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Water Resources and Management in Gori Ganga Watershed, Kumaun Himalaya by Using Remote Sensing and GIS

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ABSTRACT

Uttarakhand Himalaya has been famous for its water resources (*source for many rivers*), forest diversity, unique wildlife, rich traditional culture, tribal culture and sacred Hindu's shrine (*i.e. Gangotri, Yamnotri, Kedarnath and Badrinath*). The present study aims to assess the status of water resources in the Gori Ganga watershed. Water resources and their management were collected through field visit, use of Global Position System (*GPS*) and various methods (*include questionnaire, personal interviews, direct interaction and group discussion with the villagers*). Study explores the ability of Digital Elevation Model (*DEM*) in delineating watershed and drainage network of the Gori Ganga River basin. Gori Ganga watershed is laying in Eastern Kumaon Himalaya with great utility of water resources in socio-economic development for livelihood where the settlements are situated in valleys to high altitude. Gori Ganga drainage network i.e. Ralam, Mandakani and Bona gad is glacial fed river and these entire Rivers's water received annually from glaciers which are very useful for development of villages, towns and hydro power stations in the watershed region. Study explores some traditional water resources (*Glacier, streams, springs/Dhare/Naule, lakes/Kund/ Taals and drainage network*) and uses of water resources for traditional uses i.e. Gharat (*watermill*), drinking water, hydro power production, agriculture irrigation, fisheries and animal husbandry etc. in the study area.

Key Words: Water Resource, Management, Socio and Economic Development, Remote Sensing and GIS.

1.0 INTRODUCTION

A good water management study is always beneficial for the human and ecosystem. Himalayan River and their qualities about purity of water and quantity of water carry from origin place to ending place, values of water for people who lived in this watershed area (*INCCA- Indian Network for Climate Change Assessment, 2010*). How forest is importance for maintain water resource and environment management of the Himalayan region of Uttarakhand. Climate change increasing temperatures, effecting in water sources and changes in precipitation patterns and intensities, with knock-on effects on water flows, glacial melt etc. all of which have already been observed in the past and present study and are predicted to continue in the future (*Winther, 2017*).

After Parihar 2021, the snow line upward in the Gori Ganga watershed 99.95 m during 1990-1999 and about 303.98 m above during 1999-2016 and the snow line shifted upward at the rate of 11.1 m/year during 1990-1999 and the rate of 17.88 m/year during 1999-2016 which has been shifted 403.93 m upward at the average rate 15.53 m/year during 1990-2016 due to

global warming and climate change. These above mention data indicates dangerous for future livelihood in the Gori Ganga watershed.

Rawat and Shah (*2009*) studied about water management, traditional knowledge in Kumaun Himalaya. The development, management and conservation of water resources in the Uttarakhand Himalayan region, but no water resource management study contribution is available in the Gori Ganga watershed (*Khadse et al. 2011*).

The purpose of this research is to analyze importance of natural water resources i.e. Taals, Dhara, springs (*Naula*), water store tank, streams, river and tributaries and management of natural water resources which are as a source of drinking water for settlements in the Gori Ganga watershed. A Gori Ganga watershed is one of the Himalayan watersheds which are belonging to the Kumaun Himalaya (*Uttarakhand*).

2.0 OBJECTIVES

This research will highlight the advantages and management of water resource for socio-economic development in the study area. The fundamental objectives of the present investigation to study Gori Ganga watershed, which incorporates the follows:

1. Importance on water resources for the settlements and livelihoods and assess the status of water resources in the Himalayan region, Gori Ganga watershed.
2. Role of man and women in water resource management in the study area.
3. Study and mapping with the help of remote sensing and Geographical Information System (*GIS*) of traditional water resources, managements and uses in the study area.

3.0 METHODOLOGY

The present study based on field survey method, primary data and secondary data. A complete survey was done at household level for each studied villages (*Lodi, Tanga, Bindi, Golpha, Sera, Bangapani, Baram, Toli, Madkote, Seraghat, Munsyari, Wathi, Waiga, Basantkote, Bachhepur, Ringu, Okhali, Dhunamani, Josha, Jarajibli, Mavani, Darma, Chauna, Golma*), covering more than 24 (14.28%) villages from 168 households, with personal interviews with households. All the studied villages were surveyed in depth and head of family were interviewed and requested to provide information about water resources (*Taals, Dhara, Naula, store tank, Simar, rivers, streams, springs, etc.*) which they were used traditionally. All maps i.e., location of study area (*Fig. 1*), water resources (*Fig. 2*), drainage network (*Fig. 4*), villages (*Fig. 5*), towns (*Fig. 6*), Gharats/watermills (*Fig. 7*), hydro electronic plant location (*Fig. 8*), geologically distribution of hot water springs (*Fig. 9*) are preparing with the help of field survey, GPS coordinates and Arc GIS. The Gori Ganga watershed was delineated using DEM (*Fig. 3*) based on Cartosat-1, satellite data. Secondary data collected from Tehsil headquarter office Munsyari, district development office Pithoragarh, Uttarakhand Forest Development Corporation, e-district portal Pithoragarh (*www.pithoragarh.nic.in*), Sodhganga (*a reservoir of Indian thesis*), Village Development Office Munsyari and research articles.

