management of the natural resource for sustainable development. In the present study integration of morphometric and land use/ land cover analysis has been carried out in sub-watersheds of Neora River in Darjeeling and Jalpaiguri Districts, West Bengal using modern geospatial tools like remote sensing and GIS techniques. An attempt has been made to prioritize sub-watersheds on the basis of morphometric parameters and land use / land cover analysis.

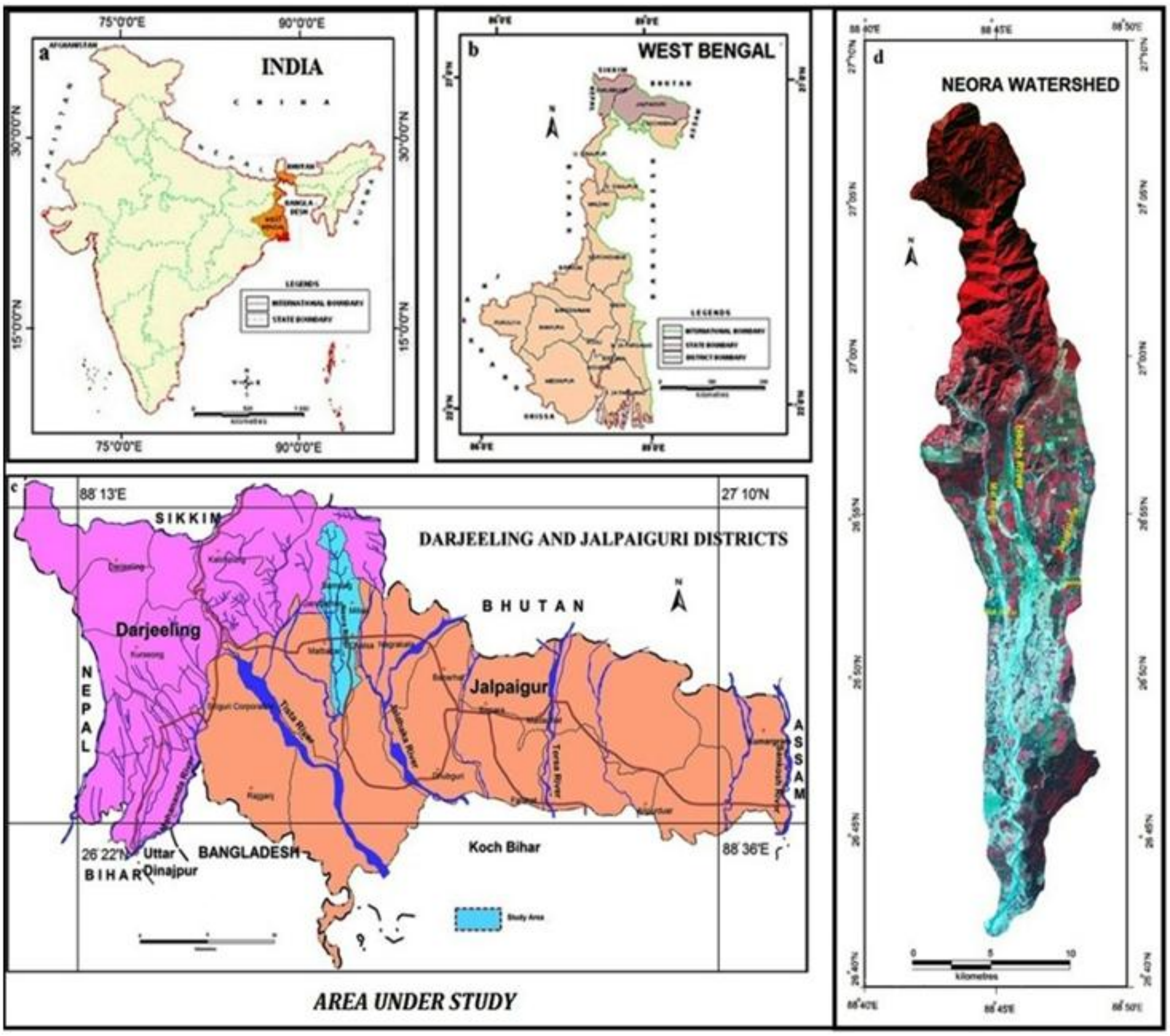

Fig. -1 - Area under Study

II. Study Area

The present study of *Neora River Watershed* covers within the districts of Darjeeling and Jalpaiguri in West Bengal. River Neora originates in the Rechila Hill Reserve Forest at an altitude of nearly 3200 meters above sea level within the *Neora Valley National Park of Darjeeling Himalayas* and subsequently flows southward and meets the River Chel near Kranti. Traversing 61km within Darjeeling and Jalpaiguri, the river Neora has joined in the River Chel to form the River Dharla which ultimately meets the River Teesta at Basusuba in Jalpaiguri district. Geographically, the study area lies between 26°40'N to 27°10'N latitudes and 88°40'E to 88°50'E longitudes and covers an area of approximately 295 sq.km. Like most Duars rivers the Neora basin also has an elongated shape (**Fig. 1**). The studied area is characterized by rugged mountainous topography in the upper part, whereas, very gentle to plain forms with slight undulating terrain has been found in the lower part. Based on various geomorphic, morpho-tectonic and structural, spacing of contour, stream ordering, lithology and bed rock condition, drainage pattern, nature and characteristic of flow direction, the Neora watershed has been classified into 13(thirteen) sub-watersheds for the specific investigation.

III. Objectives and Problems Studied:

The major objective of the study is to assign the hydro-geomorphic and land use-land cover status of the Neora watershed in micro level and to assess their individual and integrated impact on determining the present status of the sub-watersheds. For this purpose attempts are taken –

i) To distinguish studied thirteen sub-catchments and their detail physical environment study;
ii) To analyse the hydro-geomorphic, morphometric and drainage network status of the sub-watersheds for detail study;
iii) For the preparation of land use as well as land cover map of the watershed and their correlation and association with environmental parameters;

iv) To determine the standardised values of status determining parameters and their intra and inter parameter comparison for prioritization purpose; and

Finally, development policies and preparedness for restoration have been tried to extract for holistic development of the watershed and individual sub-watersheds as well. However, inferences have been drawn on the basis of quantitative and qualitative values of the parameters to take proper measures of analysis and development through sub-watershed prioritization methods and respective analysis.

