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SUB-WATERSHED PRIORITIZATION BASED ON LULC CLASSIFICATIONS OF THE GORI GANGA WATERSHED KUMAUN HIMALAYA USING GIS AND RS TECHNIQUES

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ABSTRACT
Present research paper is an attempt to classifications of the Land Use Land Cover (LULC) by using supervised classification in the Sub-watershed of Gori Ganga watershed Kumaun Himalaya, Uttarakhand (India) where Gori Ganga watershed has 2191.63 km^2 area. For the study of detect sub-watersheds used of remote sensing data Cartosat-1 of 2008 and LULC classified by using of Santinal-2 of 2018. Using pour point technique for the Gori Ganga watershed is divisible in to 9 sub-watersheds. Geographically distribution of 9 sub watersheds are about 8.69% (190.51 km^2) area covered by Goukha Gad, about 10.83% (237.31 km^2) area covered by Gori Gad, about 7.42% (162.53 km^2) area covered by Lwan Gad, about 10.39% (227.82 km^2) area covered by Ralam Gad, about 8.83% (193.46 km^2) area covered by Mandakini Gad, about 9.82% (215.15 km^2) area covered by Bona Gad, 3.83% (83.97 km^2) area covered by Baram Gad, 3.92% (85.91 km^2) area covered by Raunits Gad and 36.27% (794.97 km^2) area covered by Gori Ganga sub watershed. Present study describes details LULC pattern of the 9 sub-watersheds based on remote sensing and GIS. A brief account of these results it's discussed in the following paragraphs.
KEY WORD: ***LULC, Sub-watersheds, GIS and Remote Sensing***

1.0 INTRODUCTION

In the Glossary of Geographical terms, a basin is "the whole tract of a country drained by a river and its tributaries" (Stamp and Clark, 1981). The term watershed also refers to a water divide between two drainage basins (Shanley and Peters, 1988). A watershed is also considered as a subdivision of a drainage basin. The Encyclopedia of Geomorphology relates the term catchment with hydrologists, who use it in connection with water supply. Larger Watershed and can also contain smaller watershed, called sub basins. The boundaries between watersheds are termed drainage divides. The outlet or pour point is the point on the surface at which water flows out of an area. It is the lowest point along the boundary of a watershed. The literature suggests that watershed can be of various sizes depending upon the size of stream, drainage density and its distribution. The size of watershed is governed by the order of stream or river in question or the confluences of the stream or river likes dams, barrages etc. the size of the watershed is important for land and water resources development. Normally a watershed describe with pour point and drainage line. Total area of the water flowing are given to an outlet point or more often known as pour point. Pour point is the point at which the water flows out of the area. This is the lowest point in elevation along the boundary of the drainage lines. Delineation of watershed depends on the catchment drainage pattern of the watershed.

Accurate delineation of a watershed plays a positive role in the watershed management. The watershed delineated boundary helps in management efforts, analyzing and in drawn appropriate conclusions (Savant et al., 2002). GIS tools can be automated in implementation of various practical applications of watershed delineation (Fattah et al., 2015). Land cover, on the other hand, describes, "The vegetation and artificial constructions covering the land surface" (Burley, 1961). LULC are important component for understanding the interactions of the human relationship with environment by using satellite data with supervised classification techniques (Prakasam, 2010).

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2.0 METHODOLOGY

The present study works out classifications of the LULC by using remote sensing data with supervised classification in the sub-watersheds of Gori Ganga watershed of Kumaun Himalaya, Uttarakhand (India). To classification LULC, Santinal-2 of 2018 from www.USGS.com, website and Global Land Cover Facility (GLCF) and sub-watershed, Cartosat-1 Satellite images for the year 2008 were used from Natural Resource Data Management System- NRDMS, Department of Geography, S.S.J. Campus, Almora Uttarakhand. For 2018 cloudless images of selected for the month of November. The study area, i.e., sub-watersheds and Gori Ganga watershed was clipped using its shape file from satellite images and the image was given the base map coordinates, i.e., UTM projection, 44 N zone for the purpose to identify the study area in the images. For the LULC raster data of the 2018 was calculated in ERDAS IMAGINE and Arc GIS 10.2.2 software using the equation of supervised LULC classification.

3.0 STUDY AREA

The study area, viz., the Gori Ganga watershed (Kumaun Himalaya) extends between $29^0$45'0''N to $30^0$35'47''N latitudes and $79^0$59'33''E to $80^0$29'25''E longitude, and encompasses an area of 2191.93 km^2 in Figure 1. The altitude of the Gori Ganga watershed varies between 626 m and 6639 m. The Gori Ganga watershed has 168 villages and total population is about 40616 (2011).

