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A Study on Temporal Variation of Snow and Glacier in Langtang Basin

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ABSTRACT–Snow cover and glacier in the Himalaya play a major role for generating stream flow in South Asia. It is already observed that the snowline is retreating in the Himalaya region. While there are relatively more studies on glaciers fluctuation in this region, studies on snow cover are relatively rare. Present study is aimed to analyze the temporal variation of snow and glacier cover (both debris and clean ice covered) of Langtang area within the catchment 432.32 sq.km at outlet 28°12'10.78"N and 85°27'44.58"E. Currently, we used intermittent medium resolution satellite imageries (Landsat) to study the fluctuation in snow cover and glacier area in the Langtang catchment. Our analysis revealed that the glaciers in the study area are tentatively shrinking in average. More specifically, the Landsat Satellite images of the concerned area processed through ERDAS Imagine and their detailed analysis conducted in ArcGIS show that the minimum snow coverage area is declining and maximum snow coverage is in the average range and in the case of debris coverage glacier and clean ice glacier, the trend is declining. The novelty of this study was to develop a robust process having potentiality to predict snow coverage that would be ultimately applicable to agricultural sectors.

KEYWORDS– Langtang Himalyan Region, Snow Covered Area, Glacier, NDSI, NDVI

1. INTRODUCTION

Nepal is a mountainous country with most of the area covered by mountains and hills. Glaciers of the Himalayas are storehouse of fresh water from which hundreds of millions of people downstream benefit, when needed in dry season. These Himalayas are also termed as the "water tower" and "third pole" of the earth[1]. It was documented that there are 3,252 glaciers in Nepal. Area of 5,324 square kilometers is covered with high frozen reservoirs that release their water at the top of their watershed [2]. Generally the area higher than 4,000 meter above mean sea level is covered by snow and ice throughout the year[3]. Mountains are particularly vulnerable to climate change[4].

The impacts of climate change, mainly melting of snow cover have been noticed in Nepalese Himalayas. Temperature rise between 0.15 and 0.6 degree Celsius per decade is recorded in Nepal[5]. Previous studies shows that the temperature in the Langtang Glacier is increasing 0.27 degree Celsius per year[6]. Increased snow and glacial melt and frequency of extreme weather have exacerbated livelihood risks including poverty, food insecurity, hazards and social inequity[7].

The country is vulnerable to various hazards due to fragile geological conditions, active tectonics rich diversity of climates, hydrology, ecology and great elevation differences and steeply sloping terrain. Apart from the landslides and river erosion, this region is quite susceptible to hazards due to glacial lake outburst floods (GLOFs) [8].

The estimation of the quantity of contribution of snow and ice for river discharge, present study tries to provide the basic information of temporal distribution of snow coverage area and clean and debris covered glaciers over the time at Langtang river basin. This study find the trend of minimum and maximum snow coverage area and debris and clean ice coverage glacier of Langtang with time analyzing data from year 2000 to 2017. There are various snow melt run off models which simulates the river discharge considering the basic information provided by the present study.

Describing and tracking the snow cover disintegration and glacier melting down is difficult using field based method, with respect to the large areas affected. Therefore remote sensing technique can be used for tracking the areas extent of snow cover using Landsat satellite image and remote sensing software.

