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Terrain Analysis of the Gori Ganga Watershed by Using Geospatial Techniques

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ABSTRACT

Terrain analysis is the interpretation and analysis of topographical features through Geographic Information System (GIS). Terrain is represents of cartographic of the broad scale physical regions of the study area, often based on Digital Elevation Model (DEM) i.e. elevation, slope, aspect and contour lines etc. The Gori Ganga watershed lies between the Great and Lesser Kumaun Himalayan region. The elevation of this watershed varies in between 626 m at Jauljibi to 6639 m in the snow capped mountains. The valleys are mostly steep down merging the river Gori Ganga come apart by perennial very small stream emerging through the forest covers of the river basin. For the study of terrain analysis of Cartosat-1 satellite image of time period 2008 was used. Importance of Terrain analysis studies suggest that indentifying most appropriate sites for horticulture, solar energy plant using relief, slope and aspect map of Gori Ganga watershed.

Key Words: DEM, Relief, Slope, Aspect, Remote Sensing and GIS

1.0 INTRODUCTION

Terrain/Relief maps are important geographic and everyday tools that allow us to see geography in three dimensions (vertical and horizontal) of land surface and terrain is usually expressed in terms of the elevation, slope and orientation of terrain features (Rowland, 1955). Terrain assists the understanding of watershed boundaries, environmental quality, supports soil conservation, agriculture, drainage characteristics, drainage systems, groundwater systems, water movement and impacts on water quality of an area (Baker and Capel, 2011).

Slope is the measure of steepness or the degree of inclination of a feature relative to horizontal plane and slope is typically expressed as a percentage, angle and ratio (after www.geokov.com). The slope of land is an important geo spatial parameter for all geographical study which is refers to the elevation difference between two points of a unit distance and meaning of slope is the rise and fall of the earth surface which studying is very important for the studies like hydrological models (Jenson, 1994); landslide analysis (Duan and Grant, 2000); soil erosion (Biesemans et al. 2000); geomorphology, avalanches, farming, irrigation and settlement (Balasubramanian, 2007). Esteban et al. (2017), study presents slope maps are used to represent the land relief with in contrast to topographic maps where the altimetry is represented numerically with color bands and the slope values correlation to the angle (in degrees) of the ground surface. For slope calculation algorithms employed Esteban et al. (2017) and Wessel et al. (2013) was used Generic Mapping Tools (GMT) software V. 5.1 for generate slope grid from the General Bathymetric Chart of the Oceans (GEBCO) and resulting slope grid has the same spatial resolution as the original data grid. Other one popular slope calculation algorithms employed Chang et al. (2013), derived from DEM that is based on raster data structure used in Arc GIS software's for given the

importance of slope estimations in these applications.

Importance of aspect delineation can have a strong influence on temperature because of the aspect angle of the sun in the northern hemisphere the northern side of aspect is often shaded, while the southern side aspect receives more solar radiation because of southern aspect is tilted toward the sun (Jonathan et al., 2006). An aspect map simultaneously shows the direction for the continuous surface and aspect directions categories are symbolized by using brilliances of color (Buckley, 2008). Importance of aspect delineation of the study area can have a strong influence on temperature because of the aspect angle of the sun in the northern hemisphere (i.e. Gori Ganga Watershed is in Northern Hemisphere), the north side of aspect is often shaded, while the southern side aspect receives more solar radiation because of southern aspect is tilted toward the sun. Direction of aspects can make influences on its micro climate (local climate i.e. Gori Ganga watershed). In the Himalayan regions effect can be seen with south facing aspect being warm, wet and forested and north facing aspect cold, dry and much more glaciated (Eriksson et al., 2009).

2.0 LOCATION AND EXTENT

The study area, viz., the Gori Ganga watershed (Kumaun Himalaya) (Fig. 1) extends between 29045’0’’N to 30035’47’’N latitudes and 79059’33’’E to 80029’25’’E longitudes, and encompasses an area of about 2191.63 km2 (Parihar, 2021). Internationally known Milam glacier lies in this watershed from which the Gori Ganga River originates. It is a valley glacier having compound basin belonging towards south east from the Trisul peak. The Milam glacier is the second largest glacier of the Kumaun Himalaya. The glacier is 16.7 km long and it receives ice from the Trishul peak and from seven other tributary glaciers of the Gori Ganga watershed. The Gori Ganga watershed has 168 villages and total population is about 40616 as per 2011cencess. Munsyari remains one of the last accessible hill stations by motor road in the region. The Munsyari and Madkote towns located in the study area are currently the starting point for many track routes into the Himalayan interior. Munsyari town one of its key advantages is the superb backdrop that is provided by the high Himalayan Pancha-Chooli range, in full view. It is an awe inspiring place surrounded by undisturbed nature and high mountains. Land uses spread across region comprise settlements, terraced farms, Van Panchayat (forests governed by village forest councils), reserve forests and the Askote Musk Deer Sanctuary.

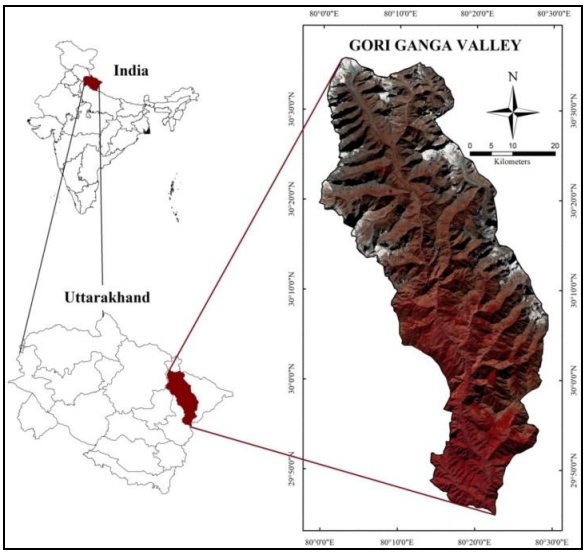

Figure-1: Location map of the Gori Ganga watershed, Kumaun Himalaya (Uttarakhand).