IV. Methodology

For the fulfillment of the specific objectives, a number of interactive and analytical methods, apart from traditional and observational, are taken into consideration. As an initiative part of research *collection, observation and tabulation have been done* and finally area under study is worked out. SOI Topographical maps (1:50,000), TM and ETM+ Images of better resolution, SRTM (DEM) images of 90m resolution (for the preparation of contour and relief map) and other litho-tectonic and structural maps are consulted as an integrated part of intensive field study. Watershed and sub-watershed maps are prepared in consultation with above information and intensive ground checking. The linear, areal and shape parameters are extracted and dimensionless indices are also deduced using standardized laws and hypotheses. The sub-watershed boundaries were demarcated on the basis of contour, drainage flow direction, stream ordering, lithology, geology, tectonic, bed rock condition of the watershed for intensive study. *The morphometric parameters i.e. drainage density (Dd), stream frequency (Fs), mean bifurcation ratio (Rb), drainage texture (T), length of overland flow (Lg), relief ratio (Rh), gradient ratio (Gh) dissection index (Di) form factor (Rf), basin shape (Bs), circulatory factor (Rc), compactness coefficient (Cc) and elongation ratio (Re)* were calculated ***as erosional risk assessment parameters and have been used for prioritization of sub-watersheds.*** Selected satellite image of landsat-8 dated 23rd January, 2014 has been used to prepare present land use / land cover status map with the help of ground truth verification. Moreover, status differences of sub-watersheds and consequent inferences are considered using updated analytical methods on the lap of modern technological environment.

V. Result And Discussion

Neora watershed has been classified into thirteen sub-watersheds with codes NSW1, NSW2, KSW2, KSW1, MSW1, MSW2, NSW5, MSW3, MSW4, KSW3, NSW6, NSW3 and NSW4 (**Fig. 2**) having geographical area from 3.76km^2 to 51.86km^2. Considering the environmental situation of the watershed development programme, priority based sub-watershed development is needed for proper management practice.

a. Morphometric Parameters

*Morphometric parameters play deceive role in the evaluation and management of micro-watersheds. Observation and i*dentification of stream network, and the hierarchical order is the first step in morphological analysis of a drainage basin or a watershed, based on hierarchic making of streams proposed by Strahler (1964). In the study area NSW1, NSW2, KSW2, KSW1, MSW1, MSW2, NSW5 and MSW3 are of forth order; NSW3, NSW4, KSW3 and MSW4 are of fifth order; whereas NSW6 have sixth order (**Fig. 3**). The entire Neora watershed is falls under sixth order. The morphometric analysis is discussed under linear, relief and shape parameters which are based on given formula in **Table 1**.

5.1.1 Linear Aspects

Linear aspects include drainage density, stream frequency; mean bifurcation ratio, drainage texture and length of overland flow are described below:

a) *Drainage Density (Dd)*

Drainage density is defined as the closeness of spacing between channels. High value of drainage density indicates well developed network and observed in regions of weak or impermeable sub-surface materials, dense vegetation and high mountain relief while low value of drainage density indicates less developed network and observed in regions of high permeable subsoil material under thick vegetation cover. Taking into account of relationship with soil erosion and drainage density weightage has assigned to each sub-watersheds.

b) *Stream Frequency (Fs)*

The stream frequency is defined as the total number of stream segment of all order per unit area (Horton, 1932). Generally stream frequency depends on lithology of the basin and texture of the drainage network. The stream frequency values of sub-watersheds are well relating with drainage density indicating a positive correlation with soil erosion also.

c) Bifurcation Ratio (Rb)

It is the ratio of number of a given order to the number of streams of the next higher order (Schumm, 1956). Lower R_b values are the characteristics of structurally less disturbed watersheds without any distortion in drainage pattern. The mean bifurcation ratio (Rbm) may be defined as the average of bifurcation ratio of all order. In the present study, Rbm varies from 2.28 to 7.32.

d) Drainage Texture (T)

It is the total number of stream segments of all orders per perimeter of that area. Drainage texture depends on a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and drainage development. The drainage texture values of sub-watersheds ranges from 0.57 to 6.42 indicating very coarse to moderate drainage texture for Neora watershed.

e) Length of Overland Flow (Lg)

It is the length of water over the ground before it gets concentrated into definite stream channels. It is approximately equal to half of reciprocal of the drainage density. Lower value of length of overland flow indicating more vulnerable to the flash flooding compared to higher values.

5.1.2 Relief Aspects

Evaluation of some relief aspects such as relief ratio, gradient ratio and dissection index of the sub-watersheds are discussed below:

a) Relief Ratio (Rh)

It indicates the overall steepness of a drainage basin and is an indicator of intensity of erosion processes operating on the slope of the basin. Rh normally increases with decreasing drainage area and size. Relief ratio in the sub watersheds is varying from 0.0006 to 0.24.

b) Gradient Ratio (Gh)

Gradient ratio is an indication of channel slope from which the runoff volume could be evaluated. The gradient ratio value of sub-watersheds ranges from 0.001 to 0.21.

c) Dissection Index (Di)

It is the crucial aspects of relief being explored to know the degree of dissection or vertical erosion and illustrates the phases of terrain and landscape development. The value of Di ranges between '0' indicating absence of vertical erosion to '1' indicating vertical cliff or escarpments with high degree of erosion.

5.1.3 Shape Aspects

Computation of shape aspects such as form factor, basin shape, circulatory factor, compactness coefficient, elongation ratio are described below:

a) Form Factor (Rf)

It is defined as the ratio of basin area to square of the basin length (Horton, 1932). The values of form factor would always be less than 0.7854(perfectly for a circular basin). Smaller the value of R_f more elongated will be the basin. The elongated watershed with low value of Rf indicates that the basin will have a flatter peak flow for longer duration. Flood flows of elongated basin are easier to manage than from the circular basin.

b) Basin Shape (Bs)

Basin shape is the ratio of the square of basin length to the area of the basin. The Bs value of sub-watersheds indicates that NSW6, NSW3 and NSW4 have weaker flood discharge periods, whereas MSW2, KSW2 and NSW2 have sharply peaked flood discharge.