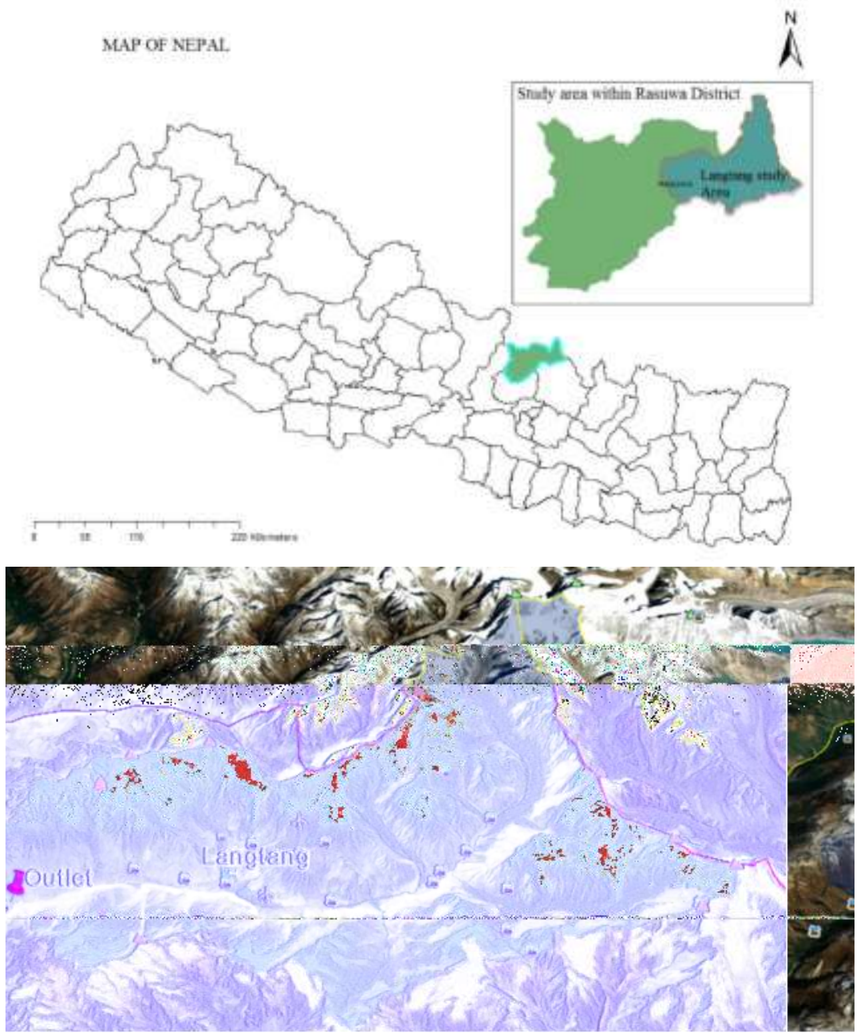


Figure 1. Study area (Langtang Basin)

2. STUDY AREA

The Langtang basin is a part of Narayani Basin. It lies in Rasuwa district. The extent of the area of interest is 28˚07'42"N to 28°22'56"N latitude 85˚26.32.55E to 85°41'41"E longitude. Outlet point of studied catchment is taken at 28°12'10.78"N and 85°27'44.58"E latitude and longitude respectively. The total area of the catchment

is 432.32 square kilometer with elevation ranging from 3652m a.s.l. to 7215 m a.s.l. the glaciers of this catchment cover and area of 137.5 km^2 while remaining area of 216.1 km^2 is covered by rock and vegetation. From March to mid – June, the air temperature is gradually increase. More than 80% of annual precipitation falls during the monsoon season, from mid - June to the end of September.

No many studies have been done in this sector in the Langtang Bain, which is actually very important for the agricultural point of view, initiation of water related project specially hydropower – plant and irrigation. Therefore, this study aims to provide information about rate of changes of snow coverage area.

3. METHODOLOGY

To identify the different snow cover area and glacier (clean and debris covered) the Landsat Satellite image of Langtang basin were used. The spectral reflectance characteristics as depicted in Figure 2 has been used. Ratio of band 5 and band 2 is used for snow to eparate snow from rest of the image. Similarly, standard algorithm separates the clean and debris covered glacier from rest of the image using the bands as presented in figure 2.

