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Field-based Tectonic Assessment and Spatial Correlation with Land Use and Land Cover in the Goriganga River Basin

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Abstract:
This research focuses on different morphometric indices including drainage frequency, drainage texture & drainage density and their spatial variation within the Goriganga River Basin which transects with numerous known/ unknown faults and thrusts. Further Land Use and Land cover statitics was prepared to delineate the impact of different land cover classes on morphometric parameters. These morphometric indices and land use and land cover data shows correlation, clearly indicate spatial variation in tectonics. Imprints of such influence clearly appeared on landscape appearance. Drainage network data shows dendritic pattern which follows many known and unknown faults and lineaments in the Goriganga river basin from north to south. To estimate the spatial variation of different components within the Goriganga river basin, the quantification of land use and land cover, morphometric indices and drainage network have done to measure the anomalies that provide significant clues about the intensity of the erosional and tectonic processes and their imprints were documented during detailed field analysis. Land use and land cover data shows that Goriganga river basin is a tectonically carved basin as northern extremities are dominant by glaciaers, regoltihs and barren land while valley areas are dominant by the sparse and dense vegetation. For analyzing the significant relationship between tectonic activities and land use and land cover, the Goriganga river basin is highly suitable basin. Geologically and tectoncally, it is highly active basin due to presence of Main Central Thrust (MCT), Munisiari Thrust (MT) and many unknown faults and thrusts. These active faults and thrusts dominate the tectonics of the basin which also influence the vegetation cover. Mormetricinidces results display that the Goriganga river basin is highly tectonically active. However, in many places or regions, erosional forces override the tectonic process, resulting low drainage density in southern region while high drainage density is associated with faulting and thrusting.

Keywords: *Land Use and Land Cover, Landsat, Morphometric Indices, Field work*

1. INTRODUCTION

Various surface expressions are cited as indicators of netectonic activity viz. surface outcrops of fault gouge, breccia's, hydrothermally altered mineral assemblage zone, faults scarps, ponding of rivers, paleochannels, paleolake deposits, hot springs, stream offsets etc. These surface expressions are studied by many researchers Valdiya, 2001; Schumm et al., 2002; Thakur, 2004, Kothyari and pant, 2008; Joshi et al., 2016; John et al., 2013 and Malik et al., 2014 to assess magnitude and intensity of neotectonic activity in the different regions as well as in Himalaya. In addition, the drainage networks in the tectonically active regionsexpress strong manifestations and influenced by the tectonic forcing and erosional changes, and hence potentially instrumental in decrypting the tectonic status of the area under consideration (for example, Keller et al., 2000; Beneduce et al., 2004; Bull & Mc Fadden, 2007; Bishop et al., 2005; Ribolini and Spagnolo, 2008; Pérez-Peña et al., 2010 and Mumipour and Nejad, 2011). Therefore, the drainage network of the Goriganga river basin in first instance displays tectonic influences which expresses in the form of various landforms, styles and patterns that correspond to the tectonic and erosive forces which, though not measurable in the form of any index, are nevertheless unequivocal indicators of ongoing and/or recent tectonic activity in the Basin.

In the current study, drainage network anomalies, hydrothermally altered zones, land use and land cover and various geomorphic indicators have put forwarded to analyze spatial variation of tectonic activity in the Goriganga river basin. It is evident that the basin transects with number of tectonic structures and lithological formations from north to south. For example, Trans Himadri Fault (THF) that separates the Tethys sediments, lying over the Higher Himalayan Crystallines (HHC) from Vaikrita formation. The Higher Himalaya or Central part of the basin is comprised of Higher Himalayan Crystallines (HHC) which include high grade metamorphic rocks of Precambrian, Paleozoic and Early Mesozoic ages which metamorphosed duering the late Eocene to early Miocene, and intruded by granites of Miocene age (Larson and Godin, 2009; Valdiya, 2001). After passing the Main Central Thrust (MCT) or Munisiari Thrust, the Goriganga flows through Almora Group of rocks and Mandhali Formation near Munisiari (Valdiya, 1980). Before confluencing with Kali River, Goriganga also flows through Rautgarh and Gangolihat Formations which transecting with numerous transverse faults such as Baram Fault (Figure 1). This paper also correlates the intensity and magnitude of different lithotectonic regulators that modify the landscape of the basin and manifested in the form of vegetation pattern and distribution, landscape appearance, drainage network anomalies, hot springs, fault gouges and breccias etc.

2. MATERIALS AND METHODS

2.1 Study Area

The Goriganga river basin lies between latitudes 29°45'03" to 30°35'53" north and longitudes 79°59'10" to 80°29'25" east and originated from Milam glacier which fed it round of the year. This glacier itself originated on the eastern slope of Trishuli and southern slope of Kohli.

