*International Research Journal of Earth Sciences*_____ E-ISSN 2321–2527
Vol. **4(11),** 1-9, November **(2016)** *Int. Res. J. Earth Sci.*

Inter and Intra Micro Watershed Analysis of Land Use Change – An Appraisal on Sustainability, Southern Sikkim, India

Sandipan Chakraborty[1*] and Sanghamitra Sarkar[2]
[1]P.G. Dept of Geography, Chandernagore College, WB, India
[2]University of Calcutta, WB, India
Sandipan2k6@gmail.com

Available online at: www.isca.in, www.isca.me
Received 2nd June 2016, revised 8th November 2016, accepted 15th November 2016

Abstract

Systematic watershed analysis is now a rational track for development strategies. Natural forms and factors in terms of location had been in the way of the major land use change for a long time especially in the area of the present study. However, through time the dynamicity has increased to such an extent that a close scrutiny and relevancy of management for sustainability issues have invited the present study. The southern part of the state, with maximum physical and social alteration, has been taken into consideration in the present context to assess the changes of land use in the different micro watersheds within this area. The topography of the southern three districts is characterized by a host of different landform features. There are sharp, rugged, snow bound mountains with inaccessible scarp faces at higher altitudes. The present study area takes into consideration 12 watersheds, as geographical subdivisions, extending over the entire southern part of the state. Recently, sudden influx of population has evidently maneuvered the ground for land use changes in the comparatively favourable pockets within the southern half bringing inter and intra watershed differences in land use pattern and change. Field observation in association with all possible reports and records with analytical treatment, have been some essentials to fulfill the objectives of the study.

Keywords: Micro watersheds, Sustainable issues, Multi-Variate analysis, Cluster combinations, Land cover and Land use.

Introduction

Essentially as a Himalayan Kingdom, Sikkim became the 22nd state of Indian Union only in 1975, which laid down the foundation stone for successive changes that swept this mountainous land in every sphere within a very short span. Sikkim's story has always been unique, as this region is one of the most diverse and dynamic in terms of its natural assemblage as well as the anthropogenic built up[1]. However, the intra regional contrast in terms of this dynamicity offers maximum in the southern half of the state comprising of the three districts viz. east, west and south districts. The topography of the southern three districts is characterized by a host of different landform features. There are sharp, rugged, snow bound mountains with inaccessible scarp faces at higher altitudes. This intensely depicts the presence of numerous rivers and streams all over, all joining the principal drainage channel of Teesta to form an intricate network in this landmass. The southern part has more landscape forms due to the prominence of the causative factors of river erosion and deposition away from the source. Hence it is evident that this part can be divided into maximum number of river basin areas demarcated by individual network of drainage basins. The present study area takes into consideration 12 watersheds, as geographical subdivisions, extending over the entire southern part of the state. Each landscape has given way to the development of different natural land cover and man's land use type in the watersheds[2]. The fact that is concerning is that the land cover is rampantly under modification by land use change due to increasing human interference. Southern Sikkim, being more amenable for such change has invited scopes and concerns for regular watershed management plans and policies to sustain the natural earth. The human influx in the southern Sikkim since the time of its merger with India and mostly in the recent times due to various factors of life and livelihood has made the area a progressively populous part[3]. This has evidently maneuvered the ground for land use changes in the comparatively favourable pockets within the southern half bringing inter and intra watershed differences in land use pattern and change[4].

Location and Environment of the study area: Sikkim is a small but magnificent mountainous region in the East Himalayas. There is marked contrast with the size and scope of the landmass. The large heterogeneity of the characteristics of the area's physical and socio-cultural aspects is just opposite to the smallness of the geographical area. The present study area covers the entire southern half of the state which roughly extends over $27^0$04'46''N to $27^0$35'01''N and $88^0$00'58''E and $88^0$55'25''E longitude. The total geographical area in this part is 2870 sq. km. approximately; running approximately 57 km north-south and 64 km. from east to west[5]. The north is bordered by the North district and the south by another Indian state, West Bengal. The east and the west boundaries are international borders, viz. in the west Nepal borders the region; South-East is

bordered by Bhutan and North east of the study area by China[6]. The study area falls under the Lesser Himalayan zone and are hence comparatively less rocky and accessible, but very fragile[7]. This has resulted in a quick influx of population in this part and a resultant instability of the geo-environment due to such pressure and change of the natural cover.