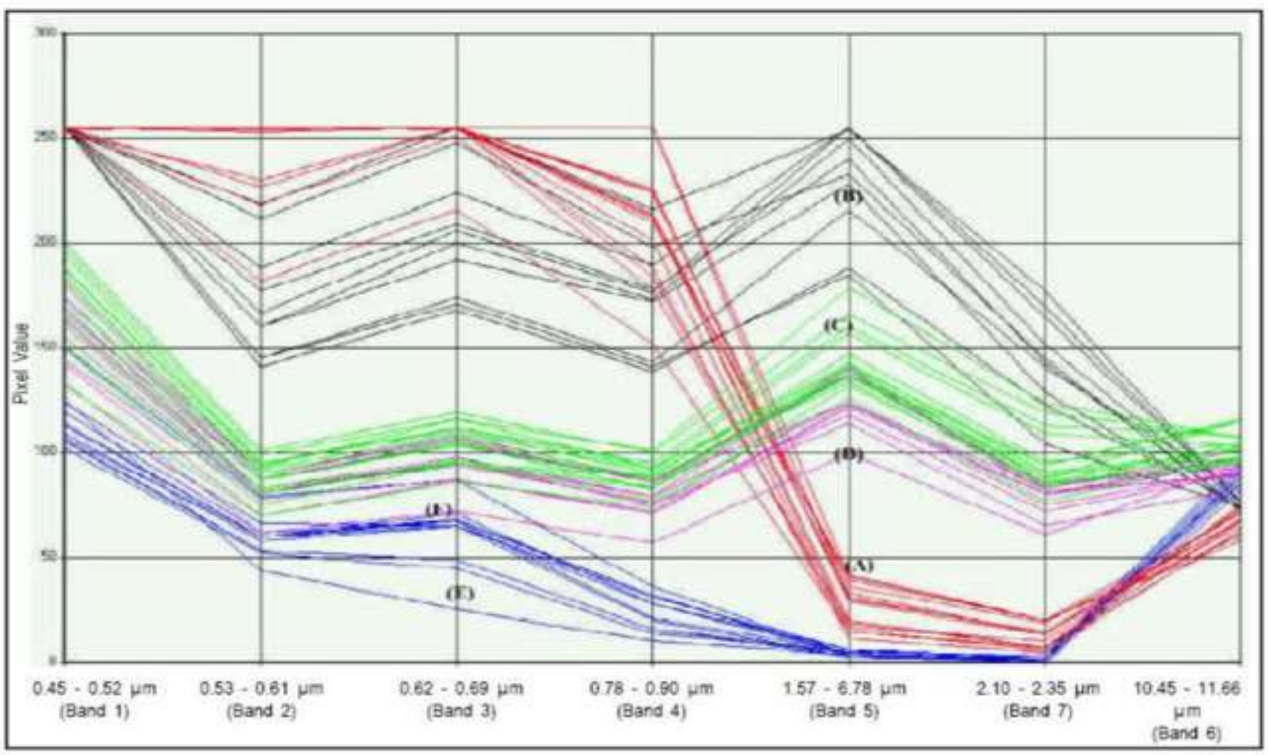
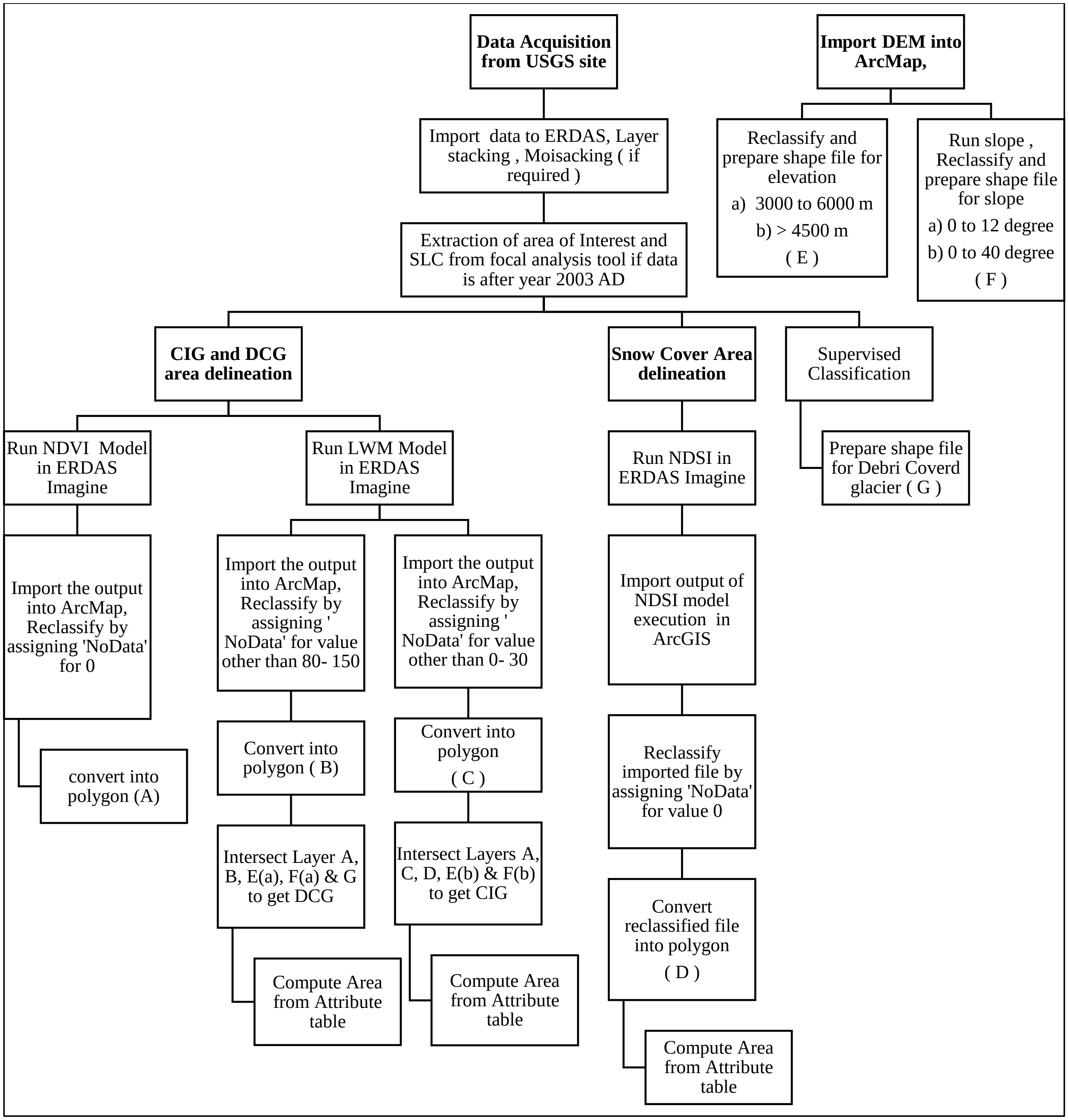