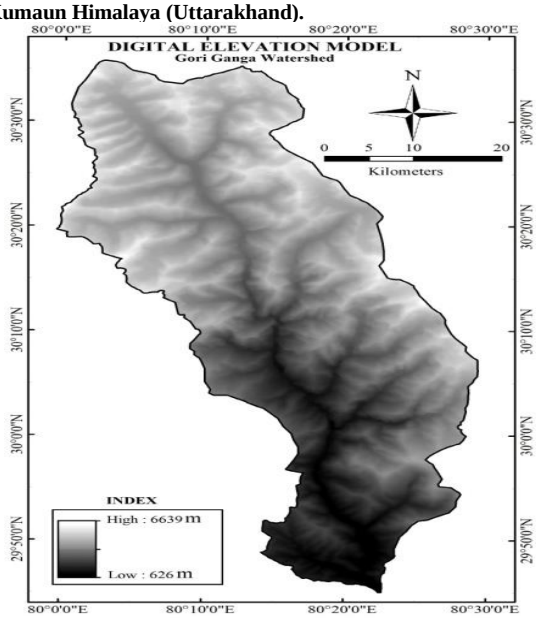

Figure-2: Digital elevation model of the Gori Ganga watershed (based on Cartosat-1 satellite, data).

3.0 METHODOLOGY

To examine the terrain in the Gori Ganga watershed, Cartosat-1 satellite image, DEM was used after Centre of Excellence for Natural Resources Data Management System (NRDMS) in Uttarakhand, Department of Geography, Kumaun Universitym, S.S.J. Campus, Almora. The image used in the present study is Cartosat-1 of 2008 at 2.5 m resolution. This image helped in understanding of the terrain areas in the watershed. The elevation of the Gori Ganga watershed varies between 626 m and 6639 m (Fig. 2) based on Cartosat-1 satellite data. The slope map (Fig. 5) of the study area was generated through the DEM using Arc GIS software tools which is navigate to system toolboxes select spatial analysis tool than select surface and Slope. This map describes slopes for every rater cells in degrees based on the every elevation point. Using of DEM aspect map (Fig. 7) of the Gori Ganga watershed was delineating with Arc GIS software tools. Village data based on Censes of India 2011 which is use in Figure 4, 6 and 8. This involves tools under spatial analyst tool select surface and aspect. Aspect map displays the every raster cell grouped into compass directions (i.e. north, northeast etc.).

4.0 RESULT AND DISSCUSSION

The results obtained through the analysis Digital Elevation Model (Fig. 2) image diagrammatically illustrated in Figure 3 depict relief analysis and registered in Table- 1. Figure 4 depicts geographical distribution of villages on relief groups which is registered in Table- 2. Figure 5 depicts slope analysis and registered in Table- 3. Figure 6 depicts geographical distribution of villages on slope zones which is registered in Table- 4. Figure 7 depicts aspect analysis and registered in Table- 5. Figure 8 depicts of geographical distribution of villages on aspects zones which is registered in Table-6. A brief account of these results it's discussed in the following paragraphs.

5.0 RELIEF

The Digital Elevation Model (DEM) of the Gori Ganga watershed (Fig. 2) developed by using Cartosat-1 data at 2.5 m resolution, depicts that in the study area, elevation varies between 626 m to 6639 m. Using this high resolution DEM data the study area is divided in to four relief zones. These are:

(i) Low relief zone (<1000m)
(ii) Medium relief zone (1000-3000m)
(iii)High relief zone (3000-5000m)
(iv)Very high relief zone (>5000m)

Figure 3 depicts the spatial distribution of above relief zones and the distribution of area under these relief zones is presented in Table 1. Figure 4 provides distribution of villages in different altitudinal zones and the summary of these villages in different altitudinal zones is given in Table 2. A brief description of different relief zones is presented in the following paragraphs.

Table-1: Distribution of relief zones in the differential altitudinal groups of the Gori Ganga watershed, Kumaun Himalaya (based on Cartosat-1 Satellite data).

Altitudinal groups (m)	Area		Cumulative area		Relief zones
	In km^2	In %	In km^2	In %	
<1000	34.52	1.57	34.52	1.57	low
1000-3000	636.17	29.03	670.69	30.60	medium
3000-5000	1133.73	51.73	1804.42	82.33	high
>5000	387.21	17.67	2191.63	100	very high

Table-2: Distribution of villages under differential relief zones of the Gori Ganga watershed Kumaun Himalaya (based on Censes of India and Cartosat-1 satellite data).

Relief zones (in m)	No. of villages	villages in %	Relief zones (in m)	No. of villages	villages in %
0-500	0	0	2500-3000	1	0.59
500-1000	13	7.74	3000-3500	12	7.14
1000-1500	49	29.17	3500-4000	1	0.59
1500-2000	64	38.10	>4000	0	0
2000-2500	28	16.67	Total	168	100