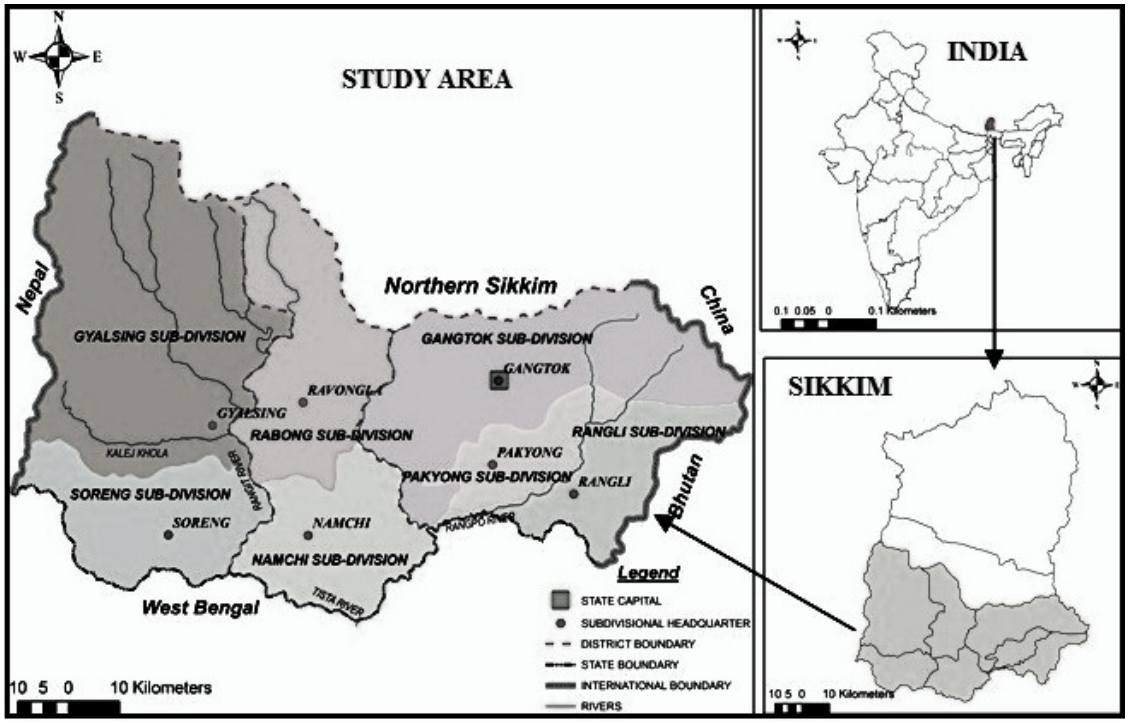
The map shows the location of the present study area. In the present context of the study it can be mentioned that around 90% of the total population of the state is concentrated within this southern half and more precisely in some of the watersheds. This has created an imbalance in the change scenario. This apart, the entire study basin is covered with forests and rivers throughout[8]. Teesta and its main tributary Rangit extends from almost all possible corners of the area. However, towards the extreme east a small area of drainage is under a tributary of river Brahmaputra.

Hence the following map depicts the different watersheds in the southern half of the state, which roughly coincides with the political boundaries separating the north district from the south, east and west district[9]. The 12 micro watersheds under the study area are: *i. Prek Chhu, ii. Relli Chhu, iii. Rathong Chhu, iv. Dik Chhu, v. Rangpo Chhu, vi. Rangit River, vii. Kalej Khola, viii. Ramam Khola, ix. Manpur Khola, x. Teesta (Lower Part), xi. Rani Khola, xii. Jaldhaka (part of a small sub-tributary).* We can get a bird's eye view of all those micro-watersheds within the following compact network of Teesta drainage system[10] (Figure–02).

Objectives: The southern part of Sikkim and the study area in the present context is the major hub of all socio-cultural growth and changes impacting the landmass for some time. In this connection there has been a considerable change taken place in the land use pattern in this part[11]. The southern half of the state of Sikkim provides wide scope for such study of the watersheds, especially when, there is constant trigger for change in the fragile land due to various land use change. *Hence the primary objectives of the study are: (i) to assess the land use pattern of the different micro watersheds; (ii) their intra and inter correlation of changing pattern of land use scenario and (iii) finally to ascertain the status of the watersheds and subsequently to analyze the aspects of change and inter connection of the demographic and physical condition to carve out a balance for such change in land use*[12].

Materials and Methods

In view of fulfilling the major objectives of the study, suitable data and information have been gathered from both primary and secondary sources. Field observation as well as analyzing the data from published and unpublished records, memoires, reports and maps and images have been some essential to fulfill the need of the study. Modern and interactive analytical techniques and software tools have also been applied in suitable GIS environment to analyze and interpret all those reports and resultant data to make fruitful inferences of the study. Modern mapping tools have also been used to represent the data and to prepare the interactive maps of the area.