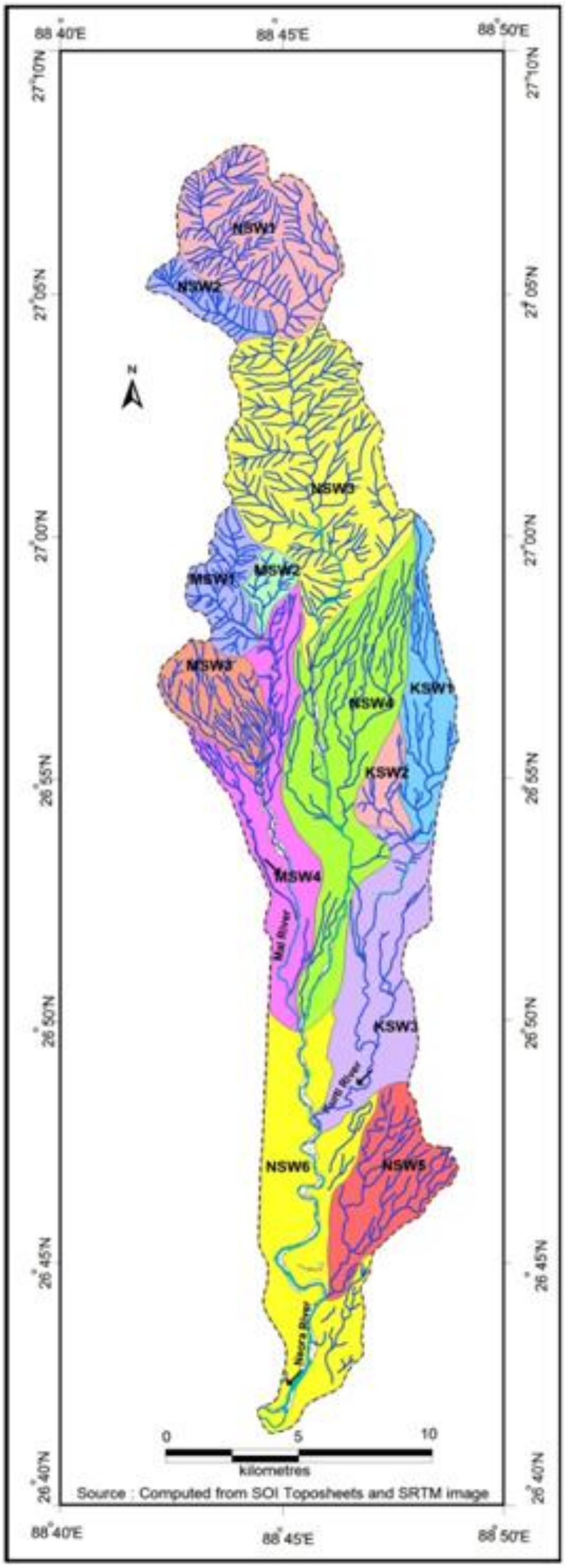

Fig.-2- Sub-Watersheds of Neora River

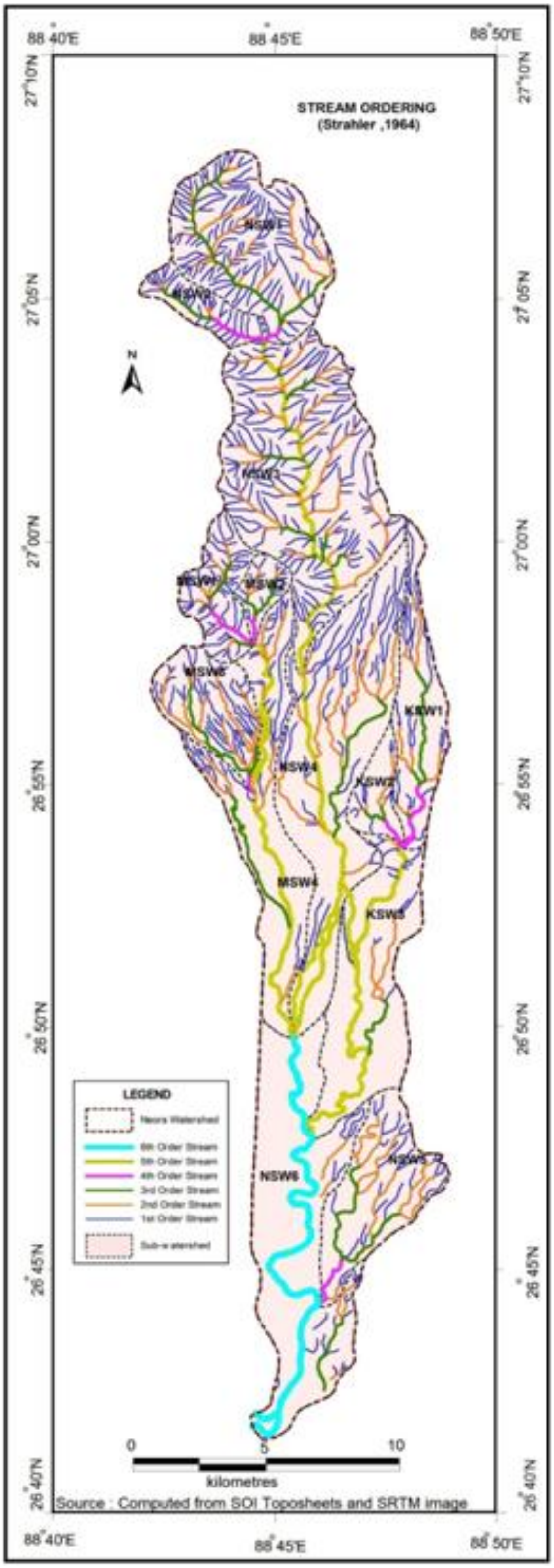

Fig.-3- Drainage Network of Neora River

c) Circulatory Factor (Rc)

It is the ratio of the area of the basin to the area of the circle having the same circumstance as the perimeter of the basin. It is influenced by the length and frequency of streams, geological structures, land use / land cover, climate, relief and slope of the basin. The Rc values of NSW1, MSW2, NSW5, MSW3, NSW3 are more than 0.5 which shows more or less circular and all the rest sub-watersheds shows less than 0.5 indicating they are less or more elongated.