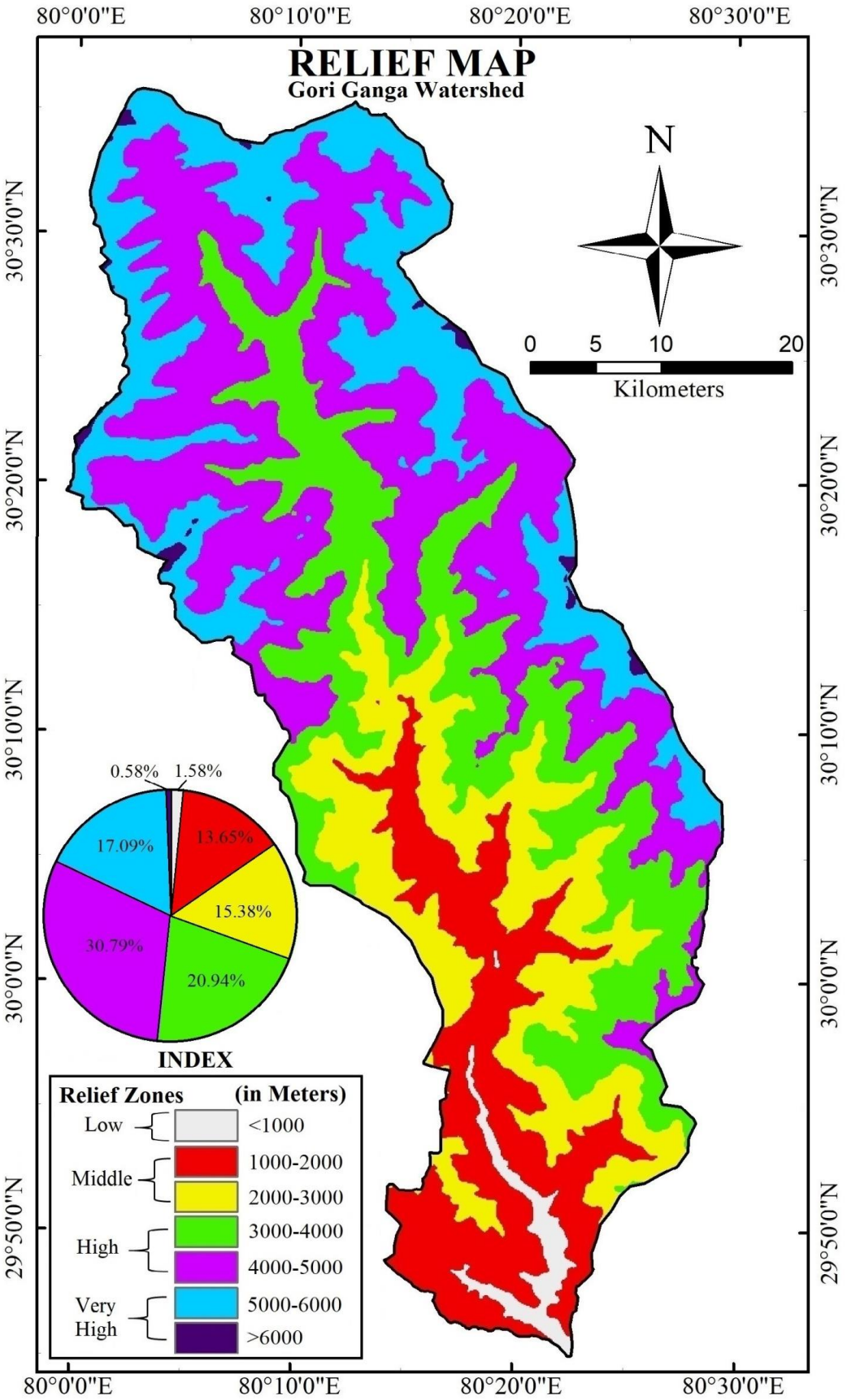

Figure-3: Relief map of the Gori Ganga watershed Kumaun Himalaya (based on Cartosat-1 satellite data).

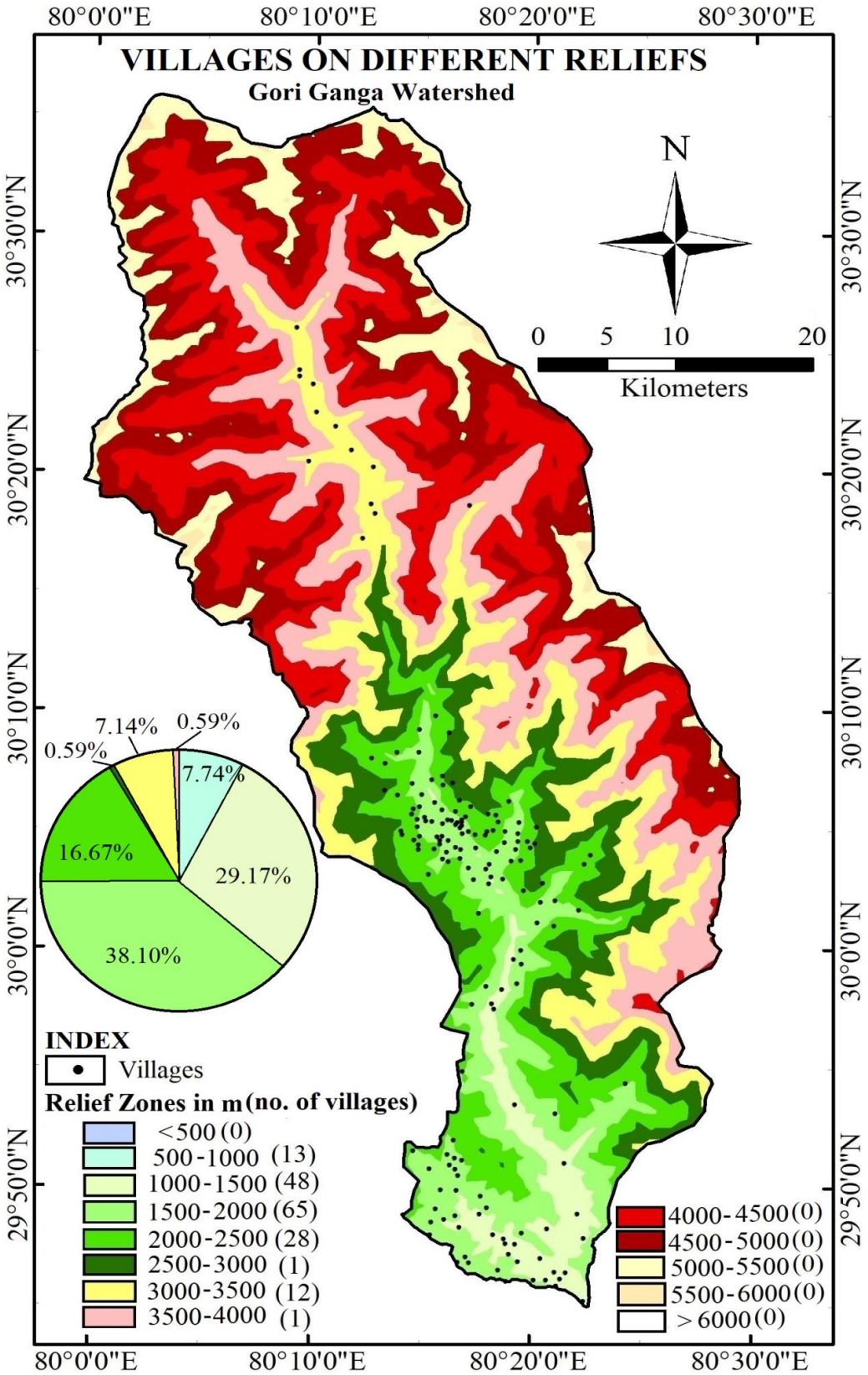

Figure-4: Distribution of villages on different altitude zones of the Gori Ganga watershed, Kumaun Himalaya (based on Censes of India and Cartosat-1 satellite data).