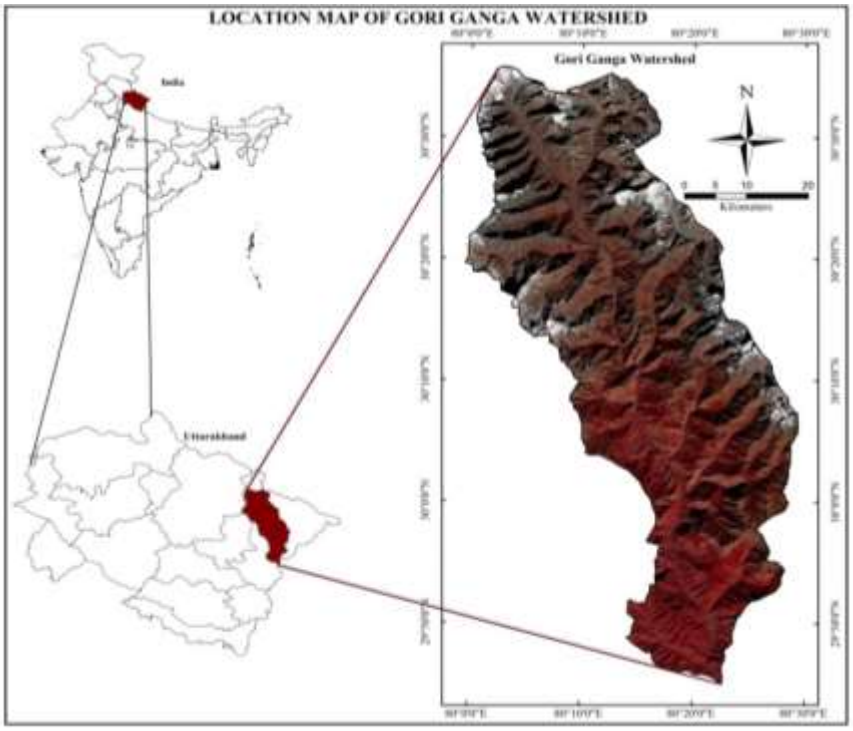

Figure 1: Geographical location and extension of the study area Viz. Gori Ganga watershed, Kumaun Higher Himalaya, Uttarakhand.

4.0 RESULT AND DISCUSSION

Figure 2 depicts the geographical distribution of point based sub-watersheds and registered in Table-1. Figure 3 depicts geographical distribution of villages superimposed in sub-watersheds of the Gori Ganga watershed which is registered in Table 2. The results of sub-watershed LULC distribution categories obtained through the analysis of supervised classification imagery are diagrammatically illustrated in Figure 4 and registered in Table- 3. Figure 5 (1) to (9) depicts separately geographical distribution of LULC in sub-watersheds of Gori Ganga watershed. A brief account of these results it's discussed in the following paragraphs.

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5.0 SUB-WATERSHED DELINEATION

A watershed describes an area of land that contains a common set of streams and rivers that all drain into a single larger body of water, such as a larger river, a lake or an ocean. A watershed can cover a small or large land area. A brief account of these results it's discussed in the following paragraphs.

5.1 Point Base Sub-Watershed Delineation

The selection of pour points and watershed delineation are the final steps. All of the water from within the watershed will flow through the pour point. The pour point defines the lowest point in watershed and must be located on a flow accumulation cell. The chosen pour points will be the basis for the watershed or sub-watershed delineation. Pour points chosen for this analysis can be classified into major sub-watersheds. Using GIS techniques, the Gori Ganga watershed was divided into 9 sub-watersheds based on selected pour point. Figure 2 depicts the geographical distribution of point based sub-watershed which is registered in Table 1.

6.0 LULC IN SUB-WATERSHEDS

Using GIS techniques, geographical distribution of Land Use Land Cover into 9 sub-watersheds of the Gori Ganga watershed. Figure 3 depicts geographical distribution of village in the sub-watersheds of Gori Ganga watershed was superimposed on the sub-watershed maps which registered in Table 2. Figure 4 depicts the spatial distribution of LULC in the sub-watersheds which is registered in Table 3. A brief account of LULC in those sub-watersheds is presented in the following paragraphs

Table 1: Area of point based sub-watershed in the Gori Ganga watershed *(based on Cartosat-1 Satellite, 2008)*

S. N.	Name of Sub-Watershed	Area		S. N.	Name of Sub-Watershed	Area	
		km^2	in %			km^2	in %
1	Goukha Gad	190.51	8.69	6	Bona Gad	215.15	9.82
2	Gori Gad	237.31	10.83	7	Baram Gad	83.97	3.83
3	Lwan Gad	162.53	7.42	8	Raunits Gad	85.91	3.92
4	Ralam Gad	227.82	10.39	9	Gori Ganga	794.97	36.27
5	Mandakini Gad	193.46	8.83	Total		2191.63	100

Table 2: Distribution of village's in sub-watersheds of Gori Ganga watershed (*based on Censes of India-2011).*

S. N.	Sub Watershed	Villages		S. N.	Sub Watershed	Villages	
		Number	%			Number	%
1	Goukha Gad	0	0	6	Bona Gad	8	4.76
2	Gori Gad	1	0.60	7	Baram Gad	2	1.19
3	Lwan Gad	1	0.60	8	Raunits	39	23.21
4	Ralam Gad	1	0.60	9	Gori Ganga	95	56.54
5	Mandakini Gad	21	12.5	Total		168	100

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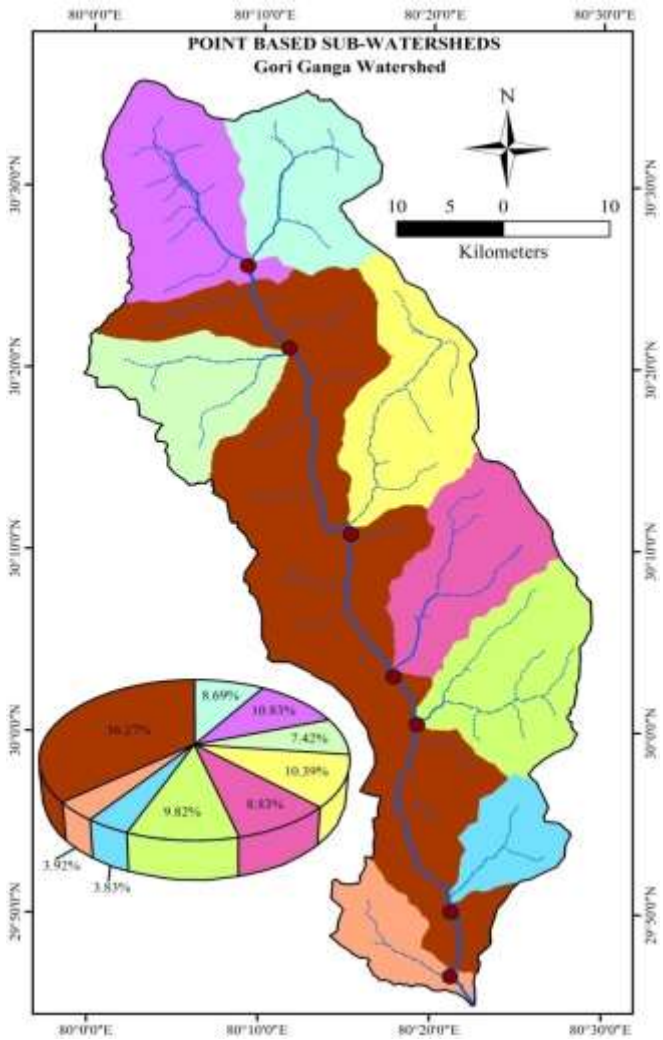

Figure 2: Geographical distribution of point-based sub-watersheds of Gori Ganga watershed *(based on Cartosat-1 Satellite, 2008)*.