4.0 STUDY AREA

The study area, viz., the Gori Ganga watershed, Kumaun Higher Himalaya, Uttarakhand (*Fig. 1*) which is 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 2191.95 km^2. The Milam glacier (*largest glacier of the Kumaun Himalaya*) is a valley glacier having compound basin belonging towards south east from the Trisul peak which is the source of Gori Ganga River. The glacier is 16.7 km long and it receives ice from the Trishul peak and seven tributary glaciers in the Gori Ganga

watershed. The altitude of the study area varies between 626 m and 6639 m (*Fig. 2*) and it has 168 villages (*Fig. 4*) and total population as per censes 2011 is about 40616 (*male 20249, female 20367*). Female population is higher than the male population in the region and the sex ratio of male to female is 1000:1006. The total population of scheduled tribes (*9840*) and scheduled cast (*6634*) contribute 40.56% (*16,474*). Although the population is not distributed uniformly throughout the blocks, it is mainly distributed along the Gori Ganga watershed with the average density of 18.53 people per km^2 and population working density of the study area is 1104.62 people per km^2 (*COI- Censes of India, 2011*). Study area spreads in three blocks, i.e., Munsyari, Dharchula and Didihat. Land uses spread across region comprise settlements, terraced farms, Van Panchayat-52, reserve forests and the Askote Musk Deer Sanctuary. As per Uttarakhand Gram Panchayat report as on 12/08/2016 and 168 villages under three Tehsil (*Muansyari- 120, Dharchula- 08, Didihat- 40*) as per censes of India 2011 (*Fig. 5*). Four types of tribes live in the study area which is Bhotiya Janjati, Rang Samuday, Barpatiya Samuday and Anuwal Samuday. There are three main valleys (*Gori Ganga valley, Ralam valley and Johar valley*) are famous for tracking, tourism, camping, site scene etc. in the study area. Physiographically, the Gori Ganga watershed is constructed of two physiographic regions. There are Great Himalayan region and Lesser Himalayan region separated by the Main Central Thrust (*MCT*) which is cross between villages Laspa, Khilanch, Rilkote, Ralam in the Great Himalayan region and Zimiya, Quiri, Leelam, Paton and Bunie villages in the lesser Himalayan region. About 7.74% villages (*total 13 villages*) are situated in the Great Himalayan region and about 92.26% villages (*total 155 villages*) are situated in the Lesser Himalayan region of the Gori Ganga watershed (*Fig. 5*).

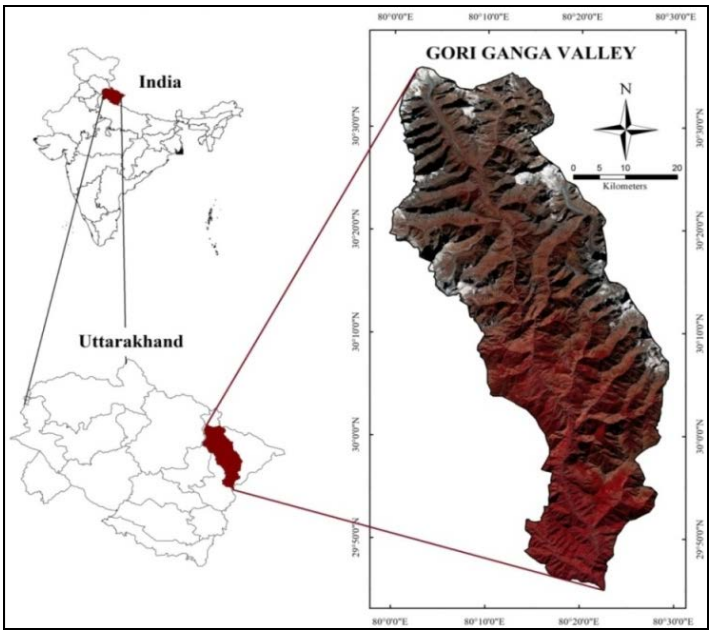

Figure-1: Location map of the study area, viz., the Gori Ganga watershed, district Pithoragarh, Uttarakhand.

5.0 RESULT AND DISCUSSION

Figure-2 depicted the geographical distribution of traditional water resources which is needs for development of settlements and livelihood in the Gori Ganga watershed. Figure-3 presents digital elevation model which is varies between 626 m and 6639 m, Figure-4 presents the spatial distribution of drainage network, Figure-5 and Figure-6 depicts the villages (168 villages) and developing towns (11) in the Gori Ganga watershed. Figure-7 and

Figure-8 depicts geographic distribution of hydro electronic plant (4) and Gharat/watermills (32) which are located near the river and tributaries of Gori Ganga. Figure 9 depicts geographical distribution of hot water springs in geological regions at Gori Ganga watershed. Table-1 certain stream order and length of the watershed area. Table-2 and Table-3 are certain spatial distribution of drainage network and geographical locations of the drainage network. Table-4 and Table-5 are certain town locations, hydro electronic plant and location of Gharats in the study area. Example of Gharat (Jarajibli) and hot water spring (Devibagar, Madkote) in the study area are presenting in Plate-1 and Plate-2.

6.0 TRADITIONAL WATER RESOURCES

Milam glacier is the main source of Gori Ganga River and other many glaciers are sources of Gori Ganga Tributaries River. Drainage system of the watershed is mainly controlled by the major perennial river (i.e., Gori Ganga, Ralam, Mandakini, Bona gad), tributaries (i.e., Golpha gad, Renchi gad and Baram gad), streams, springs (Dhare, Naule), Lakes/Kund/Taal, villages are depended for drinking water from tributaries/streams of Gori Ganga River (i.e., Tanga, Madkote, Gaila, Walthi, Sera, Khartoli, Bangapani, Munsyari, Baram, Ghattabagar, Jarajibili, Kanar, Golpha and Bona). A brief account of the water resources and their managements is presented in the following paragraph.