5.1 Low Relief Zone: The low relief zone of the Gori Ganga watershed includes the entire area having elevation below 1000 m from the mean sea level (Fig. 3). Table- 1 reveals that about 34.52 km2 area (smallest area of relief zone) of the watershed which

accounts for 1.57% area of the total watershed area, falls under the low relief zone. About 7.74% villages (total 13 villages) of the Gori Ganga watershed are situated in this low relief zone (Fig. 4, Table- 2).

5.2 Medium Relief Zone: The medium relief zone of the Gori Ganga watershed includes area which varies in between 1000-3000 m in height from the mean sea level (Fig. 3). This zone is second largest relief zone of the study area (636.17 km2, Table-1) which includes about 29.03% area of the total watershed. About 84.72% villages (total 144 villages) of the study area are situated in this medium relief zone (Fig. 4 and Table- 2).

5.3 High Relief Zone: This relief zone of the watershed includes the area which varies in between 3000-5000 m height from the mean sea level (Fig. 3). Table- 1 reveals that about 1133.73 km2 which accounts about 51.73% area of the total watershed area has high relief zone (Fig. 3). About 7.74% villages (total 13 villages) of the study area are situated in the high relief zone of the Gori Ganga watershed (Fig.4 and Table- 2).

5.4 Very High Relief Zone: This relief zone of the Gori Ganga watershed includes the area which lies above 5000 m in height from mean sea level (Fig. 3). Table 1 reveals that about 17.67% (total 387.21 km2) area of total watershed has very high relief zone. This relief zone is without villages due to adverse topographic and extreme climate conditions (Fig. 4, Table-2).

6.0 SLOPE

The slope map (Fig. 5) of the study area was generated at 2.5 m resolution through the DEM (Fig. 2) using Arc GIS software tools which is navigated to system toolboxes to select spatial analysis tool than select surface and slope. This map describes slopes for every raster cell in degrees based on the every elevation point. The spatial distribution of five different slope zones is depicted by Figure 5 and distribution of area under different slope groups of Gori Ganga watershed is registered in Table 3. Distribution of villages under different slope zones of the Gori Ganga watershed is presented in Figure 6 and Table 4. These are:

(i) Gentle slope (<100)
(ii) Moderate slope (100-200)
(iii)Steep slope (200-300)
(iv)Very steep slope (300-400)
(v) Very high steep slope (>400)

A brief description of above five slope categories is presented in the following paragraphs.

Table-3: Distribution of area under different slope categories in the Gori Ganga watershed (based on Cartosat-1 satellite data).

S.N.	Slope zones name	Slope groups (in degrees)	Area		Cumulative area	
			km^2	percentage	km^2	percentage
1	Gentle slope	<10	180.99	8.26	180.98	8.26
2	Moderate slope	10-20	406.59	18.55	587.58	26.81
3	Steep slope	20-30	683.09	31.17	1270.67	57.98
4	Very steep slope	30-40	600.69	27.41	1871.36	85.39
5	Very high steep slope	40-50	247.29	11.28	2118.65	96.67
		50-60	64.69	2.95	2183.34	99.62
		>60	8.29	0.38	2191.63	100

Table-4: Distribution of villages under different slope categories in the Gori Ganga watershed (based on Censes of India and Cartosat-1 satellite data).

S.N.	Slope zones	Slope groups (in degrees)	villages	
			in number	in percentage
1	Gentle slope	<10	21	12.5
2	Moderate slope	10-20	56	33.33
3	Steep slope	20-30	58	34.52
4	Very steep slope	30-40	25	14.88
5	Very high steep slope	40-50	7	4.17
		50-60	1	0.6
		>60	0	0
Total			168	100