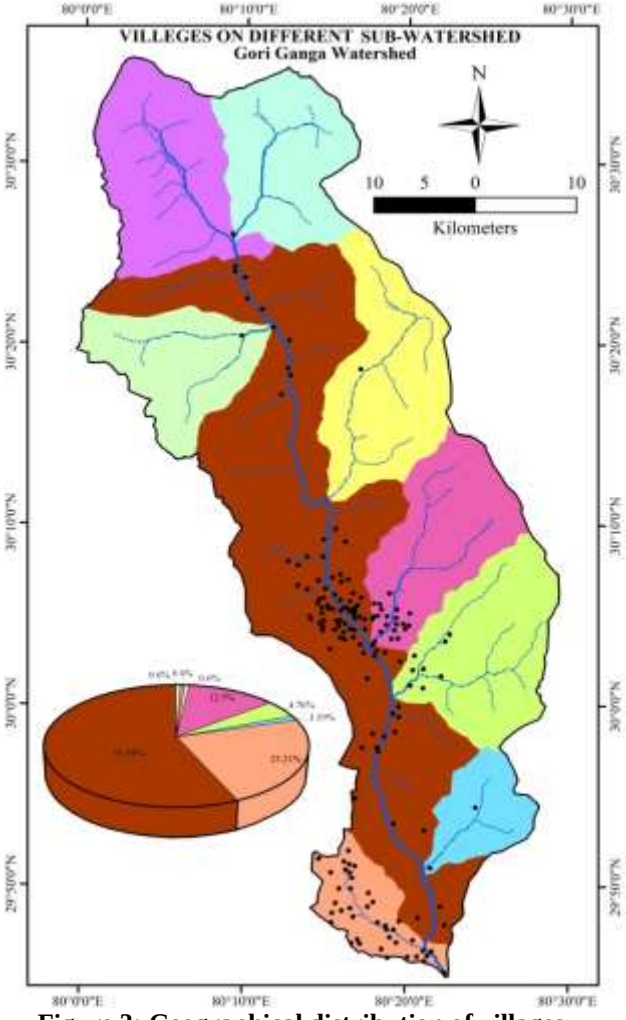

Figure 3: Geographical distribution of villages superimposed in sub-watersheds of the Gori Ganga watershed *(based on Cartosat-1, 2008, COI 2011)*.

Table 3: LULC categories in sub-watersheds of Gori Ganga watershed *(based on Sentinel-2, October 2018)*.

Sub-Watersheds	LULC categories area in km^2							
	Agriculture		Snow Cover		Glacier		Sand Cover	
	in km^2	in %	in km^2	in %	in km^2	in %	in km^2	in %
Goukha	0.01	0.005	110.97	58.256	15.86	8.325	28.46	14.937
Gori	0.15	0.06	96.54	40.68	22.65	9.55	39.19	16.51
Lwan	0.06	0.04	83.64	51.46	8.66	5.33	13.49	8.30
Ralam	0.08	0.04	109.54	48.08	10.98	4.82	12.61	5.53
Mandakini	2.98	1.54	43.16	22.31	5.43	2.81	5.69	2.94
Bona	2.16	1	20.95	9.74	1.74	0.81	2.52	1.17
Baram	1.49	1.77	0.07	0.08	0.07	0.08	0.08	0.10
Raunits	5.72	6.66	0.05	0.06	0	0	0.40	0.47
Gori Ganga	24.07	3.03	115.94	14.59	18.7	2.35	21.11	2.66
Total	36.72		580.86		84.33		123.31	

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Sub-Watersheds	LULC categories area in km^2					
	Water Body		Barren Land		Vegetation	
	in km^2	in %	in km^2	in %	in km^2	in %
Goukha	20.56	10.792	3.87	2.031	10.78	5.654
Gori	47.69	20.10	5.63	2.37	25.46	10.73
Lwan	20.48	12.60	3.69	2.27	32.51	20
Ralam	22.42	9.84	6.51	2.86	65.68	28.84
Mandakini	14.66	7.58	7.57	3.91	113.97	58.91
Bona	20.17	9.38	2.24	1.04	165.37	76.86
Baram	2.58	3.07	0.08	0.10	79.60	94.80
Raunits	1.07	1.24	0.06	0.07	78.61	91.50
Gori Ganga	69.9	8.79	12.74	1.60	532.51	66.98
Total	219.53		42.39		1104.49	