Many subsidiary glaciers which are feeding Goriganga river i.e., Hardeol, Mangroon, DeoDamla and Sakram. From Milam to Jauljibi (Outlet), the Goriganga river covers 99.2 km distance and during its journey, it shows number of landforms such as truncated broad floored valleys in the glaciated region, linear ridges, deep canyons, gorges, lakes, stream offsets, fault scarps, hot springs, strong meanders and fault aligned valleys (Figure 3).

The Goriganga nurtures by both glaciated and monsoon climate. Glaciers run its hydrological cycle throughought the year while monsoon produces torrential rainfall that modifies the landscape and drainage pattern in combination. Climatic diversity depicts from north to south aspaleolake was studied by Valdiya (2001), Kotlia and Joshi (2013) and meanders in the southern regions (Farooq et al., 2015). Vegetation pattern also expresses diversity in terms patterm and distribution as it displays dense vegetation in the central and southern part of the basin. Hence, Itcomprises considerable diversity that influences the topographic evolution of monsoon and glacially fed regions of Kumaon Himalaya, creating a distinct morphotectonic zones.

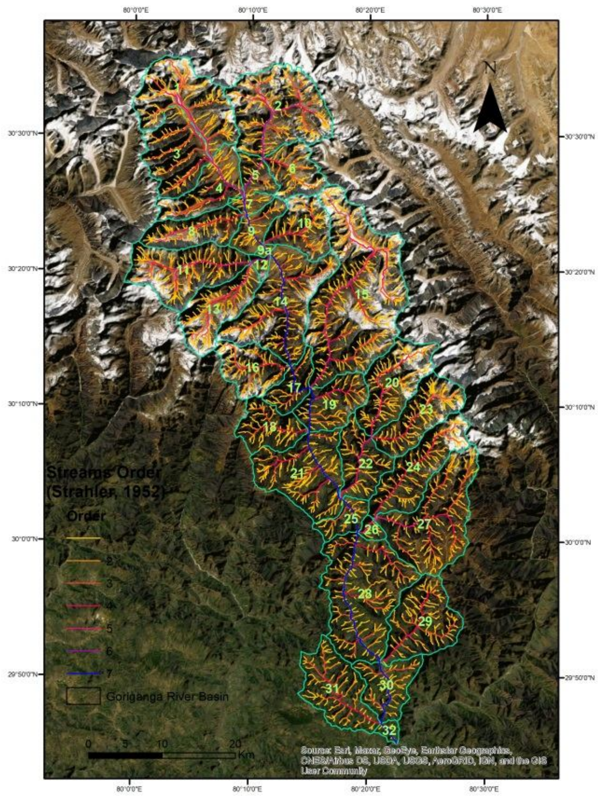

Figure 1: Shows Study Area, drainage network and Watersheds

2.2 Data & Methodology

Advance Spaceborne Thermal Emmission Radiometer (ASTER) Digital Elevation Model was used to decipher detailed drainage network and watershed. These products were further utilized to produce different morphometric indices which were used to extract significant information about landforms and processes that are altering the landscape of the Goriganga river basin.

2.3 Data acquisitition and processing

Initially, deciphered drainage network and watershed was put into GIS environment to validate and georectify its shape and dimensions with published datasets i.e,topographic maps. Utilized topographic maps were downloaded from perrycastanda university web archive for validation and information extraction. For example, locality information was derived from topographic maps. For the prepration of land use and land cover maps, Landsat 8 OLI data was used which was obtained from USGS Earth Explorer. Further, necessary combinations have produced to prepare data for image processing (Figure 2).

Initially, maximum likelihood classification method was adopted to classify a bit more bigger area than Goriganga and classified into optimum number of classes on the basis of field observations, made during two consecutive field visits. Further, Natural Difference Vegetation Index (NDVI) was calculated to derive more better statistics about vegetation in the basin. NDVI results were used to extract pure vegetation classes through masking in the ArcGIS, results of image classification are portrayed in the results section.