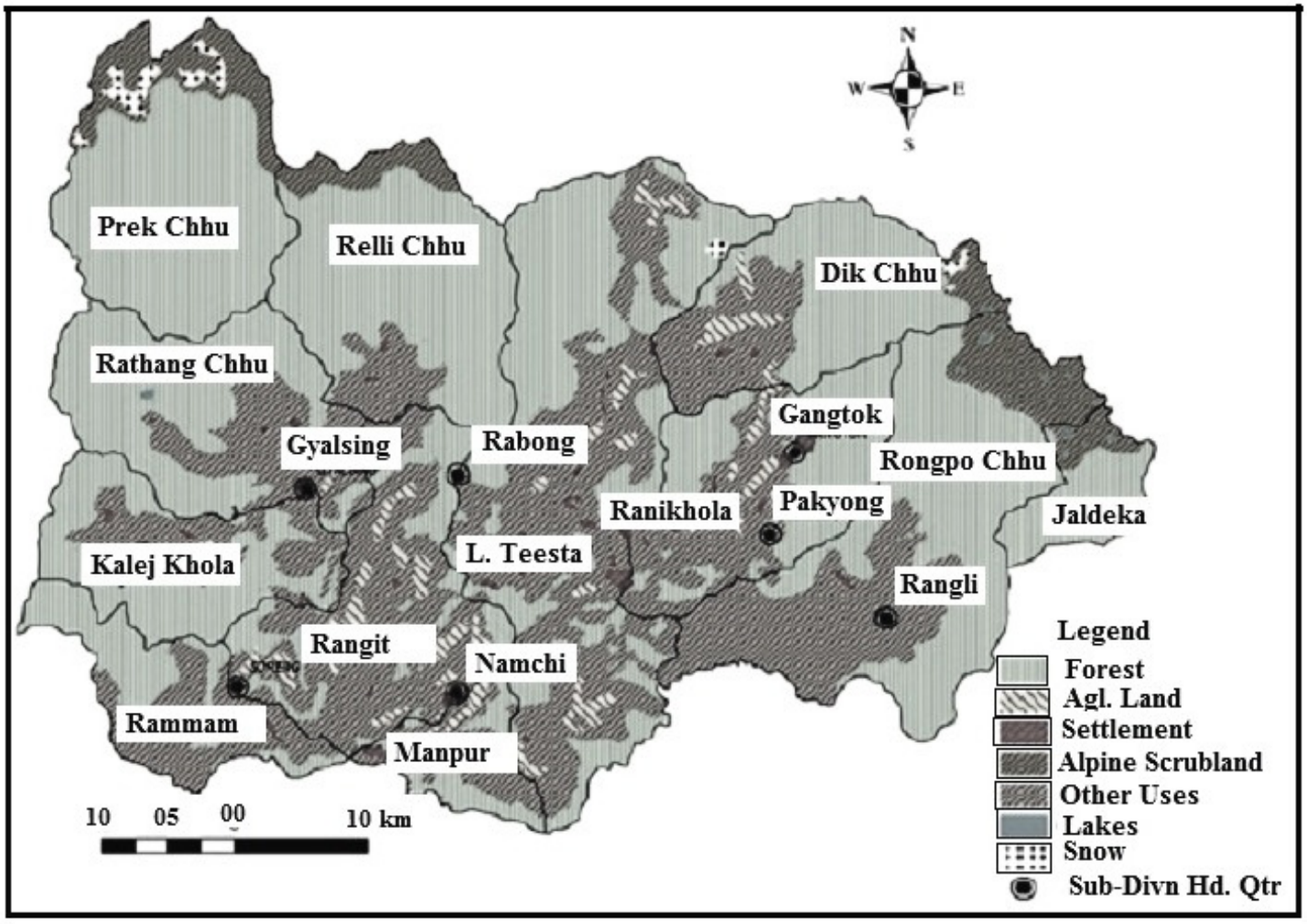
Source: Compiled from Administrative Atlas, India, 2011

Figure-1
Location of the study area

Results and Discussion

The study area offers a bunch of diverse and unique characteristics of the physical and cultural environment. The lithospheric, atmospheric, hydrospheric and the biotic environment through constant interplay have made this part a unique hotspot. Hence in the natural cover of land, forests, water bodies, glaciers, etc. have been greatly impacted and modified through land use change by the dominant species of biotic environment-man[13]. The resultant outcome is witnessed in the major land under the utilization of cultivation, settlement, roads and railways, etc. The study of the land use and land cover of the 12 micro watersheds in the study area generated from the present image and reports exemplifies the following characteristics pattern of land use and land cover[14]. Following table (Table-1) depicts the land use scenario of the present study area that also highlighting the potentials for development of the studied area.