Glaciers and Glacial Lakes

Gori Ganga watershed has rich in physical landscape and natural scenic beauty. It has beautiful glacial landforms which provided large amount of water over the year to the livelihood, large number of tourist and trekking attraction in the watershed. There is major 7 glaciers which names are Milam glacier, Ralam glacier, Jimba glacier, Gaukha glacier, Panchachuli glacier, Shalang glaciers, Poting glacier and 20 minor glaciers in Gori Ganga watershed. Figure-2 depicts the geographical distribution of glaciers, lake, Kund, and Taal i.e. Milam glacier, Ralam glacier, glacial lakes, Messar Kund and Thamari Kund etc. and example presents in Plate-1.

6.2 Lakes/Kund/Taal

There are found numerous water lakes in the Gori Ganga watershed which is called Lakes, Kund and Taals also. Basically Kund (lake) are used for religious lakes and communities of the watershed worshiping of the Kund which found very far from settlements and high altitude, near the Bugyals. Taals are found near the settlements basically in the watershed which is used for the purpose of drinking water, feeding animals and some time for irrigations. Gori Ganga watershed has more than 42 lakes/Kund/Taals (Fig. 2) where Plate-2 present Chhipla Kedar Kund (Chhipla Kedar Bugyal) and Najuri Kunds (Charthi Bugyal) are very famous for religious and spiritual to the communities. Taals found all over the region, some are very famous in the study area which names are heart shape Taal (Khaliya Bugyal), Thamri Kund (Kalamuni highland) and Mesar Kund (Plate-3) in the study area.

6.3 Springs/Dhare/Naule (Hot and Normal)

Dhara/Naule is a local name for common source of water resources/springs which is basically found two types, hot and cold water springs/Dhare in the Gori Ganga watershed. It is a natural water spring which is used by livelihoods (villages and towns) for drinking, irrigation and feeding animals in the study area. Water from springs or subterranean sources is channeled out through carved outlets. Plate-4 depicts the hot and cold water springs/Dhara in the Gori Ganga watershed.

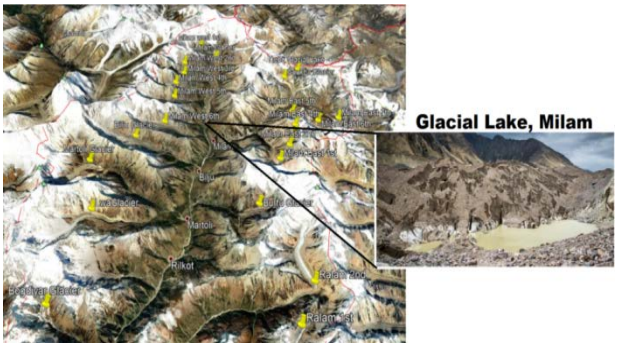

Plate-1: Glaciers and glacial lakes in the Gori Ganga watershed

Plate-2: Chhipla Kedar Kund (Chhipla Kedar Bugyal) and Najuri Kund (Charthi Bugyal) in the Gori Ganga watershed.

Plate-3: Heart shape Taal (Khaliya Bugyal) and Thamri Taal (Kalamuni Highland) in the Gori Ganga watershed.

Plate-4: Hot water spring/Dhara (Devi Bagar, Madkote) and cold water spring/Dhara (near Bangapani) in the Gori Ganga watershed.

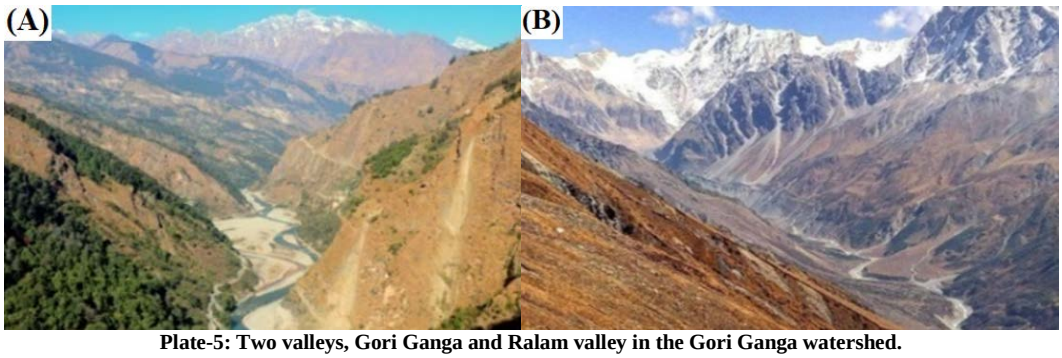

Plate-5: Two valleys, Gori Ganga and Ralam valley in the Gori Ganga watershed.

6.4 Drainage Network

Rivers are very important agent of landscape. There are more than 45 large and small tributaries which join Gori Ganga River at different altitudes. Mostly tributaries are snow fed which is beneficial for developing towns near the river bed, hydro projects, Gharats/watermill, agriculture, animal husbandry and some small rivulets springing up from Lesser

Himalayan ranges which is beneficial for Gharats in villages. Using DEM (Fig. 3) drainage network map (Fig. 4) and the length of drainage was measured by Arc GIS tool which results are presented in Table-1. Table-1 and Table-2 are presents details of these river names, origin places, types, lengths and confluence geographical points with Gori Ganga River. The total length of rivers in Gori Ganga watershed is about 263.05 km having density of 0.120 km/km2. Plate-5 depicts the main Gori Ganga river valley and famous tributary river (Ralam Gad) valley.