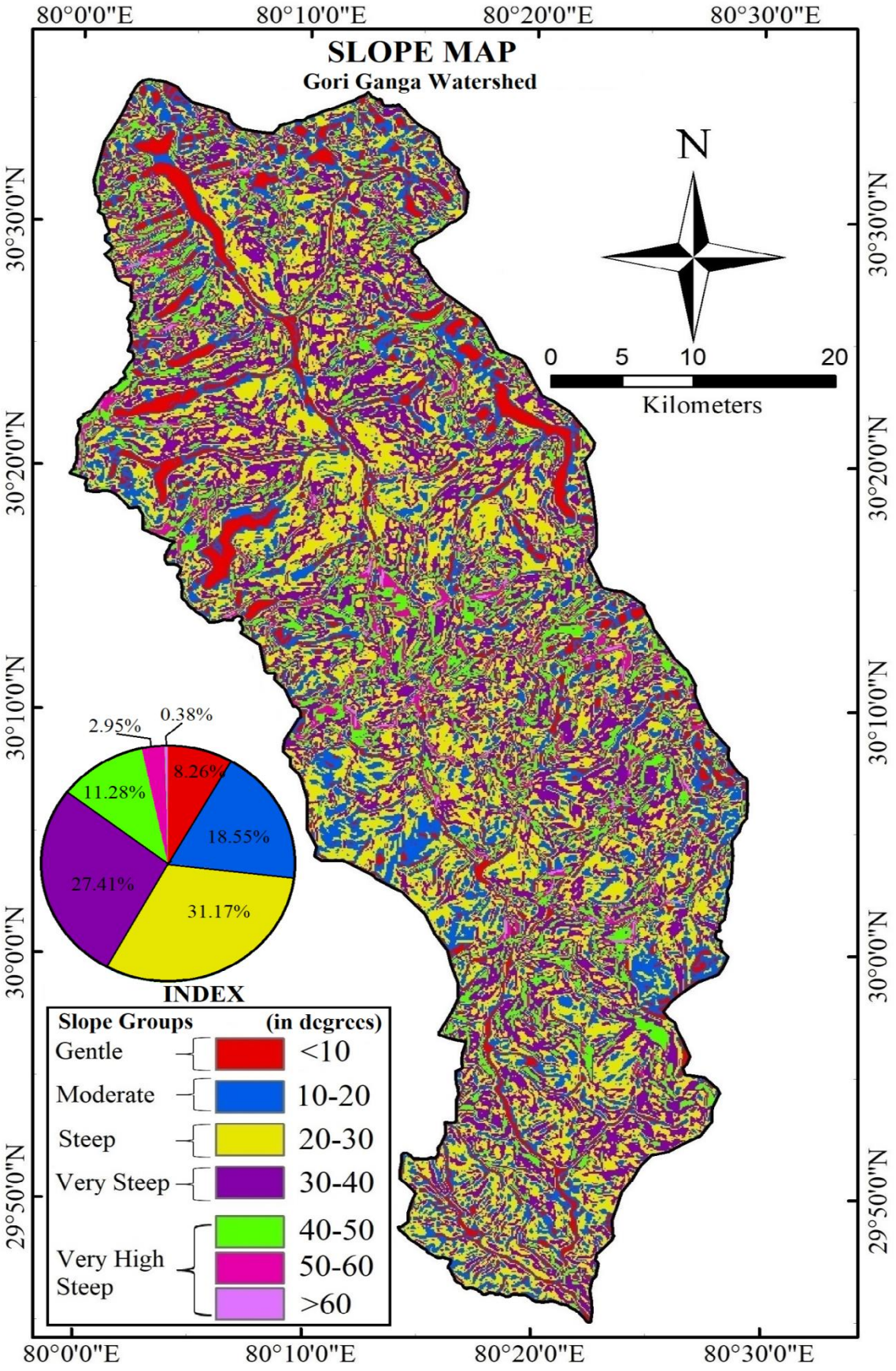

Figure-5: Slope map of the Gori Ganga watershed, Kumaun Himalaya (based on cartosat-1 satellite data).

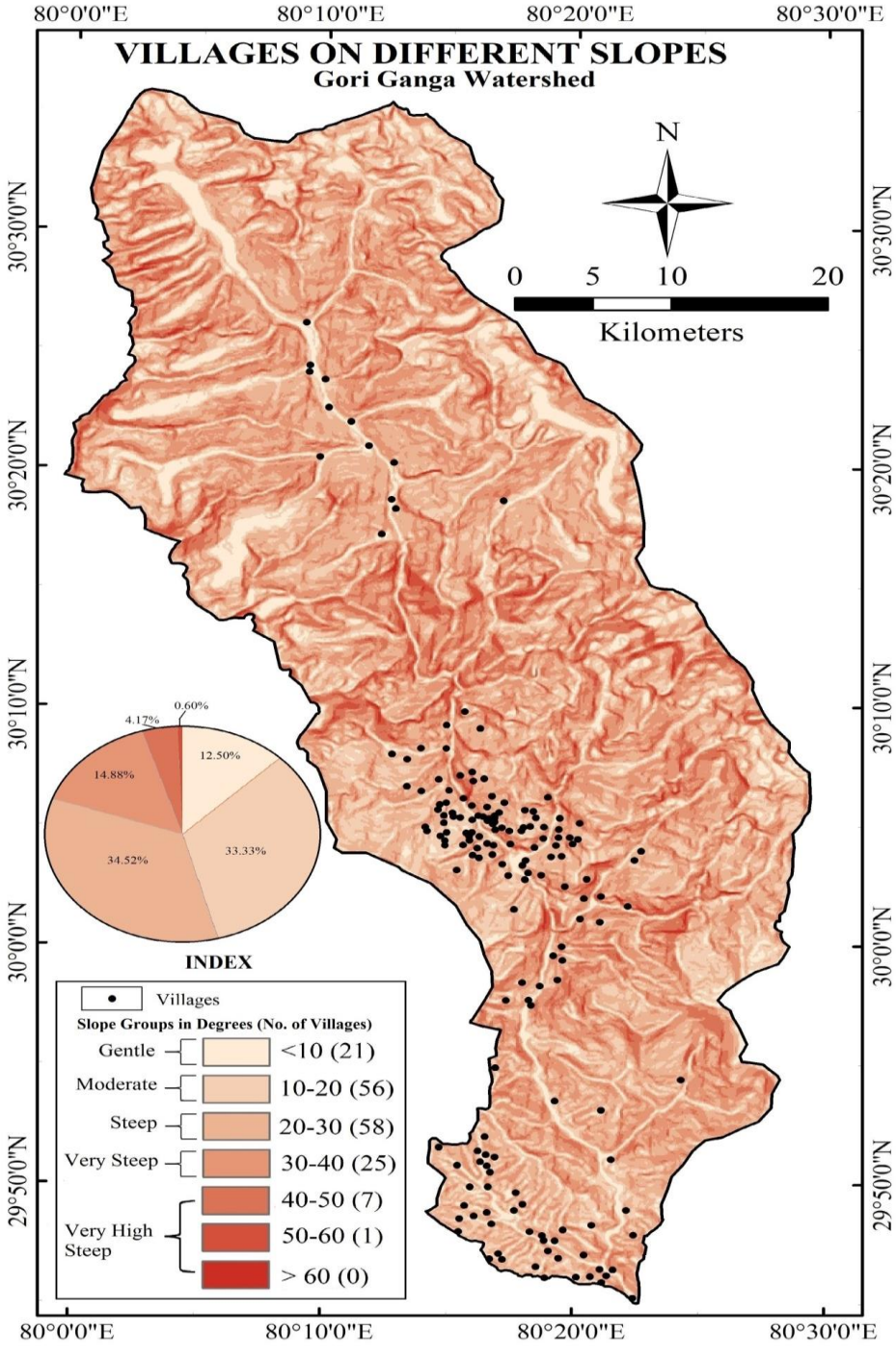

Figure-6: Distribution of villages on different slope categories of Gori Ganga watershed, Kumaun Himalaya (based on Censes of India and Cartosat-1 satellite data).