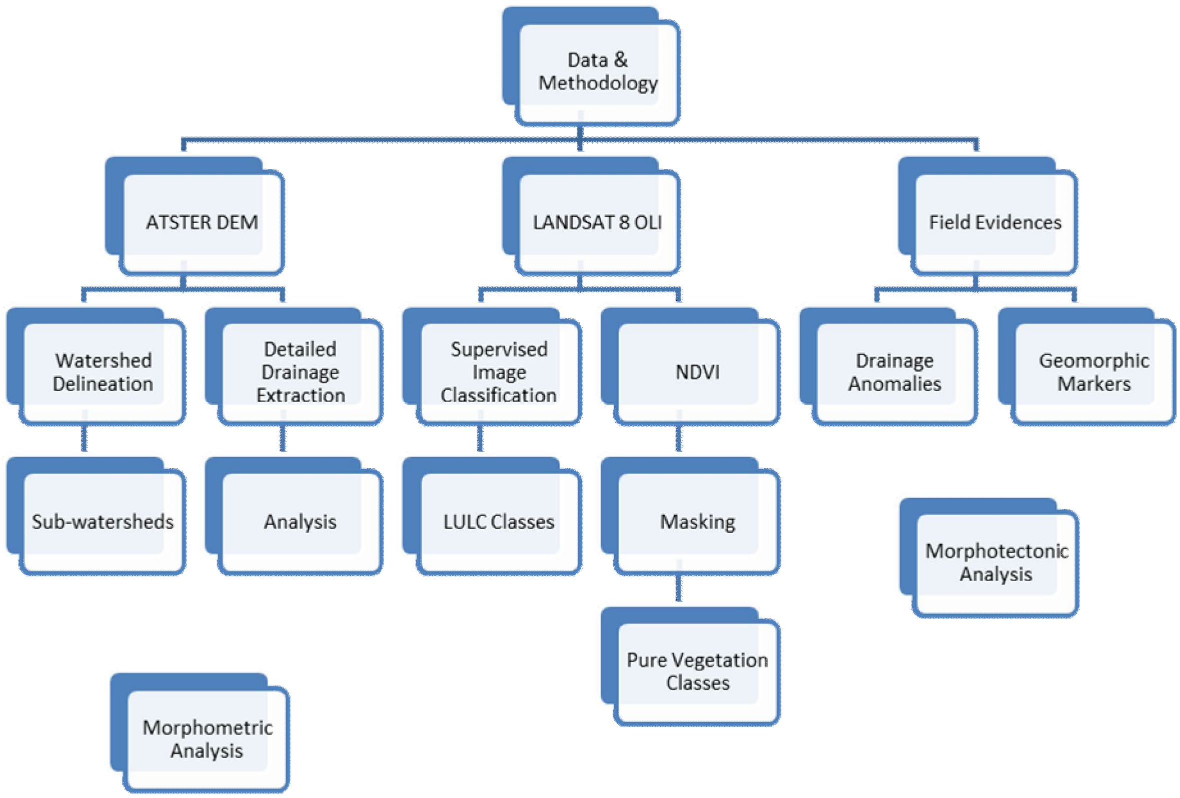

Figure 2: Shows flow chart of data used and methodology

For generating accurate and precise datasets, an intensive field work was made from Jauljibi (Outlet) to Milam (Originating point), to demarcate morphotectonic features such as canyons, linear ridges, offset streams, shutter ridges, dislocations zones, fault scarps, hydrothermal alteration zones, drainage network anomalies, thermal springs and springs etc., pattern recognition about land use and land cover and different landforms (Figure 3).

Figure 3: shows field photographs, depicting various geomorphic signatures

3 RESULTS AND DISCUSSIONS

Supervised Image classification and NDVI were fused to get end image of the Goriganga river basin. Results of the image classification reveal some remarkable facts. The Goriganga river basin comprises of glaciers (26.98%), barren land (44.64%), sparse vegetation (9.23%), Dense vegetation (15.73%) and water (3.39%).

Table 1: Shows total area of the Goriganga river basin and distribution of different land use and land cover classes.

S. No	Name of Class	Area	Percentage
1	Glacier	605.0929	26.98%
2	Barren Land / Regolith	1001.1139	44.64%
3	Sparse Vegetation	207.0074	9.23%
4	Dense Vegetation	352.8106	15.73%
5	Water	76.2108	3.39%
6	Total	2242.2356	100%

Table 2: shows sub-basin wise statistics of LULC and total area of sub-basins.