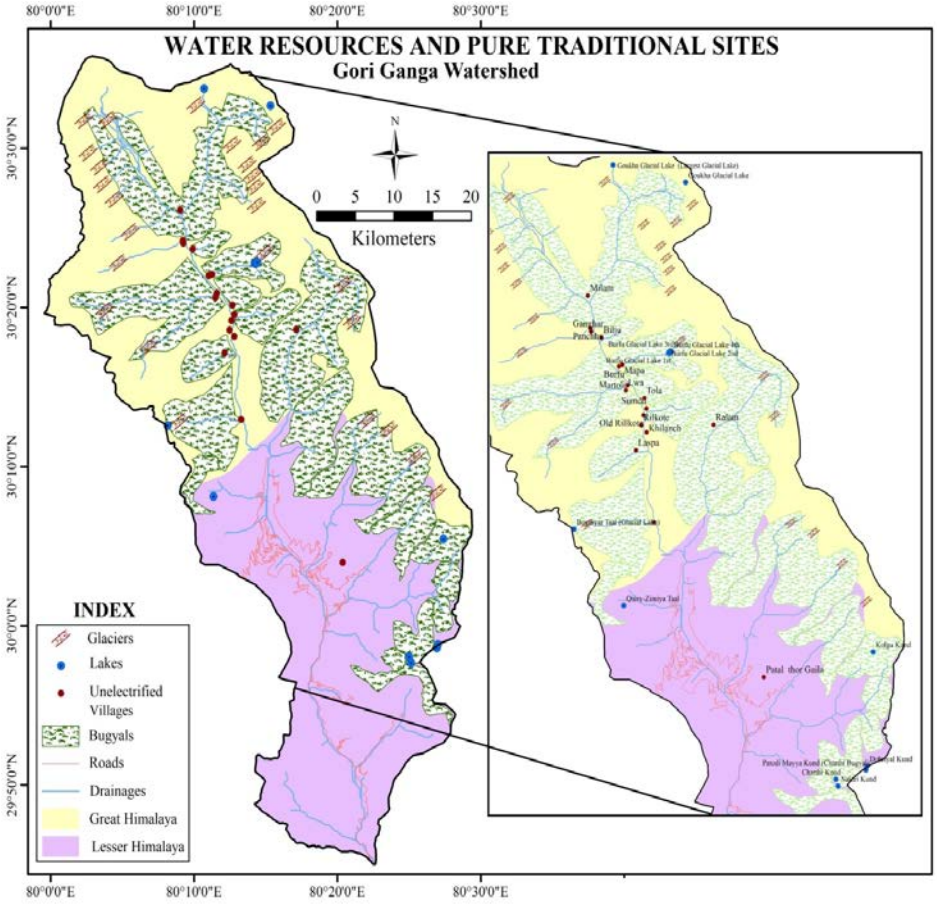

Figure-2: Geographical distribution of water resources and traditional villages in the Gori Ganga watershed (based on field survey and GPS).

7.0 TRADITIONAL WATER RESOURCE MANAGEMENT

Gori Ganga watershed is known for various types of traditional water systems, which are used for daily water needs i.e. drinking, irrigation, cleaning, feeding to the animals etc. Apart from Gori Ganga watershed, names of these structures may vary in different parts of Uttarakhand. The construction of natural springs (Dhara, Naula), Chal-Khal develop in Khaliya highland, Simar, Taal, Kund and water store tank are the most common conventional water conservation devices used by the villages. Most respondents have expressed their experience in traditional water management from various techniques. The people from the watershed area develop water harvesting devices according to their need and use them for drinking water and irrigation purposes.

7.1 Water Resources and Settlements

Most of the settlements (villages and towns) in the Gori Ganga watershed are lies in the river terraces which are depending on nearby water resources i.e. springs (Naule and Dhara), streams and rivers etc. some villages are Gaila, Rapti, Timphu, Dolma, Ropar, Okhali, Basant Kote, Bhadeli,

Malpati, Ghorpatta, Munsyari, Dhapa, Syannar, Paton, Madkote, Lodi, Farveykote, Bona, Sirtola, Sera, Khartoli, Mori, Mavani, Bangapani, Chhori Bagar, Jara, Jibli, Mori, Baram, Kanar and Ghattabagar etc. Figure-5 depicts the geographical distribution of the villages (168) in the Gori Ganga watershed. In the present time many villages are migrating from high altitude to low altitudinal/river terraces villages/towns i.e. Madkote, Munsyari and Bangapani etc. (Table-3). Figure-6 depicts 12 relief zone with 600 m interval and only two relief zone has growing town which are: first relief zone <1200 m has 10 growing towns (Madkote, Bangapani, Chhori Bagar, Bansh Bagar, Lumti, Chami, Baram, Garali, Toli and Jauljibi) and second relief zone 1800-2400 m has only one growing town (Munsyari) in the study area. High altitudinal villages are suffering with migration problems due to lack of development and in the present towns are growing near the river bed/river terraces/old flood plain and road network because of these growing towns are connecting to clean drinking water, internet, telecommunications, transporting motor road and other needs in throughout the year. Munsyari town is the most rapidly growing town near the natural water resources which is worldwide famous for tourism as a natural beauty, traditional and tribal cultures etc.

7.2 Hydro Electronic plants

Hydro electronic plant is one of the most sources of economy in Himalayan regions of Uttarakhand viz. Gori Ganga watershed district Pithoragarh. Tehsil Munsyari has 4 micro-level hydro electronic plants which names are Seraghat (Seraghat, Tanga)* Danibagar and Suring Ghat. Those plants are increased economical sources for local habitant because of project construction work is long term work and daily workers received daily work and healthy money. Many healthy workers (who have technical skills and good communication) are selected permanently for running those plants. Seraghat hydro project is one of the biggest plant of the study area because of this hydro electrical plant has largest number of workers. The permanent working staff (20) in and 12 contract based staff (Table-4). Table-4 and Figure-7 depict the geographical distribution of hydro electronic plants (name, location, working staff and productions) in the Gori Ganga watershed.