Table – 1-Geo-morphometric

SL No.	Parameters	Formula	References
Linear Aspects			
1	Stream order (U)	Hierarchical order	Strahler, 1964
2	Stream length (Lu)	Length of the stream	Horton, 1945
3	Drainage density (Dd)	Dd = Lu/A where, Lu=Total length of streams; A=Area of watershed	Horton, 1945
4	Stream frequency (Fs)	Fs = N/A where, N=Total number of streams; A=Area of watershed	Horton, 1932
5	Bifurcation ratio (Rb)	Rb = Nu/ Nu+1 where, Nu=Total number of stream segment of order 'u'; Nu+1=Number of segment of next higher order	Schumn,1956
6	Drainage texture (T)	T = Nu/P where, Nu= Total no of streams of order 'u'; P=Perimeter of watershed	Horton, 1945
7	Length of overland flow (Lg)	Lg = 1/2Dd where, Dd=Drainage density	Horton, 1945
Relief Aspects			
8	Basin relief (Bh)	Vertical distance between the lowest and highest points of watershed	Schumn, 1956
9	Relief ratio (Rh)	Rh=Bh/Lb Where, Bh=Basin relief, Lb=Basin length	Schumn, 1956
10	Gradient ratio (Gh)	Gh=(H-h)/L where, H-h=Fall in height between highest and lowest points of elevation of watershed, L=Length of main stream	Sreedevi et al., 2005
11	Dissection index (Di)	$Di=RR/H_x$ where, RR=Relative relief, H_x=Highest elevation	Miller, 1949
Shape Aspects			
12	Form factor (Rf)	$Rf=A/Lb^2$ where, A=Area of watershed, Lb=Basin length	Horton, 1932
13	Basin shape (Bs)	$Bs=Lb^2/A$ where, Lb=Basin length, A=Area of basin	
14	Circulatory ratio (Rc)	$Rc=4\pi A/P^2$ where, A=Area of watershed, π=3.14, P=Perimeter of watershed	Strahler, 1964
15	Compactness coefficient (Cc)	$Cc=0.2821\ P/A^{0.5}$ where, P=Perimeter of watershed, A=Area of watershed	Nooka Ratnam et al., 2005
16	Elongation ratio (Re)	$Re=2\sqrt{(A/\pi)}/Lb$ where, A=Area of watershed, π=3.14, Lb=Basin length	Schumn,1956

Aspects and Parameters of Neora Watershed

d) Compactness Coefficient (Cc)

Compactness coefficient is used to express the relationship of a hydrologic basin with that of a circular basin having the same area as the hydrologic basin. A circular basin is the most hazardous from a drainage stand point because it will yield the shortest time of concentration before peak flow occurs in the basin. The values of Cc in the study area vary from 1.14 to 2.45 showing wide variations across the sub-watersheds.

e) Elongation Ratio (Re)

Elongation ratio is the ratio between the diameters of a circle of the same area as the basin to the maximum basin length. A circular basin is more efficient in the discharge of runoff than an elongated basin. The value of elongation ratio generally varies from 0.6 to 1.0 associated with a wide variety of climate and geology.

The *morphometric parameters namely drainage density, stream frequency, mean bifurcation ratio, drainage texture, length of overland flow, relief ratio, gradient ratio, dissection index, form factor, basin shape, circulatory factor, compactness coefficient, elongation ratio* are calculated and analysed for the all sub-watersheds of Neora watershed in the following paragraphs-

Sub-Watersheds Code	Area in sq.km. (A)	Perimeter in km (P.)	Basin Length in km. (Lb)	Total Length of all Streams in km. (Lu)	Drainage Density (Dd)	Stream Frequency (Fs) (km/km^2)	Mean Bifurcation Ratio (Rbm)	Drainage Texture (T)
NSW1	29.40	21.82	8.95	113.50	3.86	4.76	6.01	6.42
NSW2	6.17	12.51	3.69	26.35	4.27	6.64	4.27	3.28
KSW2	5.29	11.75	3.38	11.02	2.08	3.21	2.17	1.36
KSW1	15.11	26.86	6.13	42.38	2.81	1.99	2.68	1.12
MSW1	9.81	15.77	4.80	38.51	3.92	6.42	3.67	3.87
MSW2	3.76	8.61	2.78	12.75	3.39	6.65	2.83	2.90
NSW5	19.07	21.59	7.00	49.19	2.58	1.99	3.13	1.76

MSW3	13.00	15.47	5.63	55.22	4.25	3.92	3.60	3.23
MSW4	26.52	44.64	8.44	65.25	2.46	1.51	5.88	0.90
KSW3	27.46	30.92	8.61	38.95	1.42	0.69	3.83	0.61
NSW6	41.96	49.28	10.96	44.23	1.05	0.67	4.60	0.57
NSW3	51.86	34.49	12.36	168.80	3.25	3.76	4.78	5.60
NSW4	44.31	46.04	11.30	107.80	2.43	1.20	7.32	1.15

Table 2: Analysis of Morphometric Parameters of the Sub-watersheds

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b. Land Use / Land Cover Analysis

Sub-watersheds wise land use / land cover mapping carried out using satellite images of landsat-8 dated 23rd January, 2014. The imagery was processed and analyzed using the image processing module through standard visual interpretation method based on photo recognition elements such as tone, texture, size, shape, pattern association etc. The interpreted details are checked on Ground Truth Verification. The present land use / land cover map is show in **Fig. 4**. The classified image categorized into forest covers / trees, waste land / fallow, settlement, agricultural land, grassland, water bodies, tea plantation, dry channel bed etc. The percentage of land use/land cover under each category was also calculated for all sub-watersheds of Neora watershed (Table 3).