S.No.	Entity	Total Area	Ice Cover	Regolith	Sparse Veg	Dense Veg	Water
1	SB01	106.08	57.9683	40.9526	0.0144	0.0003	7.1421
2	SB02	129.72	71.7229	48.4256	0.0051	0	9.5643
3	SB03	75.62	18.1555	50.1946	0.0405	0	7.2306
4	SB04	59.58	18.5793	35.1116	0.1295	0.0072	5.7531
5	SB05	22.38	3.9647	16.8765	0.056	0	1.4835
6	SB06	44.45	24.668	16.7208	0.0181	0.0009	3.0491
7	SB07	12.06	1.8197	9.3843	0.0459	0.0009	0.8144
8	SB08	53.1	17.9525	29.399	0.7918	0.1107	4.8537
9	SB09	31.57	5.0653	23.9724	0.6643	0.009	1.8611
10	SB10	54.23	28.4454	22.7498	0.3868	0.0018	2.6496
11	SB11	95.67	43.9064	44.2432	0.6298	0.009	6.883
12	SB12	6.65	1.6657	4.6575	0.2221	0.0108	0.103
13	SB13	67.14	40.8742	24.1701	0.0426	0.0009	2.0574
14	SB14	130.35	37.2202	84.0703	3.9092	1.2858	3.8692
15	SB15	239.88	130.3556	97.1116	3.3383	1.2974	7.7774
16	SB16	52.08	21.6251	27.1134	1.7788	0.8563	0.71
17	SB17	30.65	1.0672	22.1181	5.0157	2.2117	0.2425
18	SB18	47.27	0.8503	28.0813	10.3735	7.7597	0.2106
19	SB19	53.38	3.1917	31.6113	9.0907	9.1017	0.3891
20	SB20	79.6	28.6298	40.5061	5.3217	2.9847	2.1638
21	SB21	105.25	0	28.2957	31.3806	44.8507	0.7258
22	SB22	53.74	0.0931	18.2525	13.3711	21.8183	0.2093
23	SB23	67.93	17.991	41.0912	3.7923	3.2889	1.7773
24	SB24	23.98	0.0009	5.6105	6.8097	11.2226	0.3458
25	SB25	83.44	13.463	37.7058	16.0167	15.3305	0.8074
26	SB26	8.24	0	3.8981	1.9831	2.3285	0.033
27	SB27	127.82	15.6747	79.4908	16.489	15.1359	1.0345
28	SB28	157.4	0.0373	42.5474	34.0148	79.3528	1.4479
29	SB29	85.51	0.1024	27.7914	15.2007	42.3913	0.0277
30	SB30	50.61	0.0027	9.1261	9.3364	31.4786	0.6655
31	SB31	80	0	9.2116	15.3823	55.3274	0.0844
32	SB32	6.86	0	0.6227	1.3559	4.6363	0.2447
	Total	2242.24	605.0929	1001.114	207.0074	352.8106	76.2108

Further, sub-basin wise statistics was calculated to demonstrate the spatial variability of vegetation within the basin to understand the impact of tectonics vice versa in the form of accrued variations.

Results of the image classification were validated through field visit of the study area and further, interpreted in light of calculated morphometric variables. Land use and land cover analysis clearlysuggests multi climate image of the Goriganga river basin, makes it more suitable location to understand tectonic status of the Himalaya.

Most of the north and northeast facing slopes are experiencing low energy distribution, resulting sparse vegetation which is quite similar to lee sides of mountains while other slopes are having comparatively dense vegetation.

Northern region, eastern and western boundaries show alpine glaciation upto a considerable distance while central part uptoBilju shows no vegetation. As fluvial cycle starts from here, very little amount of vegetation is found the down side of the valleys. It is observed that Bogdyar can be considered as junction between vegetated and hardly vegetated regions which is also prominent faulting zone, considered as Bogdyar Shear Zone (Strong meandering). Image classification results also reveal that it displays an erray of linear ridges which are barren and having no vegetation as tributary streams aligned on left bank. In southern region, most of regions are covered with dense vegetation which counted as third division at Kothigaon sub-basin from where dense vegetation is found uptoJauljibi (outlet). However, southern region transects with numerous transverse faults, anticlines and synclines which grows our understanding of earth forms and processes and their linkage between lithosphere, hydrosphere and atmosphere, have led to a better understanding of the relatioships between active tectonics and surface expressions in the form of growing vegetation, their pattern, distribution as well as drainage network and landforms.

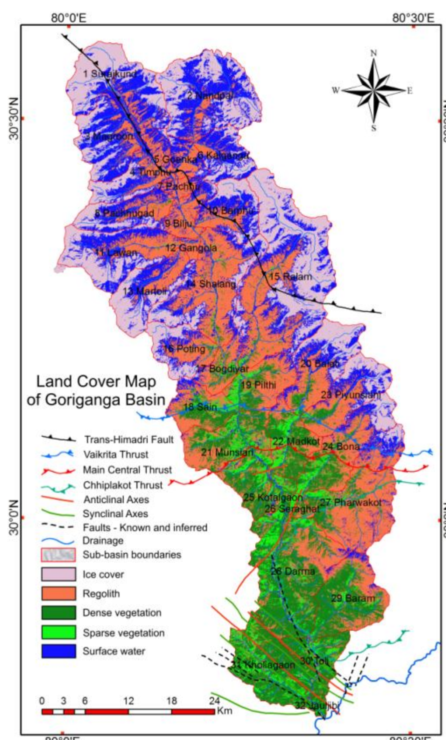

Figure 4: Land Use and Land Cover map of the Goriganga

3.1 Drainage Frequency:

The Stream frequency (Fs) was defined by Horton (1945) to assess the total number of stream segments in a basin of all orders which describe the dissection of the basin. Following formula was used to calculate:

$$Fs = \sum Nu/A$$

Where Nu is the number of all stream segments in a basin and A is the area of the basin.