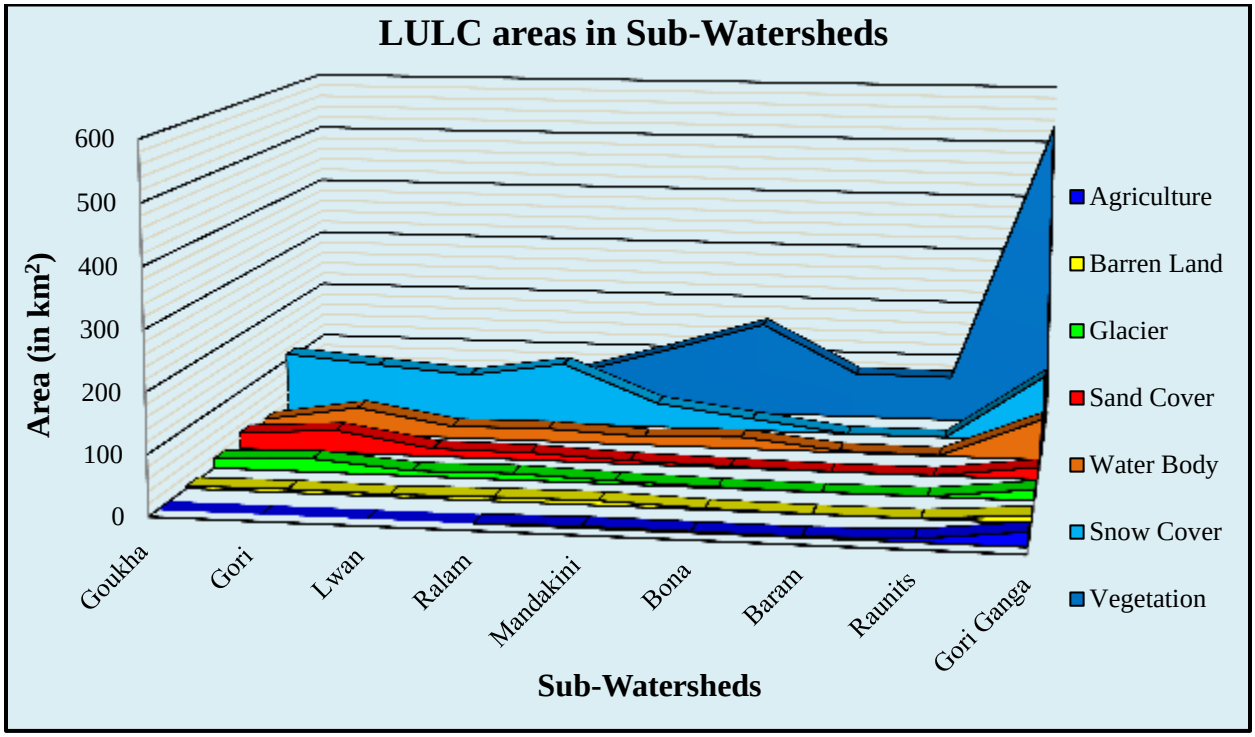

Figure 4: Diagrammatic presentation of LULC categorized area in sub-watersheds of Gori Ganga watershed *(based on Sentinel-2, October 2018)*.

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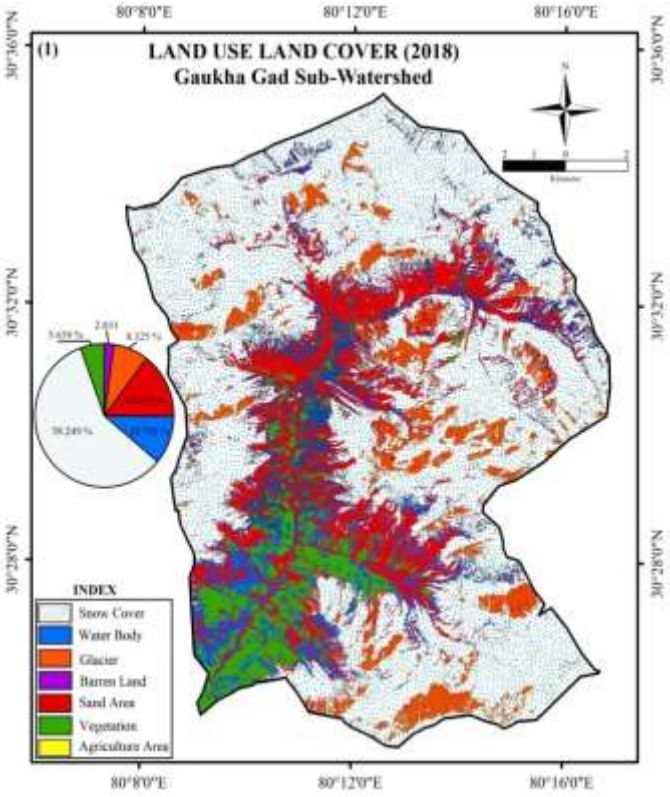