Sub-Watersheds Code	Length of Overland Flow (Lg)	Relief Ratio (Rh)	Gradient Ratio (Gh)	Dissection Index (Di)	Form Factor (Rf)	Basin Shape (Bs)	Circulatory Factor (Rc)	Compactness Coefficient (Cc)	Elongation Ratio (Re)
NSW1	0.52	0.24	0.17	0.56	0.366	2.73	0.78	1.14	0.68
NSW2	0.468	0.23	0.209	0.45	0.45	2.20	0.50	1.42	0.76
KSW2	0.96	0.02	0.0064	0.38	0.46	2.16	0.48	1.44	0.77
KSW1	0.71	0.05	0.028	0.73	0.40	2.49	0.26	1.95	0.715
MSW1	0.51	0.21	0.17	0.77	0.43	2.35	0.50	1.42	0.74
MSW2	0.59	0.225	0.21	0.71	0.49	2.06	0.64	1.25	0.79
NSW5	0.78	0.002	0.002	0.12	0.39	2.57	0.51	1.39	0.70
MSW3	0.47	0.08	0.06	0.69	0.41	2.44	0.68	1.21	0.722
MSW4	0.81	0.04	0.029	0.86	0.371	2.69	0.17	2.45	0.688
KSW3	1.41	0.01	0.0061	0.51	0.37	2.70	0.36	1.66	0.686
NSW6	1.90	0.0006	0.001	0.09	0.349	2.86	0.22	2.15	0.67
NSW3	0.61	0.13	0.07	0.85	0.34	2.95	0.55	1.35	0.657
NSW4	0.82	0.03	0.02	0.83	0.346	2.88	0.26	1.95	0.664

Table: 3 – Sub-watershed wise land use and land cover, Neora watershed

Sub-Watershed Code	Forest Covers / Trees (%)	Waste land / fallow (%)	Settlement (%)	Agricultural. Land (%)
NSW1	99.92	0.08	0.00	0.00
NSW2	99.52	0.48	0.00	0.00
KSW2	5.93	3.91	6.85	0.00
KSW1	10.21	9.04	11.95	0.17
MSW1	60.62	3.22	1.64	20.84
MSW2	93.33	1.43	0.00	0.00
NSW5	68.44	6.74	1.33	0.65
MSW3	34.82	3.73	3.24	10.37
MSW4	25.40	4.11	12.49	7.24
KSW3	8.73	2.66	12.71	31.76
NSW6	15.07	3.07	11.84	35.72
NSW3	97.45	0.92	0.00	0.00
NSW4	14.90	11.38	6.33	9.10

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Sub-Watershed Code	Grassland (%)	Water Bodies (%)	Tea Plantation (%)	Dry Channel Bed (%)
NSW1	0.00	0.00	0.00	0.00
NSW2	0.00	0.00	0.00	0.00
KSW2	3.04	0.83	78.19	1.26
KSW1	6.01	0.44	61.85	0.32
MSW1	7.93	1.65	0.96	3.13
MSW2	2.44	2.14	0.00	0.66
NSW5	4.56	0.00	18.28	0.00
MSW3	3.98	1.59	41.45	0.82
MSW4	7.09	5.75	30.99	6.93
KSW3	8.35	3.64	25.93	6.22

NSW6	7.93	5.27	13.66	7.42
NSW3	0.63	0.82	0.00	0.16
NSW4	6.31	4.95	39.18	7.86

5.3 Morphometric Parameters as Bases of Prioritization of Watersheds

Morphometric analysis is an effective tool for sub-watershed prioritization. The *linear parameters* such as drainage density, stream frequency, mean bifurcation ratio, drainage texture have a direct relation with erodibility. Higher the value more in erodibility. Hence for the prioritization of sub-watersheds, the highest value was rated as rank 1, second value was rated as rank 2 and so on, and the lowest value was rated as last in rank. *Shape parameters* such as form factor, elongation ratio and compactness coefficient have an inverse relation with erodibility. Hence for the prioritization of sub-watersheds, the lowest value was rated as rank 1, next lower value was rated as rank 2 and so on, and the highest value was rated as last in rank. After the ranking has been done based on single parameters, the ranking values for all the linear, relief and shape parameters of each sub-watersheds were added up to find compound rank. Finally compound parameters values are calculated for each sub-watershed from the compound rank of each sub-watershed. Based on compound value of these parameters, the sub-watersheds were assigned final priority rank. Hence for the prioritization of sub-watersheds, the lowest value of final priority rank was rated as rank 1, second lowest value was rated as rank 2 and so on, and the highest value was rated as last in rank. The lowest compound value was given the highest priority, next lower value was given second priority and so on, and the highest compound value was given the lowest priority (**Table 4**). The sub-watersheds were categorized as high, medium and low. Out of 13 sub-watersheds of Neora watershed NSW1, NSW2, MSW1 and NSW3 fall in high priority; KSW1, MSW2, MSW3, MSW4 and NSW4 fall in medium priority; KSW2, NSW5, KSW3 and NSW6 fall under low priority. **Fig 5** shows priority of sub-watersheds based on morphometric parameters.

Table 4: Prioritization of Sub-Watersheds on the Basis of Morphometric

Sub-Watershed Code	Linear Parameters					Relief Parameters			Shape Parameters					Cumulative Rank	Composite Rank	Final Priority Rank	Assessed Priority
	Dd	Fs	Rbm	T	Lg	Rh	Gh	Di	Rf	Bs	Rc	Cc	Re				
NSW1	4	4	2	1	4	1	4	8	4	4	13	1	10	*60*	*4.62*	*1*	High
NSW2	1	2	6	4	1	2	2	10	11	11	8	6	3	*67*	*5.15*	*3*	High
KSW2	11	7	13	8	11	10	10	11	12	13	6	8	2	*122*	*9.38*	*10*	Low
KSW1	7	9	12	10	7	7	8	5	8	9	4	10	6	*102*	*7.85*	*7*	Medium
MSW1	3	3	8	3	3	4	3	4	10	10	7	7	4	*69*	*5.31*	*4*	High
MSW2	5	1	11	6	5	3	1	6	13	12	11	3	1	*78*	*6.00*	*5*	Medium
NSW5	8	8	10	7	8	12	12	12	7	7	9	5	7	*112*	*8.62*	*8*	Low
MSW3	2	5	9	5	2	6	6	7	9	8	12	2	5	*78*	*6.00*	*5*	Medium
MSW4	9	10	3	11	9	8	7	1	6	6	1	13	8	*92*	*7.08*	*6*	Medium
KSW3	12	12	7	12	12	11	11	9	5	5	5	9	9	*119*	*9.15*	*9*	Low
NSW6	13	13	5	13	13	13	13	13	3	3	2	12	11	*127*	*9.77*	*11*	Low
NSW3	6	6	4	2	6	5	5	2	1	1	10	4	13	*65*	*5.00*	*2*	High
NSW4	10	11	1	9	10	9	9	3	2	2	3	11	12	*92*	*7.08*	*6*	Medium