From the varied characteristics of the land in the watersheds, it is clear that most of the areas in the watersheds have a rich land cover with a few exceptions. However, due to topographic contrasts and terrain character, sizable amount of land remains unavailable for utilization purpose. Besides, as part of the policy of the state, major land under forests are still literally unutilized[15]. This is creating accelerating pressure on the available small areas of land under human habitation. Regular exploitation and increasing utilization spree due to ever increasing population is leaving these areas disfigured, in the sense that the natural face is swiftly giving up in the hands of the alteration brought by human agency. Thus there is an apprehension about the durability of the existing artificial makeover. Moreover, due to scarcity of land, there is a regular contemplation of the idea of putting the land resource under varied land use scheme in the most effective manner. But, to what extent these planning can serve the purpose of long standing sustainability is a cause of concern[16].



Source: RS Image, LANDSAT 7, 2012; ETM+, 2001

Figure-02
Land use and Land Cover of the studied watersheds, 2012

Table-1
Existing Status of Land use and Land Cover

	Present Land Use and Land Cover, Area in Sq. Km.						
Watersheds	**Area**	**Forest (%)**	**Scrub (%)**	**Alpine Scrub (%)**	**Barren &Rocky Land (%)**	**Snow & Glaciers (%)**	**Others (%)**
Prek Chu	307.34	00	25.7	00	51.2	13.9	00
Relli Chu	299.56	48.7	18	00	14.28	3	00
Rathong	278.82	44.6	18	00	10.2	00	00
Dik Chhu	235.52	44.4	23.3	6.4	11.4	00	2.0
Rangpo	437.64	35.9	24.3	8.4	18	00	3.5
Rangit	282.58	35.6	30.7	6.9	9.1	00	9.0
Kalej	200.51	48.7	24.5	4.5	7.2	00	3.6
Rammam	146.48	35.4	26.6	00	00	00	7.9
Manpur	79.16	00	45	00	00	00	00
L.Tista	581.66	38	33	00	6.3	00	9.4
Ranikhola	246.36	00	49	00	00	00	19.3
Jaldeka	74.23	49	52	14	34	00	00

Table-2
Land use and Land Cover, 1995, DESME, Sikkim; *Residence and other establishment

Sub-Watersheds	**Land use and Land Cover (Area in Sq. Km.), 1995**						
	Forest	**Agl. land**	**Settlement**	**Lake**	**Snow**	**Scrub**	**Others***
Dik chu	188.69	7.68	2.35	0.56	1.11	11.66	47.14
Jaldeka	69.89	00	00	1.25	00	5.61	00
Kalej	121.22	5.68	3.25	00	00	00	88.22
Manpur	36.25	4.65	0.23	00	00	00	47.80
Prek Chu	264.23	00	00	00	11.56	54.67	00
Rammam	69.65	00	0.22	00	00	00	77.04
Rangit	74.65	25.68	1.36	00	00	00	224.97
Rangpo	319.56	2.25	1.22	2.29	00	39.58	84.26
Ranikhola	141.65	7.56	4.22	00	00	00	116.49
Rathang	195.33	0.23	0.23	1.23	00	00	81.95
Relli Chu	263.54	00	0.21	00	00	00	36.22
Teesta	237.24	22.25	9.65	00	00	00	376.32

The land use pattern under various purposes can be taken up separately to frame an understanding of this debate. *Here is a bird's eye view of the land cover and land use of the present study area* (Table–1) and it is to note that the present study has been recorded the temporal scenario of the studied area for the year of 1995 and 2012 and highlighted many significant fact on the changing coverage of the of the land use and land cover of the studied area[17]. However the results are represented are highly interesting to note that the area under study has been marked as developed tourist growth centre and many of such centers are distributed all around the area as a mark of economic development. So, in this respect, serine environment and virgin lands are always paying for the same. However, the analysis and subsequent discussion is mostly need for holistic development of the area. The *following table also shows the total area under different categories of land use* in the 12 watersheds of the study area[18]. Hence a *comparative picture can be established from the same regarding the difference of the land use in these watersheds.* It has been extracted from this scene that remarkable decrease of forest area is noted especially in and around the tourist spot and growth centers; subsequently sliding, slipping and similar such geomorphic hazards are occurred frequently that spontaneously sending land into ditches[19]. It can also be seen that the intra dimensional gap in most of the watersheds in terms of the different land use categories throughout each of the watersheds have also been quite contrasting. The responsible factors at some places have been wholly natural which have affected the human factor to impact upon such differences.