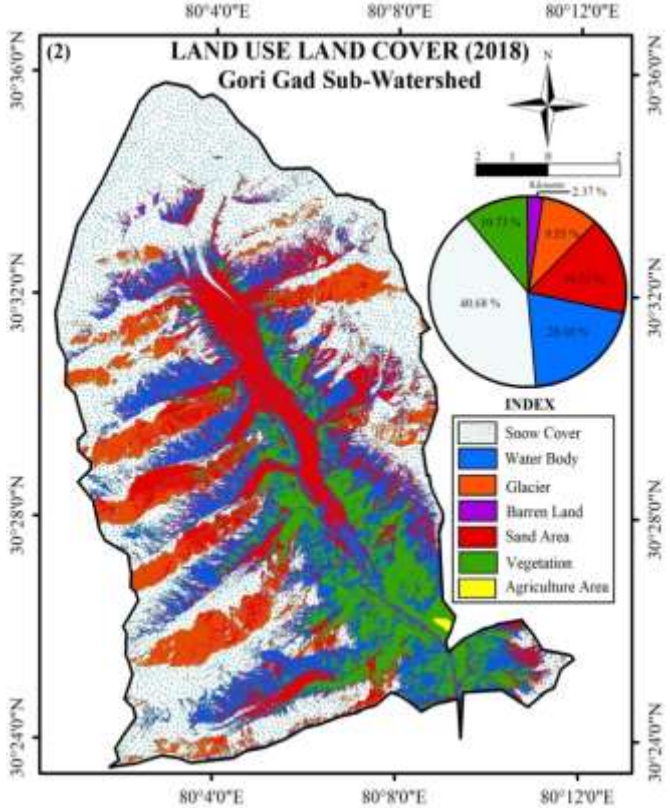

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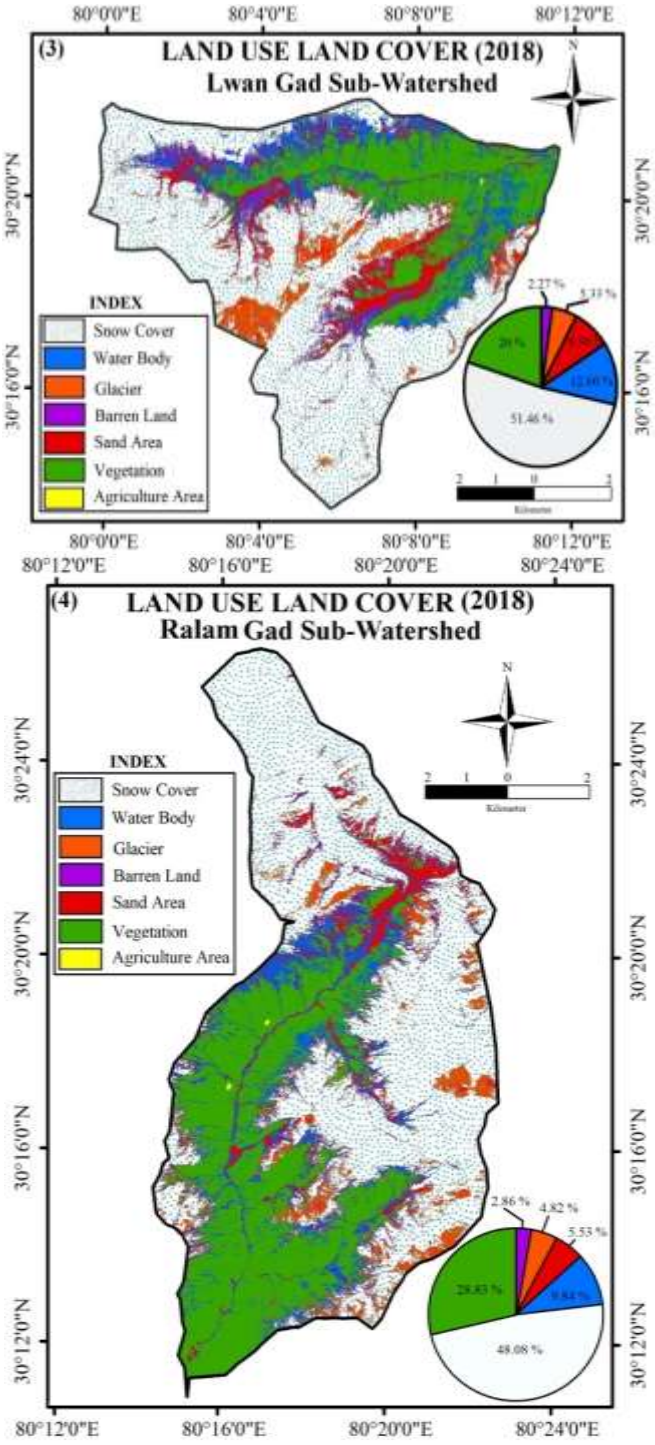

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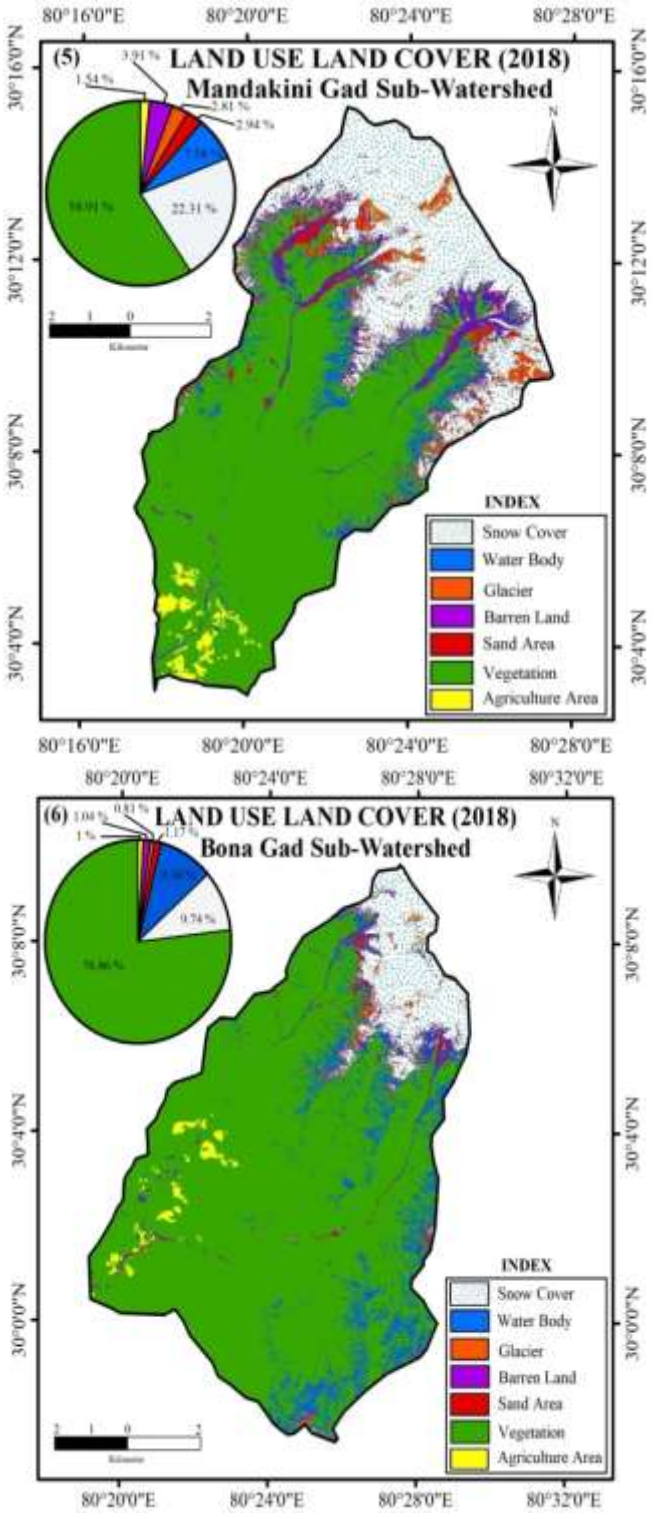