Stream frequency (Fs) was calculated for 32 sub-basins of the Goriganga river basin and grouped into three classes i.e., class 1 ranges from 0.98 to 1.25, Class 2 ranges from 1.26 to 1.50 and Class 3 ranges from 1.50 to 1.71 (Figure 5).

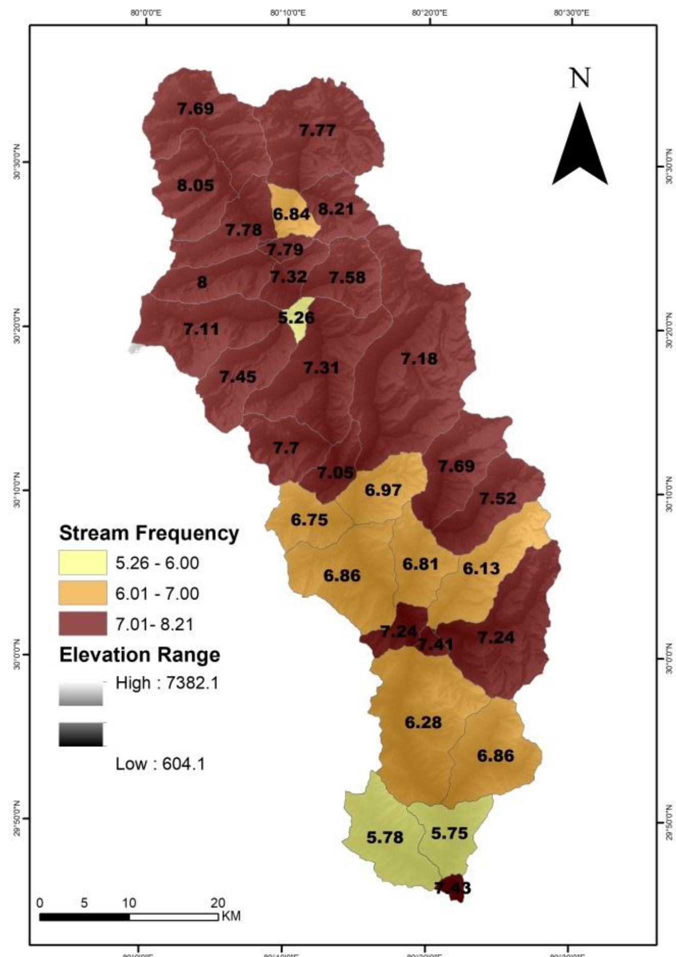

Figure 5: Shows spatial distribution of Drainage Frequency

Results reveal some distibuishable facts that high values of Fs correspond to the less vegetated area while low values are found in vegetated areas. It is also interperetd as dominant fluvial system operates from Bogdyar Shear Zone (BSZ), resulting strong flow of water in the main river system, supports vegetation in the central and southern region which inhibits growth of streams. It is evident that barren land are generally more favorable regions for the flow of water rather than vegetated areas, showing considerably high number of streams. Therefore, high values of stream frequency unequivocally are considered as strong tectonic influence on the evolution of streams which dominates over the erosiove forces such as trunk streams.

3.2 Drainage Density:

The drainage density is defined as the ratio of total length of all stream orders and total area of the basin. This formula was proposed by Horton in 1945 and assessed drainage density as follows.

$$Dd = \sum Lt/A$$

Where Lt is the total length of all streams in the the basin and A is the total area of the basin.

Drainage density values ranges from 1.78 to 2.93 and classified into three classes: class 1 ranges from 1.78 to 2.05, class 2 ranges from 2.05 to 2.47 and class 3 ranges from 2.47 to 2.93.