From the analysis of the temporal scenario of land use pattern of the different watersheds it becomes quite vital to understand that the watersheds under massive human interference as is highlighted from the total area under direct human use as settlement, cultivations etc. are the regions which calls for immediate attention. The water usage in the recharge basins forms vital aspect for the stability and management of the watersheds. The Supply of water during various seasons for cultivation in the form of irrigation supply; the domestic requirement of water; and most importantly there is a huge pool due to the tourist industry. All these factors have essentially meant the need of water resource management, together with watershed development and management strategies to sustain each of the units.

It is already evident that there is a huge contrast in the intra and inter-watershed land use types. For example Ranikhola has the highest area under settlement cover, where as there is very meager settlement in Rangpo chhu, even though it is much larger area than Rani Khola. Hence the pressure is diverse. Moreover, the density difference within each of the watersheds in terms of population or demographic order due to birth, death and migration is different due to differential environment and land character, for example, the southern part of Dik Chhu witnesses growth of settlement whereas the eastern part does not, due to its strategically sensitive location and other physical factors and the considered Jaldeka watershed is totally uninhabited and actually not suitable for human activities[21]. Thus the vulnerability of the favorable parts constantly becomes higher than the other. For better understanding about the suitability of the watersheds a number of components are considered relating to aspects of relief, slope and roughness and land related aspects which may be the major determinants of the suitability of the considered watersheds (Table–4).

Table-3
Land use and Land Cover Status, 2012, DESME, Sikkim,*Residence and other establishment

Sub-Watersheds	Land use and Land Cover (Area in Sq. Km.), 2012						
	Forest	**Agl. land**	**Settlement**	**Lake**	**Snow**	**Scrub**	**Others***
Dik chu	169.63	10.54	3.23	0.47	1.42	11.67	67.2468
Jaldeka	58.29	00	00	1.21	00	17.18	-
Kalej	110.1	10.84	5.05	00	00	00	87.463
Manpur	29.46	5.27	1.25	00	00	00	56.2186
Prek Chu	248.78	00	00	00	9.26	67.82	-
Rammam	58.40	00	1.42	00	00	00	89.4947
Rangit	68.28	31.79	1.32	00	00	00	231.7589
Rangpo	305.68	4.35	3.40	2.20	00	39.59	102.324
Ranikhola	133.31	11.79	7.49	00	00	00	132.3299
Rathang	178.52	2.48	2.42	1.23	00	00	89.354
Relli Chu	250.40	00	1.16	00	00	00	50.3261
Teesta	227.12	27.41	13.36	00	00	00	395.3038

Table-4
Status of Morphological and Land use Parameters considered for watershed Prioritization

Sub-Watersheds	Components of Land use and Land Cover Considered; * Index Value										
	Relative Relief (m) V-01	Relief Ratio* V-02	Road Density (km/sq.km) V-03	Drainage Density(km /sq.km)V-04	Stream frequency (No/sq.km V-05	Form Factors* V-06	Basin Perimeter (km) V-07	% Forest V-08	% Agl. Land V-09	% Settlement V-10	Av no of landslides
Dik chu	4330	17.5	.27	.75	.23	.003	77.54	72.02	4.47	3.22	8
Jaldeka	2172	25.1	.16	1.97	1.31	.003	44.27	78.5	00	00	2
Kalej	2931	15.1	.46	.81	.25	.004	75.87	54.91	5.4	5.05	3
Manpur	1855	12	.41	.68	.25	.003	47.28	37.21	6.66	1.25	1
Prek Chu	4668	26	.23	.76	.24	.005	78.94	80.94	00	00	2
Rammam	2940	12.2	.34	1.03	.44	.002	80.04	39.87	00	1.42	2
Rangit	2912	8.7	.64	.96	.36	.002	91.82	24.16	11.25	3.32	4
Rangpo	4163	10.8	.43	.51	.13	.003	128.79	69.85	0.99	3.39	12
Rani-khola	3486	31.5	.35	.5	.13	.016	76.59	54.11	4.79	7.49	11
Rathang	4080	15.0	.27	.97	.34	.003	79.65	64.03	0.89	2.42	1
Relli Chu	4897	15.9	.20	.61	.21	.003	79.85	83.58	00	1.16	2
Teesta	3418	5.0	.45	.73	.19	.001	149.36	39.05	4.71	13.35	18

Table-5
Bi-Variate Correlation Matrix showing association among variables; *Level of significance 5% and ** denotes 1%