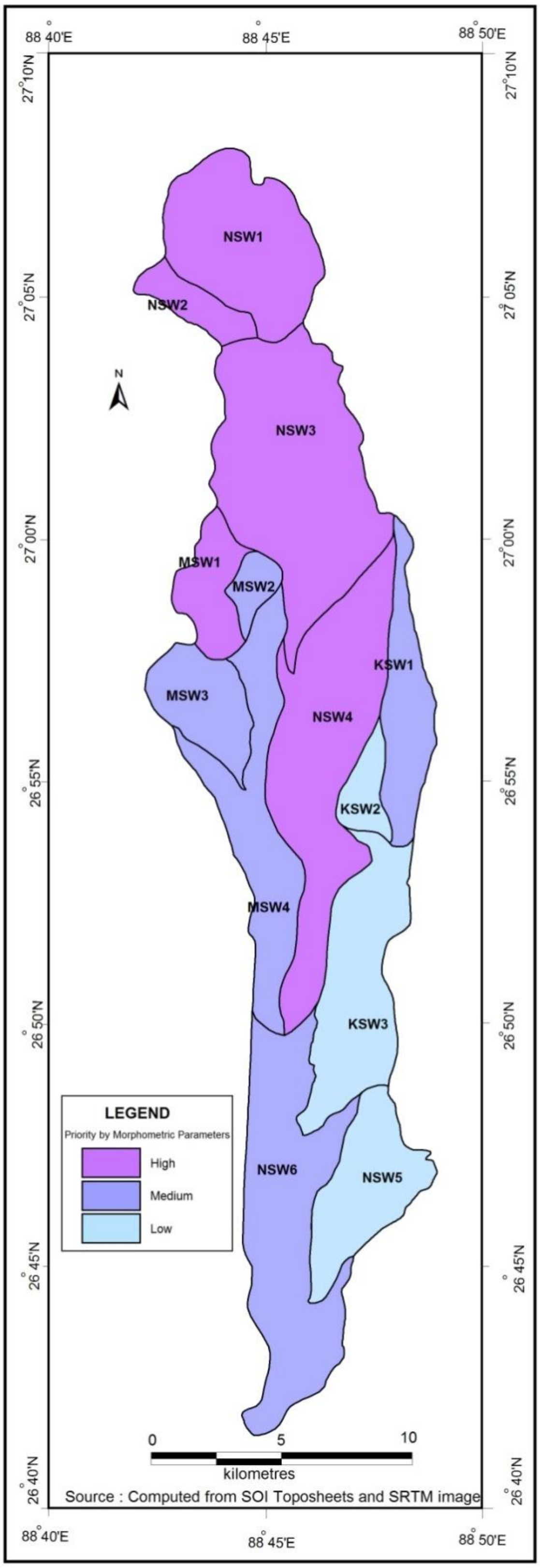

Fig. 5- Prioritization Map by Morphometric Parameter

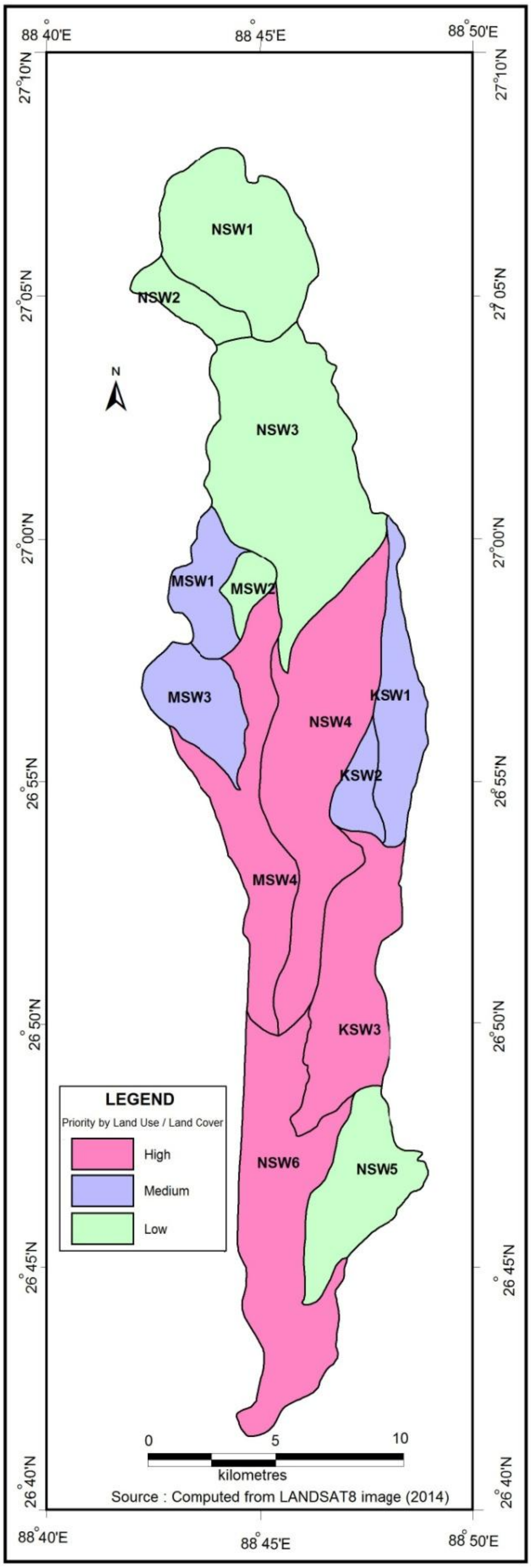

Fig. 6- Sub-watersheds Prioritization Map by Land Use / Land Cover

5.4 Land Use and Land Cover Elements as Bases of Prioritization of Watersheds

The existing land use/ land cover categories of the sub-watersheds such as forest covers, waste lands, settlement and other , agricultural land, grassland, water bodies, tea plantation, dry channel bed and land under settlement and other uses which are not available for cultivation are studied in micro level and were considered for prioritization of sub-watersheds. In land use/ land cover categories waste and other fallows, settlements, agricultural land, water bodies, dry channel bed have a direct interaction with erodibility. Higher the value of their intensity more will be the erodibility status. For prioritization of sub-watersheds the highest values (per cent area) under land use/ land cover categories waste land / fallow, settlement, agricultural land, water bodies, dry channel bed were rated as rank 1, second higher values as rank 2 and so on, and the lowest values were rated successively. However, lowest ranks were given to the highest values among the present land use/ land cover categories of forest covers / trees, grassland, tea plantation and have a inverse relation with erodibility. The lowest compound value was given the highest priority, next lower values were given priority status successively, and the highest compound value was given the lowest priority (**Table 5**). The sub-watersheds were categorized as high, medium and low. Out of 13 sub-watersheds of Neora watershed MSW4, KSW3, NSW6 and NSW4 fall in high priority; KSW2, KSW1,MSW1 and MSW3 fall in medium priority; NSW1, NSW2, MSW2, NSW5and NSW3 fall under low priority. **Fig 6** shows priority of sub watersheds based on land use/ land cover categories.

Table 5: Prioritization of Sub-Watersheds on the Basis of Land Use / Land Cover

Sub-Watersheds	Forest cover / Trees	Waste land / fallow	Settlement	Agricultural Land	Grassland	Water Bodies	Tea Plantation	Dry Channel Bed	Compound Rank	Compound Value	Final Priority Rank	Remarks
NSW1	12	13	10	9	1	11	1	11	68	8.50	11	Low
NSW2	13	12	10	9	1	11	1	11	68	8.50	11	Low
KSW2	1	5	5	9	4	8	10	6	48	6.00	4	Medium
KSW1	3	2	4	8	7	10	9	9	52	6.50	7	Medium
MSW1	8	7	8	3	10	6	2	5	49	6.13	5	Medium
MSW2	10	10	10	9	3	5	1	8	56	7.00	8	Low
NSW5	9	3	9	7	6	11	4	11	60	7.50	9	Low
MSW3	7	6	7	4	5	7	8	7	51	6.38	6	Medium
MSW4	6	4	2	6	9	1	6	3	37	4.63	2	High
KSW3	2	9	1	2	12	4	5	4	39	4.88	3	High
NSW6	5	8	3	1	11	2	3	2	35	4.38	1	High
NSW3	11	11	10	9	2	9	1	10	63	7.88	10	Low
NSW4	4	1	6	5	8	3	7	1	35	4.38	1	High