7.3 Gharats (Watermills)

Gharats is a local name of flour mill/Aata Chakki and it is made by local people with use of local material which are water force, stone parts and hut/house. Uses of Gharats are very common in the Gori Ganga watershed because of the study area settlements are lies in hilly slope. Figure-8 is depicts geographically distribution of 32 Gharats which is block Munsyari has-26, Dharchula-5 and Kanalichina-1 Gharats. Block Munsyari has largest number of villages which are uses Gharats due to enterer Himalayan part of the district and it's very far from towns/district headquarter. Gharats are made by local people and local material i.e., water force, two stone parts and one hut/house. Plate-6 depicts very common Gharats are in the Gori Ganga watershed and location of Gharats are attached in Table-5.

Table-1: Spatial distribution of drainage network in the Gori Ganga watershed (based on field survey).

S.N.	River Name	Origin Place	Confluence place	Type
1	Gori Gad	Milam Glacier	Jauljibi	Glacial
2	Mandakini Gad	Panchachuli Glacier	Madkote	Glacial
3	Bona Gad	Jimba Glacier	Seraghat	Glacial
4	Ralam Gad	Ralam Glacier	Near Paton Village	Glacial
5	Goukha Gad	Gaukha Glacier	Milam Village	Glacial
6	Rauntis Gad	Ghanghura Forest	Garjiya	Non-Glacial
7	Baram Gad	Chhipla Bugyal	Baram	Non-Glacial
8	Lawan Gad	Shalang Glaciers	Lawan Village	Glacial
9	Sain Gad	Khaliya Forest	Jimighat	Non-Glacial
10	Poting Gad	Poting Glacier	Bogdiyar	Glacia

Table-2: Geographical details of the major rivers in the Gori Ganga watershed *(based on field survey and GPS).*

Rivers	Length (km)	Origin place longitude (E)	Origin place Latitude	Confluence longitude (E)	Confluence Latitude (N)
Gori Gad	97.97	80° 22' 40.14"	29° 44' 59.64"	80° 7' 13.27"	30° 27' 7.61"
Mandakini Gad	27.95	80° 17' 46.52"	30° 03' 8.32"	80° 25' 3.52"	30° 14' 6.71"
Bona Gad	22.69	80° 19' 12.50"	30° 0' 32.53"	80° 27' 32.50"	30° 8' 46.33"
Ralam Gad	22.99	80° 15' 16.11"	30° 10' 49.60"	80° 19' 43.53"	30° 20' 34.37"
Goukha Gad	20.39	80° 9' 10.23"	30° 25' 38.73"	80° 11' 45.24"	30° 34' 6.94"
Rauntis Gad	16.97	80° 16' 13.36"	29° 52' 11.57"	80° 21' 20.74"	29° 46' 35.26"
Baram Gad	15.28	80° 21' 10.15"	29° 50' 56.68"	80° 25' 16.07"	29° 56' 58.36"
Lawan Gad	12.24	80° 4' 43.04"	30° 20' 14.68"	80° 11' 35.25"	30° 21' 8.54"
Sain Gad	9.9	80° 9' 53.58"	30° 8' 29.42"	80° 15' 7.56"	30° 8' 2.90"
Poting Gad	16.67	80° 9' 38.37"	30° 12' 42.15"	80° 13' 23.98"	30° 12' 52.06"
Total length	263.05				

Table-3: Name, location and height of towns at Gori Ganga watershed *(based on field survey and GPS).*

S.N.	Towns	Latitude (N)	Longitude (E)	Height in feet	S.N.	Towns	Latitude (N)	Longitude (E)	Height in feet
1	Bangapani	$29^0$57’26.34’’	$80^0$18”12.48’’	3297	7	Chhoribagar	$29^0$56’45.60’’	$80^0$18’08.96’’	3235
2	Munsyari	$30^0$07’15.17’’	$80^0$23’07.34’’	7200	8	Madkote	$30^0$03’24.39’’	$80^0$17’37.62’’	4154
3	Baram	$29^0$51’05.26’’	$80^0$21’16.64’’	2757	9	Toli	$29^0$48’54.24’’	$80^0$21’57.12’’	2405
4	Bansh Bagar	$29^0$55’46.71’’	$80^0$18’05.95’’	3158	10	Lumti	$29^0$53’34.21’’	$80^0$19’07.36’’	3018
5	Chami	$29^0$52’33.05’’	$80^0$19’38.65’’	3053	11	Jauljibi	$29^0$45’08.14’’	$80^0$22’35.68’’	2063
6	Gharali	$29^0$47’51.73’’	$80^0$21’30.48’’	2300					

Table-4: Descriptions of hydro electronic plants in the Gori Ganga watershed *(based on field survey and GPS).*

S.N.	Location Name	Latitude(N)	Longitude (E)	No. of workers	Production
1	Seraghat*	$30^0$0’38.44’’	$80^0$19’07.89’’	16 (10+6)*	5 Megawatts
2	Tanga*	$30^0$0’53.36’’	$80^0$19’53.16’’	16 (10+6)*	5 Megawatts
3	Danibagar	$30^0$1’29.00’’	$80^0$20’30.80’’	7	500 Kilowatts
4	Suring Ghat	$30^0$6’49.54’’	$80^0$15’01.96’’	8	800 Kilowatts
Total				47	11.3 Megawatt