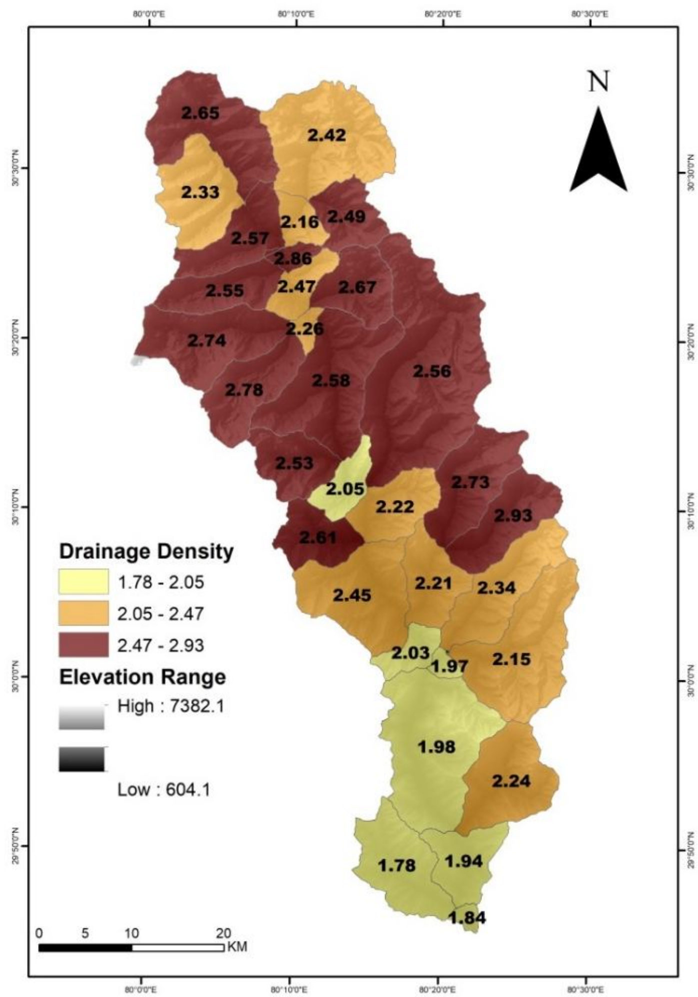

Figure 6: spatial distribution of drainage density in the Goriganga

Results of drainage density prominently follow the treand of stream frequency and vegetation with some exceptions. In central part, low drainage density is found in the Bogdyar region which introduces significant vegetation in the region along with trunk stream. Following it, moderate drainage is density is found upto a considerable distance (Munisiari). Further low drainage density corresponds to the strong erosive forces than tectonic ones. Dense vegetation coupled with low drainage density turn into a lethal combination that enhance frequency of landslides in the southern region along the trunk stream due to more infiltration of water in adjacent rocks or strata in the event of torrential and consistent rainfall during monsoon.

However, drainage density is influenced by the many factors viz. rock types, resistance to erosion of rocks, infiltration capacity of the basin and climatic conditions (Verstappen, 1983).

It is clear that many tributary streams as well as trunk stream follow faults and thrusts, run upto a considerable distance at some places while Influence of lithological domains can not be neglected as northern region conpmrises of Tethys sediments, Higher Himalayan Crsytalline (HHC), Central region made up of Almora Group of rocks and southern region lies in the Rautgarh and Mandhali Formations.

3.3 Drainage Texture:

In 1945, Horton was assessed and proposed a formula to understand the channel spacing in a fluvial dissected region which is calculated by the following equation.

$$Ts = Dd x Fs$$

Where Dd is drainage density and Fs is stream frequency.

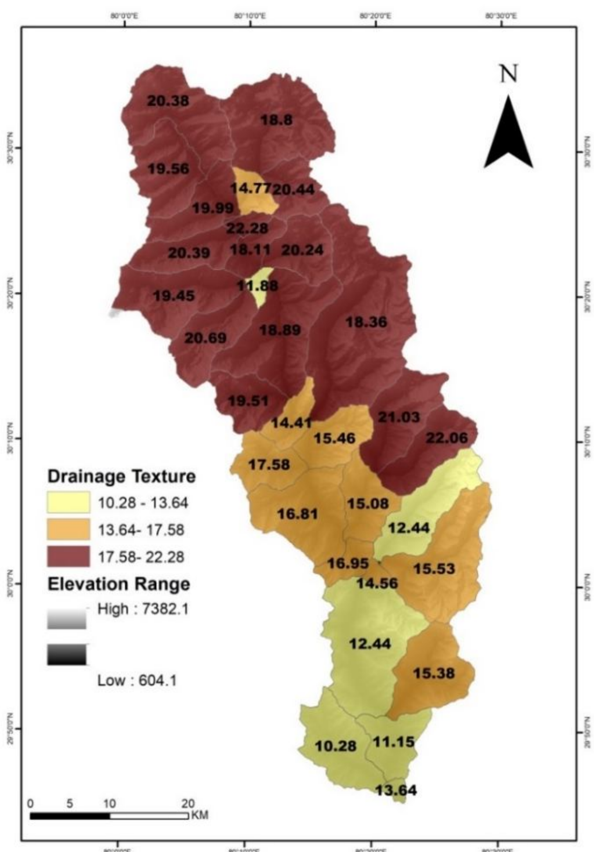

Figure 7: Shows spatial variability drainage texture

Results ranges from 10.28 to 22.28 which further classified into three classes viz. Class 1 ranges between 10.28- 13.64, Class 2 ranges between 13.64- 17.58 and Class 3 ranges between 17.58-22.28. It depends upon number factors such as climate, rainfall, vegetation, rock and soil types. In general, Goriganga river basin shows high values of drainage texture in the northern and central part which indicate strong tectonic control.