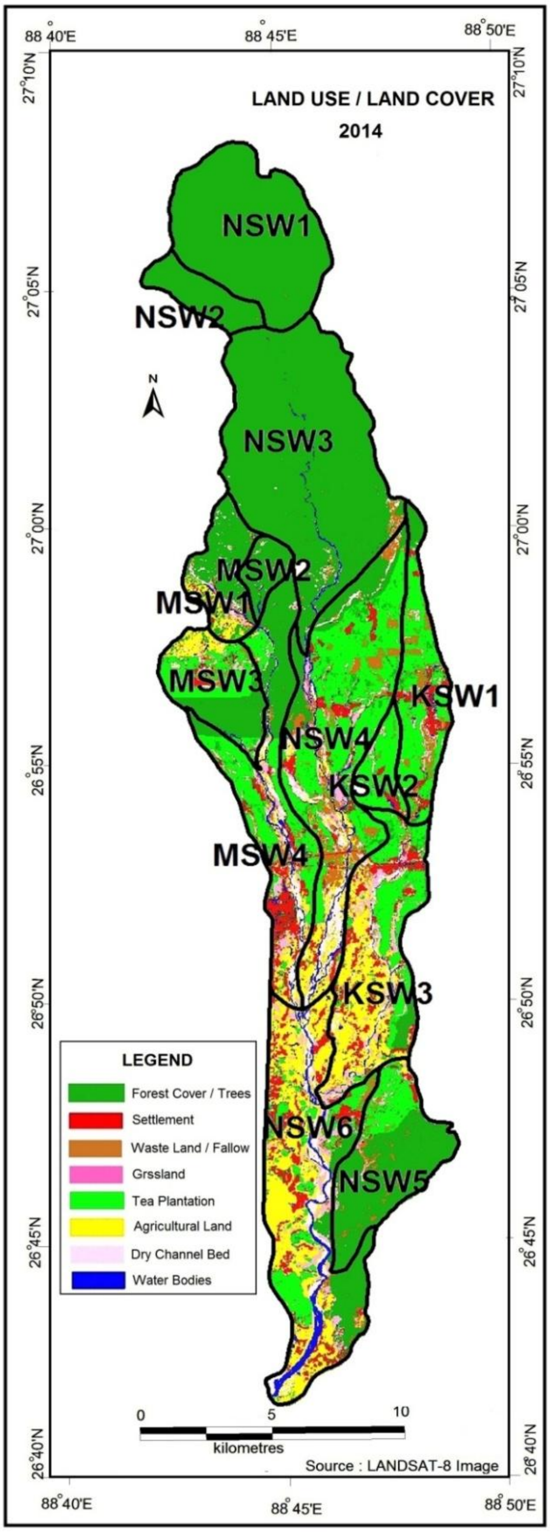

Fig.-4- Sub-watershed wise Present Land use and Land Cover

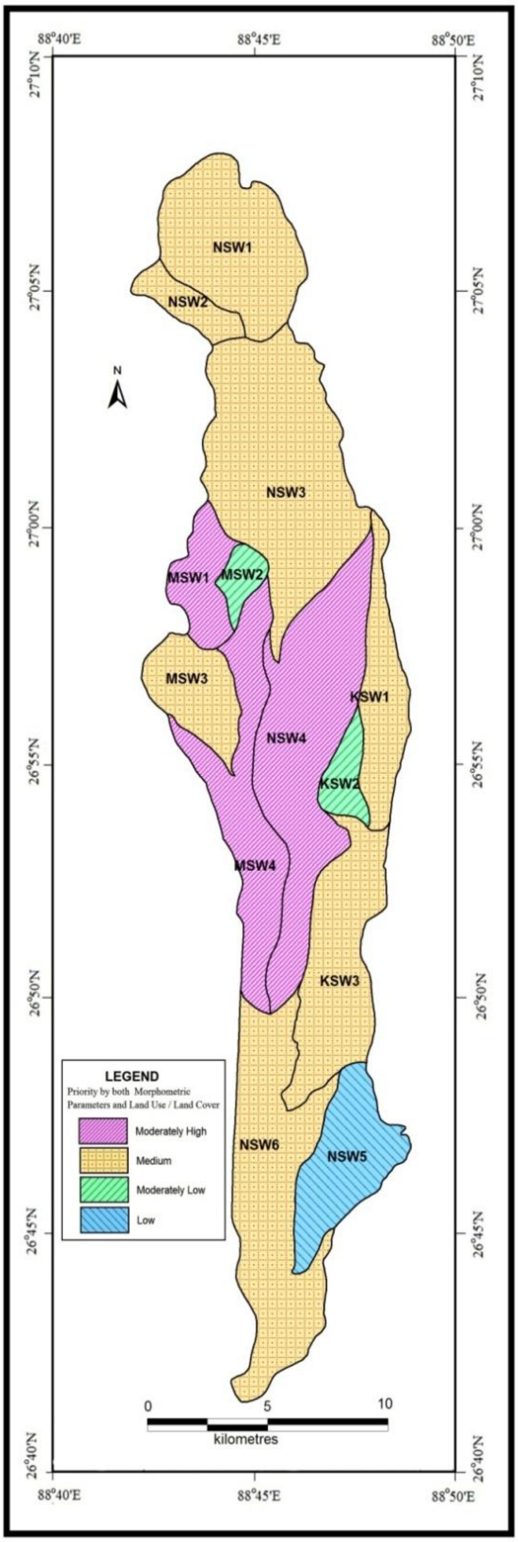

Fig.-7- Sub-watershed Prioritization Map by both Morphometric Parameters and Land Use-Land Cover

5.5 Prioritization of Sub-Watersheds on the Basis of Morphometric Parameters and Land Use / Land Cover Categories

The results obtained from morphometric parameters and land use / land cover analysis were correlated to find out the common sub-watershed priority falling under each priority. The correlation shows that NSW4 falls under high priority, KSW1 and MSW3 fall under medium priority, whereas NSW5 falls in low priority based on both parameters. However, rest of the watersheds exhibit little correlation and differ in their priority under morphometric parameters and land use/ land cover analysis (**Table 6**). The final prioritized map of the sub-watersheds is shown in **Fig. 7**. Thus the conservation measures can first be applied to NSW4 and then to the other sub-watersheds depending upon their priority.

Table 6: **Prioritization of Sub-Watersheds on the basis of Morphometric Parameters and Land Use / Land Cover**

Sub-Watershed Code	Based on Morphometry		Based on Land Use / Land Cover		Combined Priority
	Final Priority Rank	Remarks	Final Priority Rank	Remarks	
NSW1	1	High	11	Low	**Medium**
NSW2	3	High	11	Low	**Medium**
KSW2	10	Low	4	Medium	**Moderately Low**
KSW1	7	*Medium*	7	*Medium*	**Medium**
MSW1	4	High	5	Medium	***Moderately High***
MSW2	5	Medium	8	Low	**Moderately Low**
NSW5	8	*Low*	9	*Low*	***Low***
MSW3	5	*Medium*	6	*Medium*	**Medium**
MSW4	6	Medium	2	High	***Moderately High***
KSW3	9	Low	3	High	**Medium**
NSW6	11	Low	1	High	**Medium**
NSW3	2	High	10	Low	**Medium**
NSW4	6	Medium	1	*High*	***Moderately High***

VI. Conclusion

Watershed prioritization is considered as a one of the most important steps of planning and policy making for the implementation of its integrated development. Moreover, it also focused on the development for water conservation measures of natural resource development agro-related economic development. The observation and results of sub-watershed prioritization of Neora watershed on the basis of morphometric and land related parameters revealed some significant facts in the studied watershed. Though it is a small sub-tributary of Teesta river system, its watershed offers diversified environmental and socio-economic layout within this region. The present study ***demonstrated the activation of GIS and other related representation techniques for geo-morphometric analysis and priority status determination of the Neora watershed.*** Neora watershed is actually an elongated basin and no area within this watershed depicts concentration of nodes with huge volume of water concentration. In an integrated way, GIS and RS has proved to be efficient tools in drainage delineation as well as to distinguish land use and land cover categories which are strongly supported and used in the present study.