Variables	V-01	V-02	V-03	V-04	V-05	V-06	V-07	V-08	V-09	V-10
V-01	1	.135	-.350	-.482	-.499	.386	.603*	-.434	-.010	.190
V-02	.135	1	-.593*	.181	.258	-.548	.549	-.306	-.298	-.199
V-03	-.350	-.593*	1	-.324	-.379	.420	-.830**	.798**	.452	.396
V-04	-.482	.181	-.324	1	.981**	-.446	.125	-.182	-.355	-.389
V-05	-.499	.258	-.379	.981	1	-.490	.187	-.222	-.388	-.364
V-06	.386	-.548	.420	-.446	-.490	1	-.194	.022	.706*	.792**
V-07	.603*	.549	-.830**	.125	.187	-.194	1	-.745**	-.417	-.169
V-08	-.434	-.306	.798**	-.182	-.222	.022	-.745**	1	.354	.213
V-09	-.010	-.298	.452	-.355	-.388	.706*	-.417	.354	1	.788**
V-10	.190	-.199	.396	-.389	-.364	.792**	-.169	.213	.788**	1

With the help of bi-Variate and multi-Variate analysis involving the considered variables following results are drawn and subsequent inferences are also incorporated twelve physical units (watersheds) of the study area, have been studied distinctly by every aspects of their natural built up and existing climatic trends and resource bases, which categorically settled the understanding of the inclination of natural repulsion and attraction by the human world, as an environmentally favourable area generally draws more settlements and vice versa.

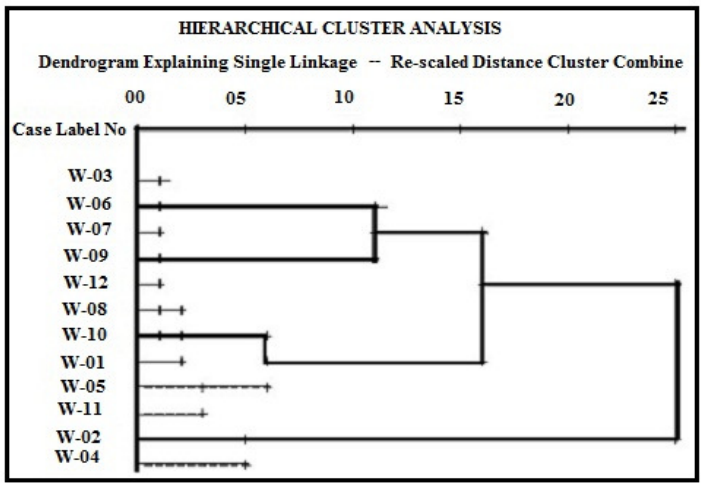


Figure-3
Clustering of Watersheds shown by Dendrogram

Table-6
Determination of watershed status by Trial and Error Cluster combination

Watersheds	05-Clusters	04-Clusters	03-Clusters
Dik Chhu(01)**	01	01	01
Jaldeka(02)**	02	02	02
Kalej Khola (03)	03	03	01
Manpur Khola (04)	03	03	01
Prek Chhu (05)**	01	01	01
Rammam Khola (06)**	01	01	01
Rangit River (07)	03	03	01
Rongpo- Rangit (08)**	01	01	01
Ranikhola (09)	04	01	01
Rathang Khola (10)**	01	01	01
Ralli Chhu (11)**	01	01	01
Teesta Lower (12)	05	04	03

First Cluster – 01, 05, 06, 08, 10 and 11; Second Cluster – 02 only, Third Cluster – 03, 04, 07; Fourth Cluster – 09 only, and Fifth Cluster – 12 only

It has been ascertained from the results that: i. In the bi-Variate analysis we like to consider here 0.05 level of significance for getting no risk as well as to achieve the stable result verifying the ground truth, because 0.01 level may restrict the resolution of ground reality and will be always tried to restrict its area within the abstract value; ii. In the Clustered and PCA also conform to this results almost in the same line of sight. Here, it has been observed that considered watersheds 01, 05, 06, 08, 10 and 11 constituting a group of similar category of watersheds, so a great number of watersheds in the studied area are similar in terms of their environment and development so far as the estimated variables are concerned; iii. whereas, other clusters excepting 02, 09, and 12 also offering a bit of dissimilarity in comparison to first cluster; iii. but, clusters 02, 09 and 12 which are constituting second, fourth and fifth clusters are representing as single member in the representation and offering some distinct kind of differentiation in terms of suitability of development and so, levels of prioritization have been determined accordingly.

Accordingly, the suitability status map has been prepared based on priority ranking of the considered variables for getting the best possible measures of the development perspectives for the studied micro-watersheds, because in the present system of development micro-level policy making and subsequent re-organization proved the best way of micro-level development planning.