It is apparent that glaciers carve their valleys rapidly and incisely in comparison of streams due to its gravitational movements where major blocks of ice displace from one place to other, resulting truncated braod floored valleys in the northern extremity, witnessed as presence of Trans Himadri Fault (THT).

As river approaches fluvial system, distinctively shows lower values of drainage texture. In the southern extremity, lower values correspond to dense vegetation while these sub-basins are transecting with numerous synciline, anticlies, faults and thrusts running transverse to the main grain of the Himalaya.

3.4 Drainage Density versus Drainage Frequency:

Comparison matrix of Dd and Fs indicate spatial variability of landform evolution and drainage development in a basin. In the current study, comparison of these two can highlight the more significant clues about tectponic as well as geomorphic status of the Goriganga basin rather than individual index.

Comparison graph shows that drainage density is accumulating correspondingly moderate values while drainage frequency is having high (sub-basin 17).

Sub- basin 17 transects with Bogdyar Shear Zone (BSZ), resulting strong meander which is translated into high values of Frequency of streams (Fs). It indicates strong tectonics rather than erosion due to presence of Munisiari Thrusts (MT) and Vaikrita Thrust (VT).

Reactivation of Munisiari and Vaikrita thrusts was suugested by Apatite Fission Tarck (AFT) and Zircon Fission Track (ZFT) observations (Patel et al. (2011) which depict topographic and exhumation steady state since 4 Ma. Correspondigly high values of drainage density and frequency at the eastern bank indicates strong quiscence between tectonic and erosional forces where tectonic forces are more dominant than erosional (Figure 9).

Upper catchment of Goriganga river basin consists of Higher Himalayan Crystallines (High grade metamorphic rocks) and transecting with many active faults and thrusts which influence the region thorugh severe faulting and fracturing. Further, this is interpreted as high values of different morphometric indices and less vegetation. A parallel perspective is that the area lies at higher altitude which does not support vegetation. While dense vegetation in the southern region is acting as shock abosrober to tectonic forces that are altering the basin and may reduce effects of faulting, cracking of strata, resulting low drainage density as well as frequency. It is also observed that tributary sub-basins are showing correspondingly high values of Dd and Fs due to barren surfaces which provide sufficient surfaces to flow of water.

Drainage texture shows that southern densly vegetated region displays far spaced river channel, witnessed in the form of low drainage texture. Low values are interpreted as the trunk stream is carving and eroding strata at fast rate rather than tributary streams as well as upper catchment, resulting less chance of development of more streams comparatively. Field data suggests that low lying regions of the valley show dense vegetation while upper parts having no or sparse vegetation. In addition, high slope linear ridges allow swift flow of rain water while in down valley dense vegetation inhibits growth of drainage scars, evidenced through field data (Figure 8).