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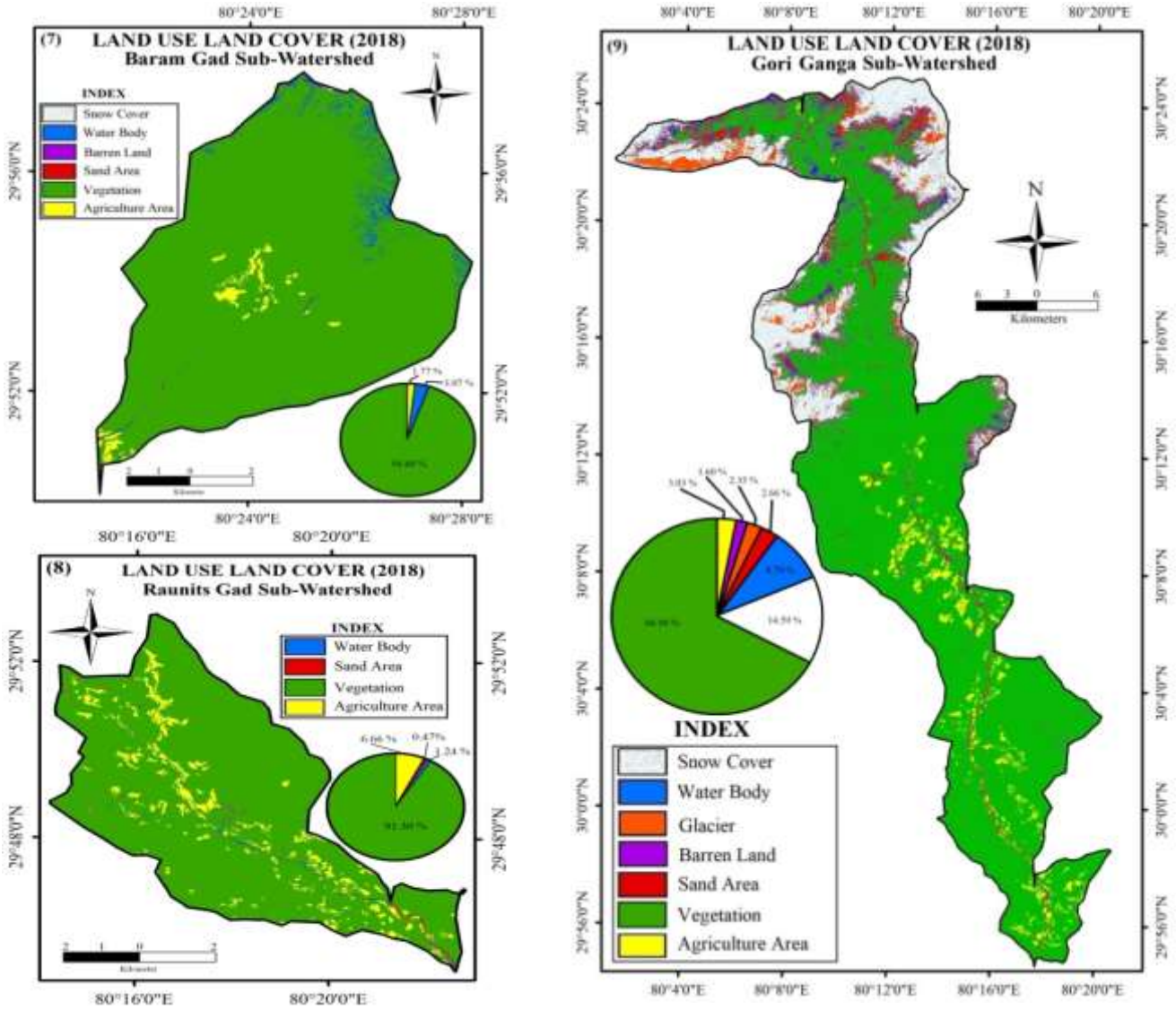

Figure 5: Geographical distribution of LULC classification in sub-watersheds of the Gori Ganga watershed (1) Goukha Gad, (2) Gori Gad, (3) Lwan Gad, (4) Ralam Gad, (5) Mandakini Gad, (6) Bona Gad, (7) Baram Gad, (8) Raunits Gad and (9) Gori Ganga Gad *(based on Sentinel-2, October 2018*).

6.1 Goukha Gad Sub-Watershed: This watershed is part of Goukha River, which is eastern stream of Milam village. This watershed encompasses an area of 190.51 km^2 which is accounts for 8.69% of the Gori Ganga watershes area. About 58.256% (110.97 km^2) area is under snow cover, 14.937% (28.46 km^2) area is under sand cover, 10.792% (20.56 km^2) area is under water body, 5.654% (10.78 km^2) area is under vegetation cover, 8.325% (15.86 km^2) area is under Glacier, 2.031% (3.87 km^2) area is under barren land and 0.005% (0.01 km^2) area in under Agriculture Land. The total length of stream in this sub-watershed is 37 km.