Priority Status Determination for Sustainable Development: As the area is located in the mountainous terrain in the Sikkim Himalaya, it faces frequent and number of hazards and disasters which are most vulnerable for society and environment. However, for holistic, rational and sustainable development a number of morphological, topographical and land use-land cover parameters are selected and considered for designing and repairing the vulnerable sections of the watersheds [20]. In this regards stresses have been given to some fundamental principles for boosting the watershed in micro level scale. Here, for this specific purpose, prioritization techniques are taken into account and proper steps have been taken to restore the vulnerable portion of the section of the micro watersheds. Following table shows the necessary steps for prioritized the sub watersheds as and where it has been needed (Table No- 07), and the resultant map (With watershed ID-01, 02, 03…etc.) is explaining the same (Figure–4).

Conclusion

The land morphology depicts the scene of the order of the watersheds in terms of such favourability. In a brief, the findings of the study conducted so far, show that the overall condition of the study area can be divided into two parts: i. the natural environment and their potentialities and explorative status in terms of the natural boundary, and ii. The human environment and their change and establishment in the present area in relation to past, existing and potentials of land, and with the essence of

both the answer to the present problem of the study is sought. In order to do away with this problem of contrast, suitable strategies of management are vital for striking a balance of the environment and achieve sustainability; the present problem of the study is sought. In order to do away with this problem of contrast, suitable strategies of management are vital for striking a balance of the environment and achieve sustainability.

Table–7
Prepared from Reference Table-4 and calculated indices of prioritization for status determination based on Composite Index (CI) and Priority Index (PI)

Watersheds	Relative Relief	Relief Ratio	Road Density	Drainagr Density	Stream Frequency	Form Factors	Basin Parameter	Forest	Agl. Land	Settlement	Landslides	CI	PI	Priority to be given STATUS
Dik Chhu	10	09	05	06	06	09	08	04	06	06	05	72	02	MOD TO HIGH
Jaldeka	02	10	01	12	12	06	12	03	10	01	02	71	02	
Kalej	04	06	11	08	08	11	10	07	03	09	03	80	03	LOW
Manpur	01	04	08	04	04	07	11	11	02	03	01	56	01	HIGH
Prek Chhu	11	11	03	07	07	12	07	02	11	01	02	74	02	MOD TO HIGH
Rammam	05	05	06	11	11	04	04	09	09	04	02	70	02	
Rangit	03	01	12	09	09	05	03	12	01	07	04	66	02	
Rongpo	09	03	09	02	02	08	02	05	07	08	07	63	02	
Ranikhola	07	12	07	01	01	01	09	08	04	10	06	66	02	
Rathang	08	07	04	10	10	10	06	06	08	05	01	75	03	LOW
RelliChhu	12	08	02	03	03	03	05	01	12	02	02	53	01	HIGH
L. Teesta	06	02	10	05	05	02	01	10	05	11	08	65	01	