6.1 Gentle Slope Zone: The gentle slope zone of the Gori Ganga watershed includes area where slope varies below 10 degree. Table 3 reveals that about 180.99 km2 which accounts for 8.26% area of the total watershed area has gentle slope (Fig. 5). About 12.5% villages (total 21 villages) of the study area are situated in the gentle slope category in the Gori Ganga watershed (Fig. 6 and Table 4).

6.2 Moderate Slope Zone: The moderate slope zone of the Gori Ganga watershed includes area in which slope varies in between 10-20 degree. Table 3 reveals that about 683.09 km2 which accounts for 18.55% area of the total watershed area has moderate slope (Fig. 5). About 33.33% villages (total 56 villages) of the study area are situated in the moderate slope category

of the Gori Ganga watershed (Fig. 6 and Table 4).

6.3 Steep Slope Zone: The steep slope zone is the largest slope zone of the Gori Ganga watershed in which slope varies in between 20-30 degree. Table 3 reveals that about 406.59 km2 which accounts for 31.17% area of the total watershed area has steep slope (Fig. 5). About 34.52% villages (total 58 villages) of the study area are situated in the steep slope zone of the Gori Ganga watershed (Fig. 6 and Table 4).

6.4 Very Steep slope Zone: The very steep slope zone is the second largest slope zone of the Gori Ganga watershed in which slope varies in between 30-40 degree. Table 3 reveals that about 600.69 km2 which accounts for 27.41% area of the total watershed area has very steep slope (Fig. 5). About 14.88% villages (total 25 villages) of the study area are situated in the very steep slope zone of the Gori Ganga watershed (Fig. 6 and Table 4).

6.5 Very High Steep Slope Zone: The very high steep slope zone of the Gori Ganga Watershed includes area having slope more than 40 degree. Table 3 reveals that about 320.27 km2 which accounts for 14.61% area of the total watershed area has very high steep slope (Fig. 5). About 4.77% villages (total 8 villages) of the study area are situated in the very high steep slope zone of the Gori Ganga watershed (Fig. 6 and Table 4).

7.0 ASPECT

Direction of aspects can make influences on its micro climate. Using of DEM (Fig. 2) aspect map (Fig. 7) of the Gori Ganga watershed was prepared through Arc GIS software tools. Aspect map displays every raster cell grouped into compass directions (i.e., north, northeast etc.). The spatial distribution of different aspects in the study area is depicted by Figure 7. A detailed account of areas of these different aspects is presented in Table 5. Distribution of villages under different aspect zones of the Gori Ganga watershed is presented in Figure 8 and Table 6. The aspect zones of the study area are:

(i) Northern (337.50-22.50)
(ii) North Eastern (22.50-67.50)
(iii)Eastern (67.50-112.50)
(iv)South Eastern (112.50-157.50)
(v) Southern (157.50-202.50)
(vi)South Western (202.50-247.50)
(vii) Western (247.50-292.50)
(viii) North Western (292.50-337.50)
(ix)level land (00)

Table-5: Distribution of area under different aspect zones of the Gori Ganga watershed, Kumaun Himalaya (based on Cartosat-1 satellite data).

S. N.	Aspect zones	Aspect in Degree	Area		Cumulative Area	
			in km^2	in %	in km^2	in %
1	Northern	337.5-22.5	221.27	10.1	221.27	10.1
2	North-Eastern	22.5-67.5	252.39	11.51	473.66	21.61
3	Eastern	67.5-112.5	233.59	10.66	707.25	32.27
4	South-Eastern	112.5-157.5	361.89	16.51	1069.14	48.78
5	Southern	157.5-202.5	238.39	10.88	1307.53	59.66
6	South-Western	202.5-247.5	310.99	14.19	1618.52	73.85
7	Western	247.5-292.5	265.69	12.12	1884.21	85.97
8	North-Western	292.5-337.5	304.09	13.88	2188.30	99.85
9	Level land	0^0 in North	3.33	0.15	2191.63	100

Table-6: Distribution of villages under different aspects of the Gori Ganga watershed, Kumaun Himalaya (based on Censes of India and Cartosat-1 satellite data).

S. N.	Aspects	Aspect in degree	Villages in different aspects	
			in number	in %
1	Northern	337.5-22.5	7	4.17
2	North-Eastern	22.5-67.5	28	16.67
3	Eastern	67.5-112.5	21	12.5
4	South-Eastern	112.5-157.5	24	14.29
5	Southern	157.5-202.5	16	9.52
6	South-Western	202.5-247.5	31	18.45
7	Western	247.5-292.5	20	11.90
8	North-Western	292.5-337.5	21	12.5
9	Level land	0^0 in North	0	0
Total			168	100

7.1 Northern Aspect Zone: The northern aspect zone of the Gori Ganga watershed includes area which varies in between 337.5-22.5 degrees. Table 5 reveals that about 221.27 km2 which accounts for 10.1% area of the total watershed has northern aspect (Fig. 7). About 4.17% villages (total 7 villages) of the study area are situated in the northern aspect of the Gori Ganga watershed (Fig. 8 and Table 6).