6.2 Gori Ganga Sub-Watershed: This watershed is part of Milam glacier and origin of Gori Ganga River, which is western stream of Milam village. This watershed encompasses an area of 237.31 km^2 which is accounts for 10.83% of the Gori Ganga watershes area. This watershed has only one village that name is Milam. About 40.68% (96.54 km^2) area is under snow cover, 16.51% (39.19 km^2) area is under sand cover, 20.10% (47.69 km^2) area is under water body, 9.55% (22.65 km^2) area is under glacier, 2.37% (5.63 km^2) area is under barren land, 10.73% (25.46 km^2) area is under vegetation cover and 0.06% (0.15 km^2) area is under agriculture land. The total length of stream in this sub-watershed is 68 km.

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6.3 Lwan Gad Sub-Watershed: The Lwan Gad is the western side tributary of Gori Ganga River. This is named after Lwan village which is situated in this sub-watershed. This watershed encompasses an area of 162.53 km^2 which is accounts for 7.42% of the Gori Ganga watershes area. About 51.46% (83.64 km^2) area is under snow cover, 8.30% (13.49 km^2) area is under sand cover, 12.60% (20.48 km^2) area is under water body, 5.33% (8.66 km^2) area is under glacier, 2.27% (3.69 km^2) area is under barren land, 20% (32.51 km^2) area is under vegetation cover and 0.04% (0.06 km^2) area is under agriculture land. The total length of stream in this sub-watershed is 34 km.

6.4 Ralam Gad Sub-Watershed: This watershed extends in the eastern part of the Gori Ganga River. This watershed encompasses an area of 227.82 km^2 which is accounts for 10.39% of the Gori Ganga watershes area. This watershed has only one village which name is Ralam. About 48.08% (109.54 km^2) area is under snow cover, 5.53% (12.61 km^2) area is under sand cover, 9.84% (22.42 km^2) area is under water body, 4.82% (10.98 km^2) area is under glacier, 2.86% (6.51 km^2) area is under barren land, 28.84% (65.68 km^2) area is under vegetation cover and 0.04% (0.08 km^2) area is under agriculture land. The total length of stream in this sub-watershed is 54 km.

6.5 Mandakini Sub-Watershed: This watershed extends in the eastern part of the Gori Ganga River. This watershed encompasses an area of 193.46 km^2 which is accounts for 8.83% of the Gori Ganga watershes area. This watershed has 21 villages which names are Phapa, Wadni Dhar, Bhatkura, Dhuratoli, Dhauliua Dunga, Chulkot, Bothi, Chhija, Ringu, Khata, Gaila Malla, Sana, Dobari Narki, Baiga, Gaila Talla, Rapti, Ropar, Walthi, Dolma, Morpatta, Ghatdhar and Ritha. This watershed has Five Road Network (Madkote to Chulkote, Pithoragarh to Munsyari, Walthi Bona, Walthi to Gaila and Basantkote to Chulkote Road), total length is 22.54 km. In this watershed have four Gharats which is located near Ropar, Dobari, Rapti and Khata. About 22.31% (43.16 km^2) area is under snow cover, 2.94% (5.69 km^2) area is under sand cover, 7.58% (14.66 km^2) area is under water body, 2.81% (5.43 km^2) area is under glacier, 3.91% (7.57 km^2) area is under barren land, 58.91% (113.97 km^2) area is under vegetation cover and 1.54% (2.98 km^2) area is under agriculture land. The total length of stream in this sub-watershed is 41 km.

6.6 Bona Gad Sub-Watershed: This watershed extends in the eastern part of the Gori Ganga River. This watershed encompasses an area of 215.15 km^2 which is accounts for 9.81% of the Gori Ganga watershes area. This watershed has 8 villages which names are Bindi, Lodi, Bona, Tomik, Tanga, Pharwakot, Nirtoli and Bata. This watershed has Seven Road Network (Tanga Road, Pithoragarh to Munsyari, Walthi to Bona, Sera to Sirtola, Seraghat to Lodi, Bindi Road and Balibagar to Pharwakot Road), total length is 21.40 km. In this watershed have four Gharats which is located near Pharwakot, Bindi, Bona Gad and Bona. About 9.74% (20.95 km^2) area is under snow cover, 1.17% (2.52 km^2) area is under sand cover, 9.38% (20.17 km^2) area is under water body, 0.81% (1.74 km^2) area is under glacier,1.04% (2.24 km^2) areas is under barren land, 76.86% (165.37 km^2) area is under vegetation cover and 1% (2.16 km^2) area is under agriculture land. The total length of stream in this sub-watershed is 53 km.

6.7 Baram Gad Sub-Watershed: This watershed extends in the eastern part of the Gori Ganga River. This watershed encompasses an area of 83.97 km^2 which is accounts for 3.83% of the Gori Ganga watershes area. This watershed has 2 villages which names are Baram and Kanar. This watershed has Three Road Network (Baram to Kanar, Pithoragarh to Munsyari and Baram to Goge), total length is 14.91 km. In this watershed have two Gharats which is located near Baram and Kanar. About 0.08% (0.07 km^2) area is under snow cover, 0.10% (0.08 km^2) area is under sand cover, 3.07% (2.58 km^2) area is under water body, 0.08% (0.07 km^2) area is under glacier, 0.10% (0.08 km^2) area is under barren land, 94.80% (79.60 km^2) area is under vegetation cover and 1.77% (1.49 km^2) area is under agriculture land. The total length of stream in this sub-watershed is 19 km.