**10 Permanent workers and 6 temporary workers.*

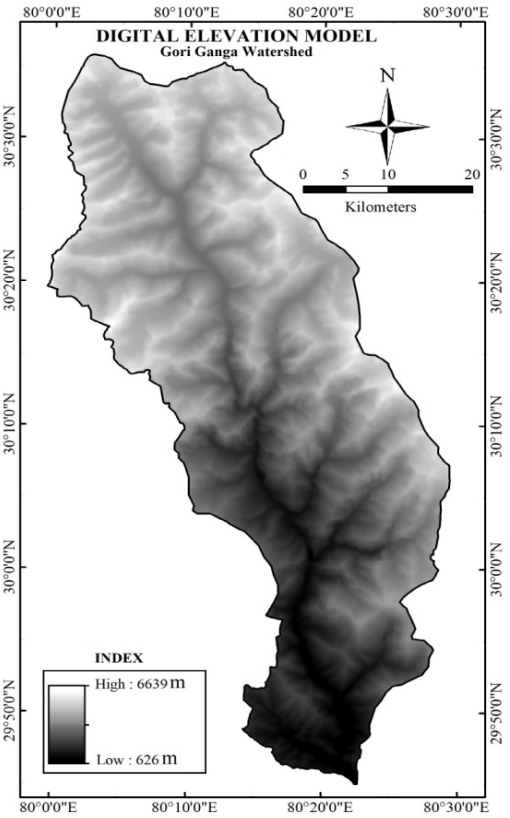

Figure-3: Digital Elevation Model (*DEM*) of Gori Ganga watershed *(based on Cartosat-1, data).*

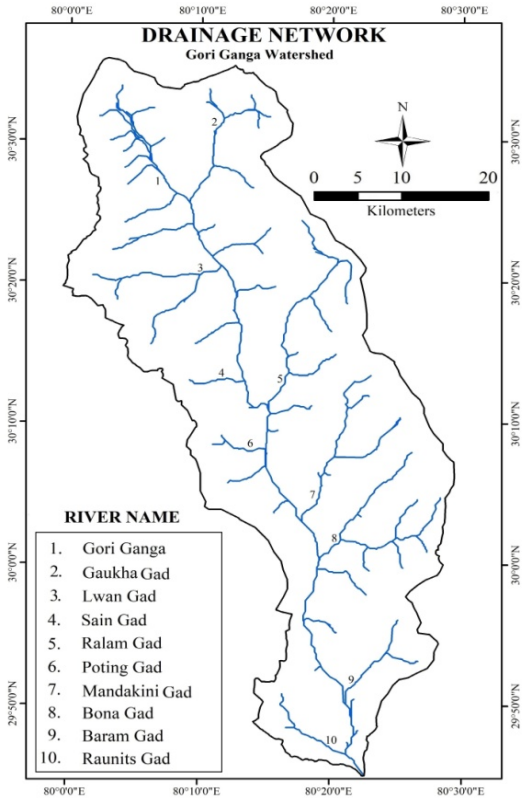

Figure-4: Distribution of drainage network in the Gori Ganga watershed *(based on field survey and Cartosat-1, satellite, data).*

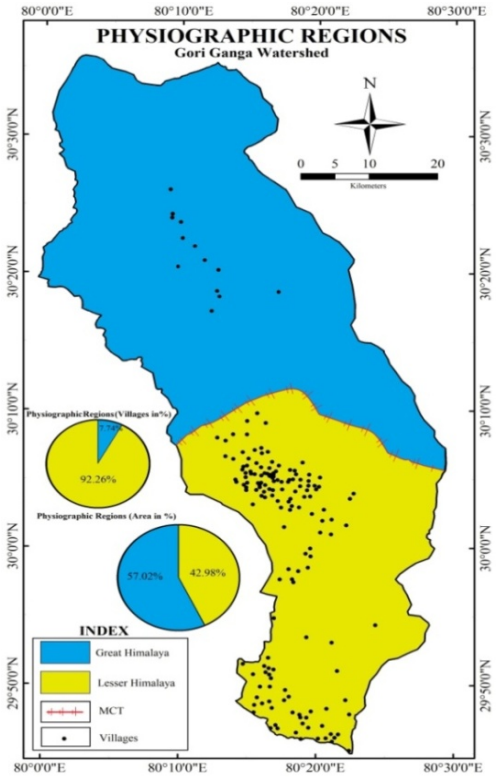

Figure-5: Physiographic regions and distribution villages in the Gori Ganga watershed, Kumaun Himalaya *(after Pathak et al. 2015 based on Censes of India- 2011).*

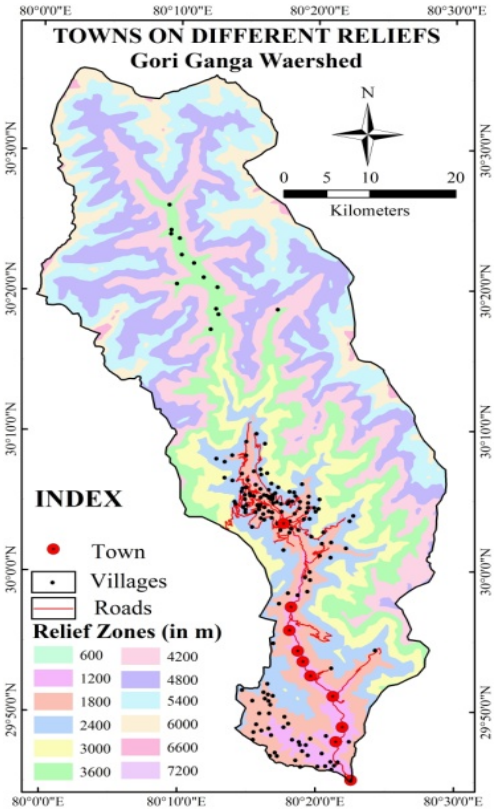

Figure-6: Distribution of towns in the Gori Ganga watershed *(based on field survey, GPS and Cartosat-1, satellite data).*