In the next part of study two tier prioritization maps have been prepared – one using fluvio-morphic parameters and other based on land use and land cover categories and with these integrated presentation, a final prioritization maps has been prepared for determining the potentials of the watershed as a whole. The Neora Watershed has three distinct socio-economic and environmental zones in terms of parametric review. The upper part is less disturbed, but declared as a unique tourist spot, so environmental degradation is an obvious result within this part of the watershed, In the middle part of the basin, the watershed is a distinct tract of Neora Fan and a number of small non-perennial streams are originated, which are causing accelerating problem of flood and different types of erosion and soil loss. But limited length of overland flow actually limits some big fluvial hazards, as the water is not concentrating so much with high volume of water. Water accumulating from small outlets is submitting less amount of water with less erosional hazards in the upper and middle part of the watershed. Apart from that the middle part of the watershed has high concentration of tea gardens, and they are almost conscious about the valuable land loss. The lower part of the basin is to some extent vulnerable and flood prone; and the Mal, Neora and Kurti has high tendency to merge their courses due to siltation of river beds and mostly by a large volume of water are submitted within single channel and the obvious result is the amalgamation of rivers, so a huge amount of soil loss occurred almost in every year .

So, in this realistic ground verification, especially due to its specific shape and form factors a small number of sub-watersheds are under the vulnerable scanner. Nearly 20 – 30% of the sub-watersheds are in priority level within moderately high priority index. But a large number of areas in the watersheds are under plantation farming and they earn great revenue from it. So, if proper implementation processes are employed overall holistic restoration and development are possible in relation watershed management and development.

Acknowledgement

The Authors are grateful to various Govt. and Non-Govt. institution and organization for their immense help and valuable suggestions for the preparation of this research. Extended financial cooperation from UGC is not also least for this painstaking presentation. The Tea garden authorities have also extended their cooperation and helping hand regarding various information and data for the smooth conduct of field observation and officials have also sympathetic attitude regarding the favourable channelization of this research work. Thanks to all other friends and personals for their valuable help.

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