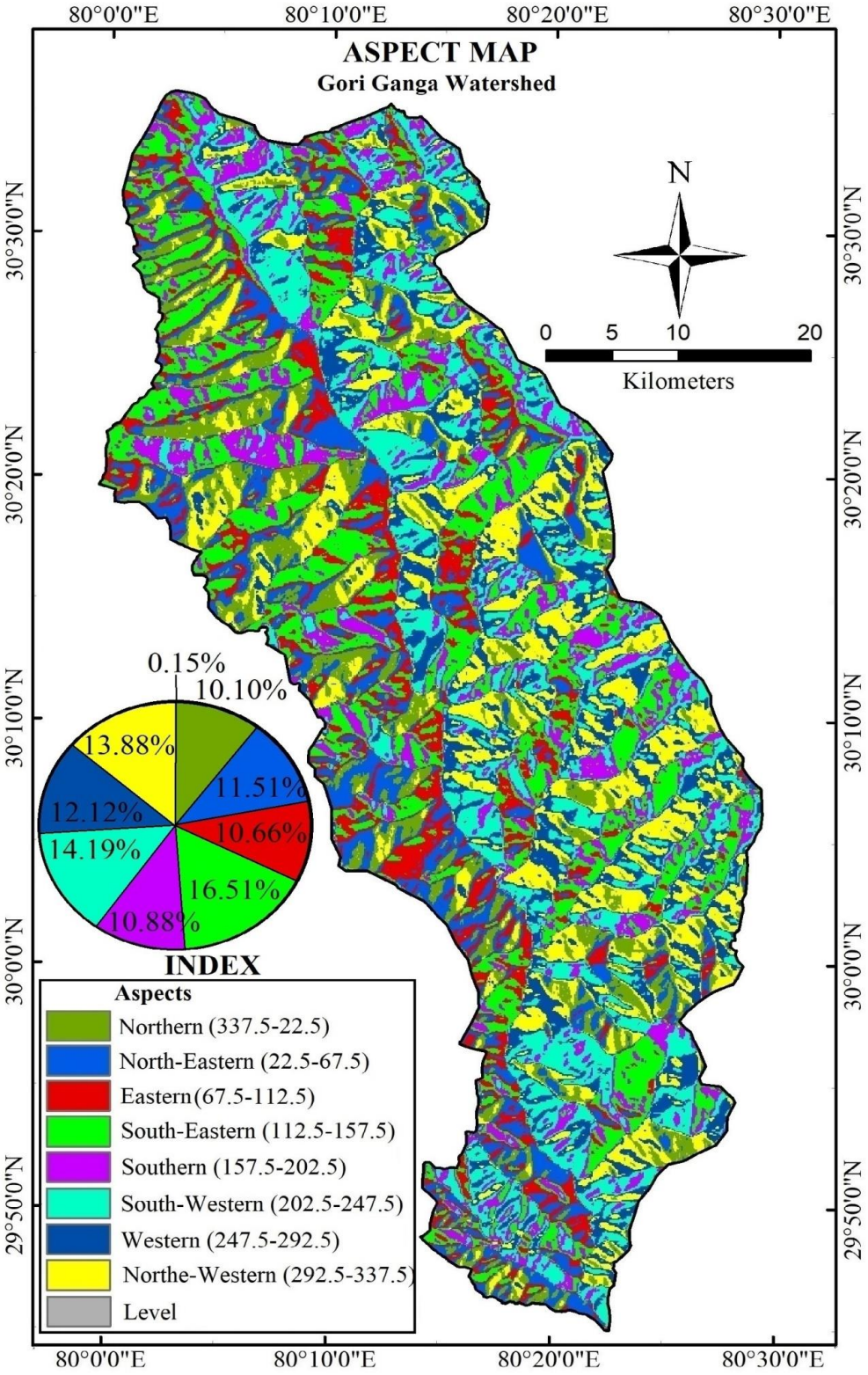

Figure-7: Aspect map of the Gori Ganga watershed, Kumaun Himalaya (based on cartosat-1 satellite data).