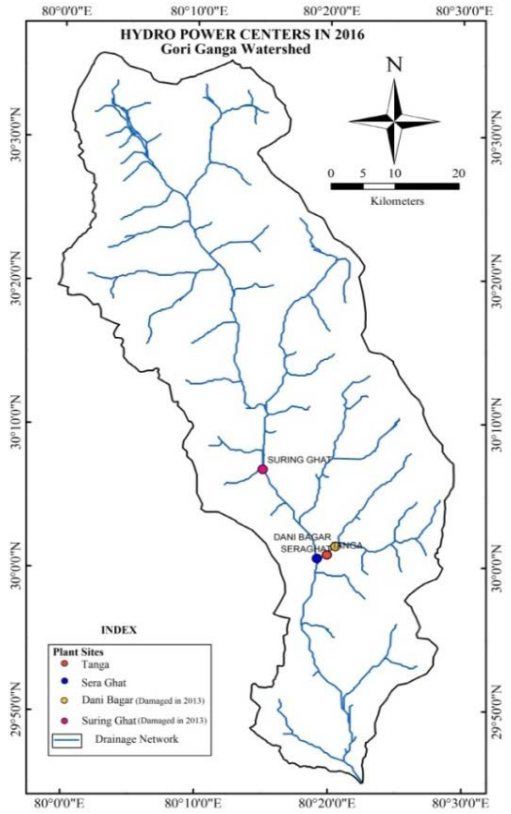

Figure-7: Distribution of hydropower project in the Gori Ganga watershed *(based on field survey, GPS and Cartosat-1, Satellite data).*

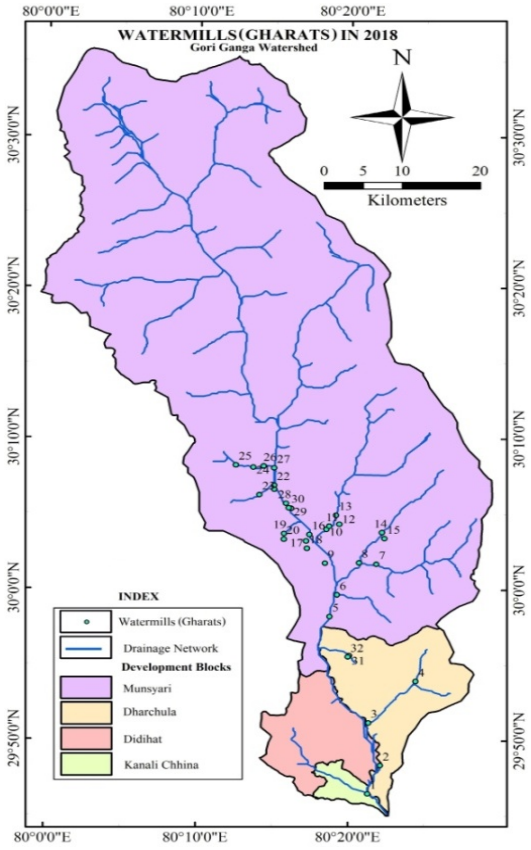

Figure-8: Distribution of Gharats in the Gori Ganga watershed *(based on field survey, GPS, Cartosat-1 Satellite data).*

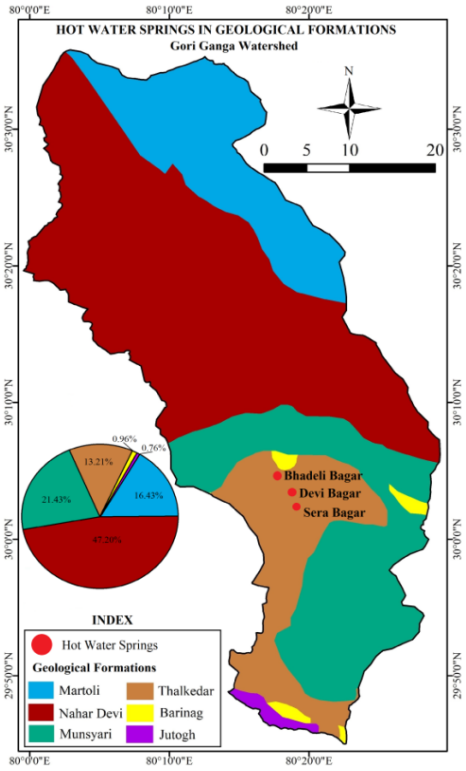

Figure-9: Geological formations of the Gori Ganga watershed, Kumaun Himalaya *(after based on field survey, GPS, Valdiya 1962, 1968, 1980; Valdiya and Gupta 1972 and Bhatt et. al. 2018).*

Plate-6: Gharat (watermill) at near Jarajibli *(based field survey).*

Plate-7: Hot water spring near Madkote town *(based on field survey).*

Table-5: Distribution of Gharats (*Watermills*) in the Gori Ganga watershed *(based on field survey and GPS).*