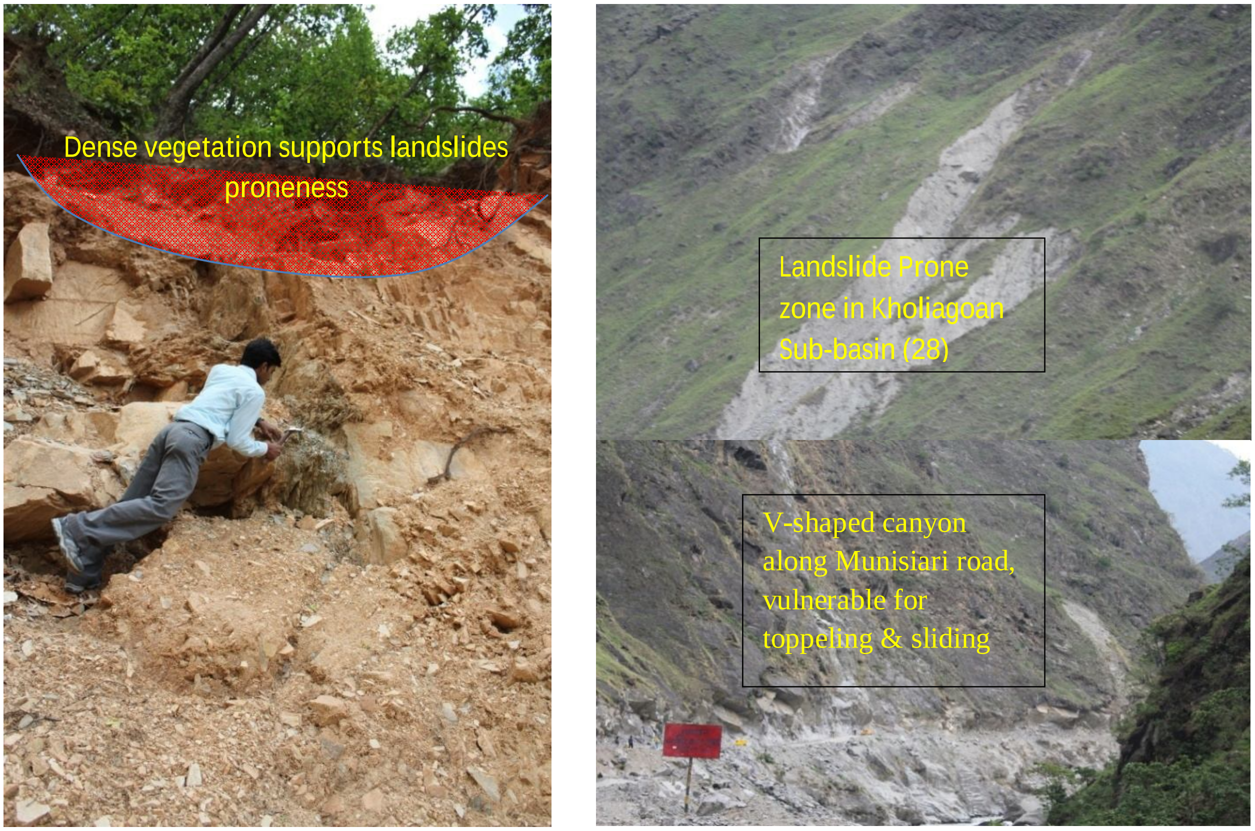

Figure 8: Shows impacts of dense vegetation on tectonic vice versa and frequency of landslides in southernmost region of the Goriganga river basin

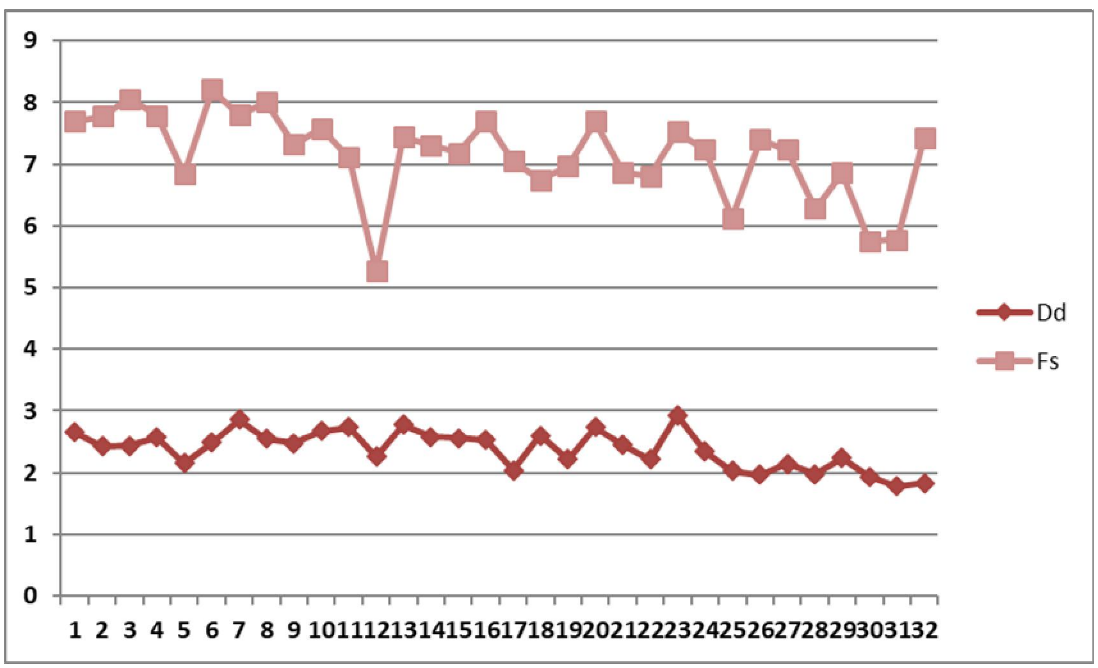

Figure 9: Shows comparison matrix of drainage density and drainage frequency

4 CONCLUSIONS

It is concluded that remote sensing and GIS is an efficient technique to assess the spatially variable neotectonic activity in any region of the world. However, data resolution may limit the details.

Goriganga river basin is highly tectonically active basin which shows distinctive morphotectonic zones, separated by transvers faults and thrusts. However, high velocity river also marks their presence in the form of cutting their valleys.

It is found that southern region experiences low values of drainage density, drainage frequency and texture due to presence of dense vegetation along trunk stream in the valley sub-basins. Howver, barren exposures are showing high values, means more number of drainage to flow water. Further, it is added that high drainage density is also attributed to flash flood at the outlet of tributary rivers.

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