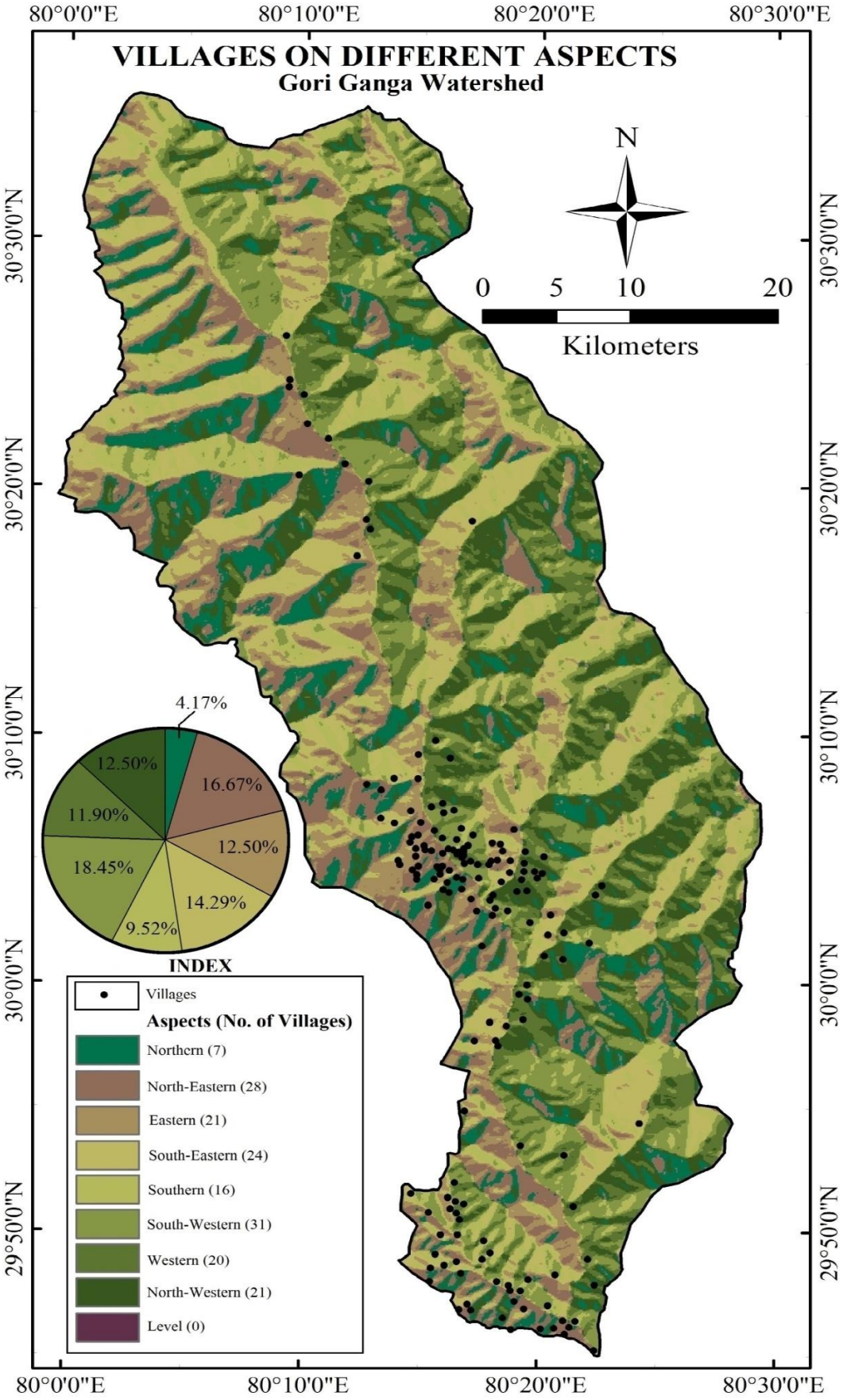

Figure-8: Distribution of villages on different aspects of the Gori Ganga watershed, Kumaun Himalaya (based on Censes of India and Cartosat-1 satellite data).

7.2 North-eastern aspect zone: The north-eastern aspect zone of the Gori Ganga watershed includes area which varies in between 22.5-67.5 degrees. Table 5 reveals that about 252.39 km2 which accounts for 11.51% area of the total watershed has north-eastern aspect (Fig. 7). About 16.67% villages (total 28 villages) of the study area are situated in the north-eastern aspect of the Gori Ganga watershed (Fig. 8 and Table 6).

7.3 Eastern aspect zone: The eastern aspect zone of the Gori Ganga watershed includes area which varies in between 67.5-112.5 degrees. Table 5 reveals that about 233.59 km2 which accounts for 10.66% area of the total watershed has eastern aspect (Fig. 7). About 12.5% villages (total 21 villages) of the study area are situated in the eastern aspect of the Gori Ganga watershed (Fig. 8 and Table 6).

7.4 South-eastern aspect zone: The south-eastern aspect zone of the Gori Ganga watershed is the biggest aspect zone includes area which varies in between 112.5-157.5 degrees. Table 5 reveals that about 361.89 km2 which accounts for 16.51% area of the total watershed has south-eastern aspect zone (Fig. 7). About 14.29% villages (total 24 villages) of the study area are situated in the south-eastern aspect of the Gori Ganga watershed (Fig. 8 and Table 6).

7.5 Southern aspect zone: The southern aspect zone of the Gori Ganga watershed includes area which varies in between 157.5-202.5 degrees. Table 5 reveals that about 238.39 km2 which accounts for 10.88% area of the total watershed has southern aspect (Fig. 7). About 9.52% villages (total 16 villages) of the study area are situated in the southern aspect of the Gori Ganga watershed (Fig. 8 and Table 6).

7.6 South-western aspect zone: The south-western aspect zone of the Gori Ganga watershed includes area which varies in between 202.5-247.5 degrees. Table 5 reveals that about 310.99 km2 which accounts for 14.19% area of the total watershed has south-western aspect zone (Fig. 7). About 18.45% villages (total 31 villages) of the study area are situated in the south-western aspect of the Gori Ganga watershed (Fig. 8 and Table 6).

7.7 Western aspect zone: The western aspect zone of the Gori Ganga watershed includes area which varies in between 247.5-292.5 degrees. Table 5 reveals that about 265.69 km2 which accounts for 12.12% area of the total watershed has western aspect zone (Fig. 7). About 11.90% villages (total 20 villages) of the study area are situated in the western aspect of the Gori Ganga watershed (Fig. 8 and Table 6).

7.8 North-western aspect zone: The north-western aspect zone of the Gori Ganga watershed includes area which varies in between 292.5-337.5 degrees. Table 5 reveals that about 304.09 km2 which accounts for 13.88% area of the total watershed has north-western aspect zone (Fig. 7). About 12.5% villages (total 21 villages) of the study area are situated in the north-western aspect of the Gori Ganga watershed (Fig. 8 and Table 6).

7.9 Level land: The level land of the Gori Ganga watershed includes area which lies in 0 degree slope. Table 5 reveals that about 3.33 km2 which accounts for 0.15% area of the total watershed has level land (Fig. 7). This zone has no villages in the Gori Ganga watershed (Fig. 8 and Table 6) and this level terrain is complete of river terrace deposits.

8.0 CONCLUSION

The present study was carried out in a Kumaun Himalayan Watershed, viz., the Gori Ganga Watershed. The study reveals that Relief maps depict contours of landmarks and terrain, based on shape and height. Geographical Information System plays signification role for indentifying most appropriate sites for horticulture, solar

energy plant using relief, slope and aspect map. Horticultural practice in the Gori Ganga watershed has the great importance not only for economically but also for environmental restoration. In the Gori Ganga watershed the elevation conditions ranges from sub-tropical to Alpine. These climatic conditions are very potential for horticulture and varieties of fruit cultivation. The southern aspects (157.5o - 202.5o) are highly suitable site, the south western slopes (202.5 o to 247.5o) are moderately suitable site and while the south eastern aspects (112.5o-157.5o) are good suitable site for solar energy plant. Figure 8 depicts the spatial distribution of suitable, moderately suitable and highly suitable sites for solar plant development in the Gori Ganga watershed. Table 6 suggests that about 16 villages (9.52%) of the Gori Ganga watershed are situated on highly suitable southern aspect, about 31 villages (18.45%) of the watershed falls under moderate suitable south western aspect, and about 24 villages (14.29%) of the Gori Ganga watershed are on the suitable South-eastern aspect for harvesting of solar energy. Present study has well demonstrated the applications of geospatial technology in studying terrain analysis.

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