S.N.	Watermills	Latitude (N)	Longitude (E)	S.N.	Watermills	Latitude (N)	Longitude (E)
1	Barigaun	29^{0}46’27.48’’	80^{0}21’16.06’’	17	Imla	30^{0}03’12.72’’	80^{0}17’08.60’’
2	Garali	29^{0}48’20.71’’	80^{0}22’05.67’’	18	Josha	30^{0}02’43.24’’	80^{0}17’12.19’’
3	Baram	29^{0}51’10.29’’	80^{0}21’18.82’’	19	Matyani	30^{0}07’20.10’’	80^{0}14’56.36’’
4	Kanar	29^{0}53’56.00’’	80^{0}24’25.08’’	20	Harkote	30^{0}07’27.30’’	80^{0}14’50.33’’
5	Umargada	29^{0}58’12.33’’	80^{0}18’44.31’’	21	Sera	29^{0}59’39.03’’	80^{0}19’12.85’’
6	Talla Ghorpatta	30^{0}06’38.30’’	80^{0}15’02.33’’	22	Dhapa	30^{0}06’53.73’’	80^{0}15’01.07’’
7	Farvekote	30^{0}01’46.74’’	80^{0}21’47.16’’	23	Syannar	30^{0}06’16.40’’	80^{0}14’03.07’’
8	Bhikuria	30^{0}01’46.74’’	80^{0}20’39.38’’	25	Quiry	30^{0}08’15.02’’	80^{0}12’30.23’’
9	Dhoonamani	30^{0}01’44.86’’	80^{0}18’24.22’’	24	Sain	30^{0}08’06.16’’	80^{0}13’39.09’’
10	Ropar	30^{0}03’58.98’’	80^{0}18’30.03’’	26	Sain Polu	30^{0}08’10.33’’	80^{0}14’19.67’’
11	Dobari	30^{0}04’11.77’’	80^{0}18’40.63’’	27	Jimighat	30^{0}08’02.86’’	80^{0}15’00.80’’
12	Rapti	30^{0}04’19.05’’	80^{0}19’20.70’’	28	Gopal Bara	30^{0}05’42.44’’	80^{0}15’48.59’’
13	Basant Kote	30^{0}05’24.16’’	80^{0}16’08.68’’	29	Khata	30^{0}04’55.31’’	80^{0}19’07.12’’
14	Bona Gar	30^{0}03’47.04’’	80^{0}22’08.45’’	30	Bachhepur	30^{0}05’24.16’’	80^{0}15’59.15’’
15	Bona	30^{0}03’22.84’’	80^{0}22’18.70’’	31	Jarajibili	29^{0}55’37.72’’	80^{0}20’1.82’’
16	Golma	30^{0}03’38.47’’	80^{0}17’22.01’’	32	Jara	29^{0}55’31.87’’	80^{0}19’56.34’’

7.4 Hot Water Springs

Geological study of the Gori Ganga watershed is based on after Valdiya 1962, 1968, 1980; Valdiya and Gupta 1972 and Bhatt et al., 2018. Based on these studies the Gori Ganga watershed is constituted of six different rock formations. These are Martoli formations, Nahar Devi formations, Munsyari formations, Thalkedar formations, Barinag formations and Jutogh formations (*Fig. 9*).

Sor/Thalkedar formation observed near Madkote and Umargarha village under the Tejam group in Gori Ganga basin. Some metamorphic minerals are noticed in these present groups which are Quartzite, white crystalline limestone with talk pockets, Granite/Gneissose granite with occasional bands of mylonite, Limestone inter-bedded with grey slates and black phyllites. The sedimentary sequence rocks are exposed between Balmara and Jauljibi. Total area

under this group is 289.61 km^2. This region has so many thermal water springs between Devibagar and Badeli (*Bhatt et. al., 2018*). Hot springs are indicating to this area very active tectonics. Gori Ganga river basin has three hot springs which names are Sera (*$30^0$00'07.05''N, $80^0$19'04.61''E*), Devi Bagar, Madkote (*$30^0$03'00.11''N, $80^0$18'04.00''E*) and Bhadeli Bagar (*$30^0$04'30.16''N, $80^0$16'53.87''E*). Figure-9 depicts the geographical distribution of hot water springs in the Gori Ganga watershed. Plate-7 depicts the most developed hot water spring spot (*Devi Bagar, Madkote*) in the study area. Two hot water springs (*Devi Bagar, Madkote and Sera*) are mostly used (*Bathing in winters*) by locals and tourists. Both hot water springs are not charging any coast for bathing/using but if all hot water spring spots will develop (*bathing facility, hygiene, maintenance, security, connectivity by motor road etc.)* for business/tourism purpose these places will be grow as a economic source for locals /tourism spot.

8.0 ROLE OF WOMEN AND CHILDREN IN WATER RESOURCE MANAGEMENT

In the Gori Ganga watershed, women and children play an important role in fetching the water from Dhara, stream, pond, community water store tank and river for drinking purpose, domestic uses, animals feeding and agricultural uses. Women have higher significant role than men in management, problem analysis and decision making process related to water resources. Women also play a key role in water resource conservation, save water, cleaning of water source and distribution of water for other families in Gori Ganga watershed. However, making Kuls/Gools, working in Gharats (*as an owner*) and repairing Dharas/pipelines, maintaining Kuls/Gools works did by the men.

9.0 CONCLUSION

The present study on the water resources in Gori Ganga basin revealed that the major sources of water in the study area are glaciers, rain water, lakes/Taals, rivers, streams, springs and Kund. Prominent lakes are Thamri Kund, Messar Kund and Chhipla Kedar Kund etc. The important rivers of Gori Ganga valley are Goukha gad, Ralam gad, Mandakini gad, Gori gad, Bona gad, Baram gad and Sain gad etc. Traditional water resources management plays an important role in maintaining water resources in the Gori Ganga watershed during the period of water crisis. Traditional water resources are being damaged due to development works and some natural/anthropogenic activities. Clusters of small scale industries, villages, towns located in the study area are depend on the springs, Taals, Gori Ganga River and tributaries networks for the drinking water. People are increasing their economic sources by tourism, tracking, Eco-tourism; development of Gharats (*watermills*), irrigation on valley region for agriculture, animal husbandry, working under hydro electronic projects and using of hot water spring in the watershed. Present study is based on field survey, GPS coordinates, remote sensing data, i.e. Cartosat-1 using GIS techniques and has demonstrates that the remote sensing and GIS techniques are very useful for the study of importance of water resource for socio-economic development. There is a need to take serious steps for effective maintenance and revival of this traditional wisdom for development, conservation and management of water resources.

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