6.8 Raunits Gad Sub-Watershed: This watershed extends in the western part of the Gori Ganga River. This watershed encompasses an area of 85.91 km^2 which is accounts for 3.91% of the Gori Ganga watershes area. This watershed has 39 villages which names are Tham, Garjiya, Dewal, Chamlekh, Kuta, Basaur, Khetar Bhandari, Raitoli, Dhaniya Khan, Dhunga, Barigaun, Jogyura, Lohargaun, Jamtari, Bankoo, Pamsyari, Hunera, Khoja, Doonakot, Humkapita, Mahargari, Bora Gaun, Koonia, Barna Airi, Khetar Kanyal, Kauli Kanyal, Baya Gaun, Kaindi, Panthali, Sinquali, Garsoli, Mirthi Biniya, Bichhata, Sirtoli, Khariyani, Chhabbisa, Nakote, Matayula and Darti. This watershed has two road network (Pithoragarh to Munsyari and Dharchula Jauljibi Road), total length is 5.31 km. In this watershed have only one Gharat which is located near Bari Gaon. About 0.06% (0.05 km^2) area is under snow cover, 0.47% (0.40 km^2) areas is under sand cover, 1.24% (1.07 km^2) area is under water body, 0.07%

(0.06 km^2) area is under barren land, 91.50% (78.61 km^2) area is under vegetation cover and 6.66% (5.72 km^2) area is under agriculture land. The total length of stream in this sub-watershed is 18 km.

6.9 Gori Ganga Sub-Watershed: This watershed encompasses an area of 794.97 km^2 which is accounts for 36.27% of the Gori Ganga watershes area. This watershed has 95 villages which names are Martoli, Tola, Rilkote Old, Laspa, Khilanch,Dhapa, Ugarali, Suring, Bachhepur, Harkot, Uchhaiti, Imla, Josha, Alam, Khartoli, Madarma, Darma, Mawani Dawani, Porthi, Seeling, Sirtola, Sain Polo, Saimat, Zimiya, Sera, Mani Dhami, Basantkot, Umadada, Pyangti, Dhunamani, Kultham, Dheelam, Dumar Talla, Sainar, Jalath, Dumar Malla, Darkot, Phalyati, Shankh Dhura, Bunga, Sarmoli, Jaiti, Namjala, Ranthi, Darati, Gopal Bara, Diya Walla, Dadabisa, Diya palla, Minal Gaon, Buie, Pato, Leelam, Ghorpatta Malla, Jaduk, Barniya Gaon, Telkot, Teli, Akhoriya, Sela, Khasiya Bara, Dhamikura, Kawa Dhar, Kaiti, Cheti Chimla, Sera Surai Dhar, Sela Chital, Sella Malla, Charkham, Ghor Patta Talla, Sebila, Papri, Mana Chulankar, Matena, Matyali, Malupati, Bhadeli, Chauna, Kholi, Pachhu, Bilju, Burphu, Mapa, Ganghar, Kotal Gaon, Kanalka, Lumti, Quiri, Metali, Toli, Bangapani, Payya Pori and Garali. This watershed has 26 Road Network which total length is 208.52 km. In this watershed have 21 Gharas which is located near Garali, Umargada, Sera, Dhoonamani, Golma, Imla, Josha, Mtyani, Harkote, Talla Ghorpatta, Dhapa, Syannar, Sain, Quiry, Sain Polu, Jimighat, Gopal Bara, Basantkote, Bachchepur, Jara Jibli and Jara. About 14.59% (115.94 km^2) area is under snow cover, 2.66% (21.11 km^2) area is under sand cover, 8.79% (69.90 km^2) area is under water body, 2.35% (18.70 km^2) area is under glacier, 1.60% (12.74 km^2) area is under barren land, 66.98% (532.51 km^2) area is under vegetation cover and 3.03% (24.07 km^2) area is under agriculture land. The total length of stream in this sub-watershed is 170 km.

7. CONCLUSION

The fundamental objectives of this chapter is to classifications of the LULC by using supervised classification using remote sensing and GIS techniques in the sub-watersheds of Gori Ganga watershed of Kumaun Himalaya, Uttarakhand (India). Based on the previous study following can be concluded.

I. Using pour point technique for the Gori Ganga watershed is divisible in to 9 sub-watersheds. Present study describes details LULC pattern of the 9 sub-watersheds based on remote sensing and GIS techniques. Which reveals that the sub-watershed size in the study area varies in between 83.97 km^2 (viz., Baram sub-watershed) and 794.97 km^2 (viz., Gori Ganga sub-watershed).

II. In 2018 largest agriculture land found in Gori Ganga sub-watershed (24.07 km^2), largest agricultural land percentages was found in Raunits Gad sub-watershed (6.66%) and Smallest area and percentages of agriculture land was found in Goukha Gad sub-watershed (0.01 km^2 and 0.005%). Largest snow cover area was found in Gori Ganga sub-watershed (115.94 km^2), largest snow cover percentage was found in Goukha Gad (58.256%) sub-watersheds and smallest snow cover area and percentage was found in Raunits Gad sub-watershed. Largest glacier cover area and percentage was found in Gori Gad sub-watershed (22.65 km^2 and 9.55%) and Raunits Gad sub-watershed was not found any Glacier cover area. Largest sand cover area and percentage was found in Gori Gad sub-watershed (39.19 km^2 and 16.51%) and smallest sand cover area and percentage was found in Baram Gad sub-watershed (0.08 km^2 and 0.10%). Largest water body cover area and percentage was found in Gori Ganga sub-watershed (47.69 km^2 and 20.10%) and smallest water body cover area was found in Raunits Gad sub-watershed (1.07 km^2 and 1.24%). Largest barren land cover area was found in Gori Ganga sub-watershed (12.74 km^2), largest barren land percentage was found in Mandakini Gad Sub-watershed (3.91%) and smallest barren land cover area and percentage was found in Raunits Gad sub-watershed (0.06 km^2 and 0.07%). Largest vegetation cover area was found in Gori Ganga sub-watershed (532.51 km^2), largest vegetation cover percentage was found in Baram Gad sub-watershed (94.80%) and smallest vegetation cover area and percentage was found in Goukha Gad sub-watershed (10.78 km^2 and 5.654%).

III. Remote sensing and GIS are very helpful techniques for delineation of sub-watersheds and LULC classified in sub-watersheds of Gori Ganga watershed.

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