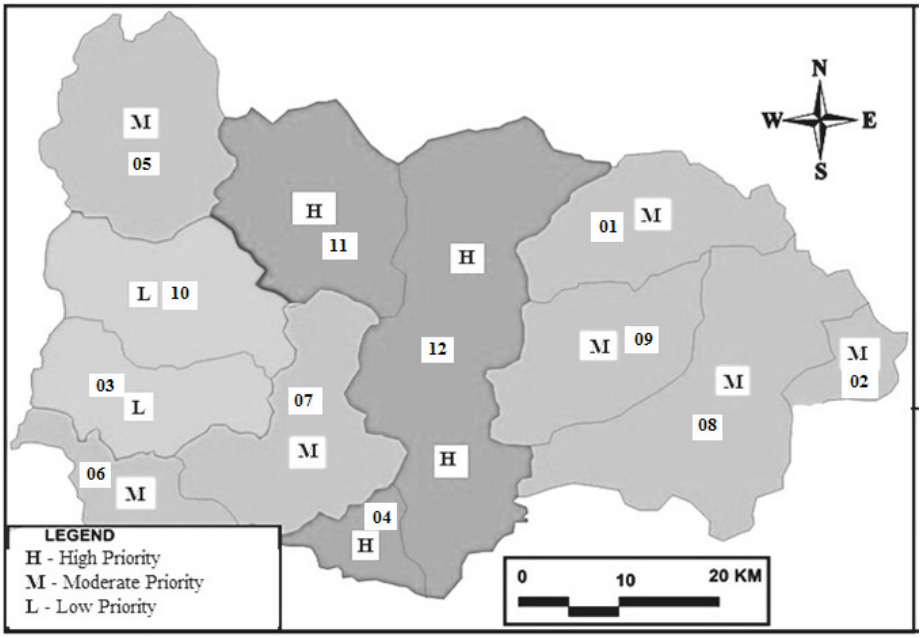


Figure-4
Prioritized Sub-watersheds based on Ranked priority Indices

Suggestions: Some of the elements of sustainability measures that deems essential are: i. In-situ moisture conservation, development and sustainable management of natural and social resources including their rational and sustainable use. ii. Enhancement of agriculture productivity and production in a sustainable manner especially for boosting of land suitability. iii. Restoration of ecological balance in the degraded and fragile rainfed eco-system by greening tree areas through appropriate mix of trees, shrubs and grasses. iv. Reduction in regional disparity between irrigated and rainfed areas, v. Creation of sustainable farming system and generation of other employment for avoiding the overburden on the land. vi. Opportunity for rural community including the landless and to increase the awareness about the fragile character of the land that may bring their danger and may throw their fate into hilly ditch. vii. Equity for resource poor and empowerment of women. Besides these above strategies planning related to reduction of surface runoff, stream water conservation, reclamation of land for increasing productivity for meeting increasing demand, going for more eco-friendly means for agriculture with suitable measures of sustenance are extremely essential for this part of the area, an environmentally sensitive but uniquely picturesque domain.

However, for achieving the major goal and to procurement of sustainability of these major as well as significant sub-watersheds, proper policy and management strategies should be implemented as and when it is necessary for combating the problems.

References

1. Arha R.S. and Sigh L. (2008). Glimpses of Sikkim. ABD Publishers, Jaipur.

2. Bhasin M.K. and Bhasin V. (1995). Sikkim Himalayas. Ecology and Resource Development, Kamla Raj Enterprises, Delhi.

3. Brigadier Gulia K.S. (2005). Human Ecology of Sikkim. Kalpaz Publications, Delhi.

4. Ministry of Environment and Forest (2011). Carrying Capacity Study of Teesta River Basin. 1, Centre for Inter Disciplinary studies of Mountain and Hill Environment, University of Delhi.

5. Ministry of Environment and Forest (2011). Carrying Capacity Study of Teesta River Basin. Centre for Inter Disciplinary studies of Mountain and Hill Environment, University of Delhi, II, III.

6. Chaudhuri B. (2008). Explanatory Brochure on Geological and Mineral Map of Sikkim. Scale 1: 150,000, Geological survey of India, Kolkata.

7. Choudhury M. (2006). Sikkim, Geographical Perspectives. Mittal Publication, New Delhi, 30-70.

8. Arrawatia M.L. and Tambe Sandeep (2012). Climate Change in Sikkim - Patterns, Impacts and Initiatives. Information and Public Relations Department, Government of Sikkim, 289-322.

9. Dhamala R.R. (2014). Problems and Strategies of Development in the Eastern Himalaya. Gyan Publishing House, New Delhi.

10. Nag. P. (2002). District Planning map series, East District, Sikkim, India. NATMO, Kolkata, India.

11. Karan P.P. and Iijima S. (1984). Sikkim Himalaya: Development in a Mountain - Environment. Institute for the Study of Language and Cultures of Asia and Africa, Tokyo.

12. Lal J.S. (1981). The Himalayas: Aspects of Change. Oxford University Press, New Delhi.

13. Nag. P. (2007). Natural Resource Atlas of Sikkim. NATMO, Dept. of Science and Technology, Govt. Of India.

14. Nag P. (2001). Primary census Abstract of Sikkim. Directorate of Census Operations, Government of India, Sikkim.

15. Lama Mahendra Lama (1994). Sikkim: Society, Polity, Economy, Environment. Indus Publishing, Sikkim, India, 201-245.

16. Rai S.C., Sundriyal R.C. and Sharma E. (1988). Sikkim: Perspectives for planning and development. Sikkim Science Society, Sikkim, B. Singh & M.P. Singh, U.P., India, 139-184.

17. Nag. P. (1997). South District, District Planning map series. National Atlas and Thematic Mapping Organisation (NATMO), Kolkata.

18. Subba J.R. (2008). History, Culture and Customs of Sikkim. Gyan Publishing House, New Delhi, 54-90.

19. Subba J.R. (1984). Agriculture in the Hills of Sikkim. Sikkim Science Society, Gangtok, Sikkim, 38-80.

20. Nag. P. (2001). West District, District Planning map series. National Atlas and Thematic Mapping Organisation (NATMO), Kolkata, West Bengal.