Figure 2. Spectral reflectance characteristics different surface

(A) Clean glaciers and fresh snow; (B) clouds; (C) debris from GLOFs; (D) debris covered glacier; (Pradeep.K, et al. 2001).



*Scheme 1. **Flow chart of the methodology used in the study***

Landsat is series of satellite mission developed by National Aeronautics and Space Administration (NASA) for the geological and mapping purposes. Landsat mission launched 7 satellites in orbit. Landsat 7 is equipped with the thematic map (TM) which coined the band name as TM1, TM2, etc.Landsat satellite has sensors to record different band of the EMR. Since May 2003 the scan line corrector (SLC) onboard Landsat 7 is malfunctioning. The error does not influence the geometry and radiometry of the other electromagnetic radiation (EMR) sensors but creates black stripes in the image. This requires additional effort to enhance the image. This requires additional effort to enhance the image. The Landsat TM image is acquired through official site of United States Geological Survey (www.glovis.usgs.gov). The image selection is comparably difficult in glaciology. Overall, images after late winter (March) and pre-monsoon (May) are reliable and available for free download from official site. The images in rest of months tend to have heavy cloud cover. For the present study, cloud cover (represented as CC in Landsat image) less than 30% have been utilized. During the selection of yearly image, calendar years 2000 to 2017 were used. But some images, due to heavy cloud coverage are not downloaded. ERDAS Imagine, ArcGIS, and Google earth pro were used for data processing and analysis. For the analysis of acquired data various model based on past studies were run incorporating some trial and error approach as well. All the process involved is shown in scheme 1.

4. RESULT AND ANALYSIS

The results of area corresponding to the snow cover, clean and debris-covered glacier are obtained using ERDAS, ArcGIS presented herein after.

4.1 Temporal distribution of snow and debris glacier

Table 1: 2000-2016 Minimum Snow Coverage

SN	Date	Snow Coverage Area (Sq. KM)	%
1	22-Nov-00	156.831	36.28%
2	27-Dec-01	149.711	34.63%
3	28-Nov-02	243.114	56.23%
4	1-Dec-03	165.502	38.28%
5	14-Sep-04	150.879	34.90%
6	3-Oct-05	110.736	25.61%
7	6-Oct-06	240.674	55.67%
8	26-Jan-07	188.931	43.70%
9	14-Dec-08	150.029	34.70%
10	30-Oct-09	180.390	41.73%
11	1-Oct-10	165.71	38.33%
12	21-Nov-11	184.15	42.59%

Table 2. 2000-2016 Maximum Snow Coverage

SN	Date	Snow Coverage Area (Sq. KM)	%
1	23-Jan-00	343.914	79.55%
2	14-Mar-01	288.686	66.78%
3	1-Mar-02	380.329	87.97%
4	25-Mar-05	431.330	99.77%
5	15-Mar-07	420.547	97.28%
6	15-Mar-08	420.735	97.32%
7	19-Feb-10	369.385	85.44%
8	10-Mar-11	382.199	88.41%
9	13-Apr-12	415.752	96.17%
10	15-Mar-13	393.586	91.04%
11	21-Mar-15	420.74	97.32%
12	7-Mar-16	412.34	95.38%
13	26-Mar-17	376.81	87.16%

13	7-Nov-12	136.04	31.47%
14	10-Jan-13	141.259	32.67%
15	12-Oct-14	161.371	37.33%
16	18-Dec-15	102.290	23.66%
17	20-Dec-16	103.920	24.04%

It is seen that the area under study incurs minimum snow cover during the months from October to December, fluctuating its occurrence among these months. During these months of low snow coverage, the snow cover in catchment varied from about 30% to 40% of the total area. It is seen that the area under study incurs maximum snow cover during the months from February to April, fluctuating its occurrence among these months. During these months of high snow coverage, the snow cover in catchment varied from about 80% to 100% of the total area.

Table 3. Debris and Clean Ice Covered glacier Coverage

Year	Debris Covered Glacier, sq.km	% of DC of total area	Clean Ice Glacier, sq.km	% of CIG of total area	% of DC and CIG of total area
2000	21.72	5%	108.99	25%	30%
2001	18.72	4%	103.07	24%	28%
2002	17.52	4%	-	-	-
2003	16.23	4%	110.98	26%	29%
2004	17.54	4%	103.65	24%	28%
2005	17.53	4%	-	-	-
2006	18.01	4%	-	-	-
2007	15.23	4%	117.00	27%	31%
2008	15.70	4%	109.89	25%	29%
2009	11.93	3%	118.30	27%	30%
2010	23.32	5%	96.03	22%	28%
2011	20.39	5%	106.37	25%	29%
2012	20.89	5%	96.78	22%	27%
2013	18.62	4%	100.34	23%	28%
2014	20.81	5%	111.08	26%	31%
2015	15.81	4%	78.64	18%	22%

2016	13.92	3%	81.15	19%	22%
2017	12.72	3%	88.00	20%	23%

4.1 Validation of the Results

Some of the snow cover results were compared with Google earth digitized image and found to be within ±15%. But it is also seen that snow cover area tends to have strong relation with the date and time of acquisition of Landsat satellite image. An image acquired a day before the snowfall and a day after the snowfall gives considerable amount of changes in snow cover area. Hence, reliable validation of snow cover area was difficult to obtain.

Validation of Glacier result is very cumbersome and nearly impossible via use of Google earth only[9]. The results were compared with previous study and found to be satisfactory.

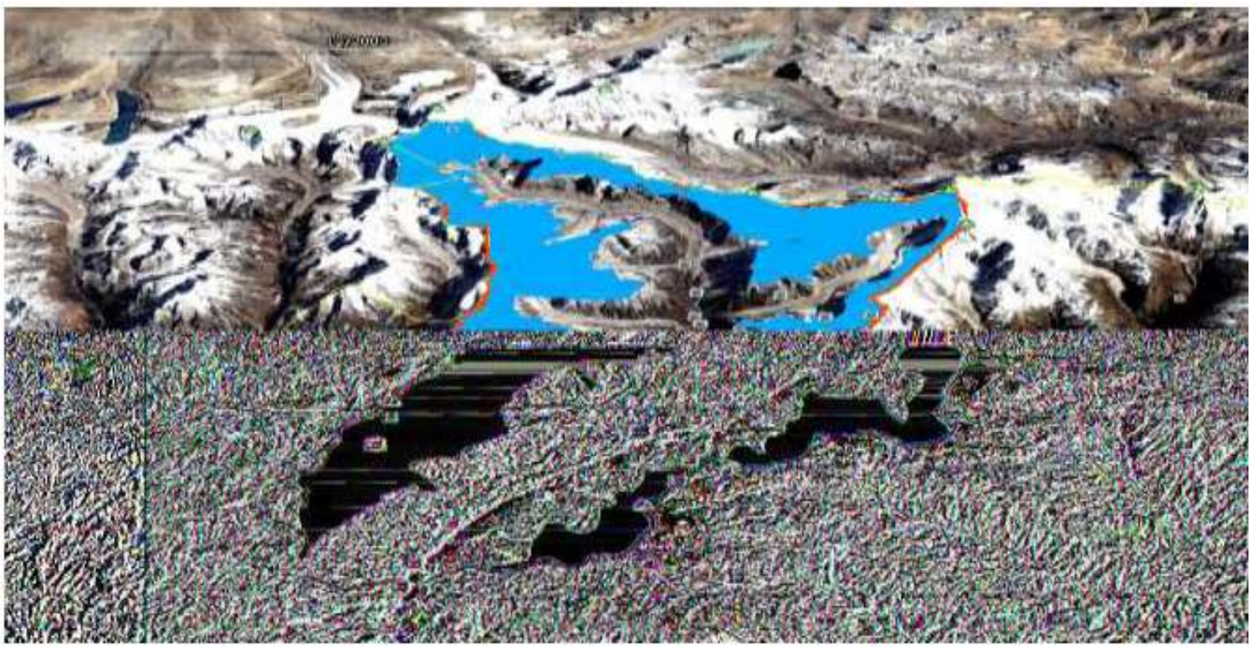


Figure 3. Digitization of Snow cover Area in Google earth (2003 December)

5. DISCUSSION AND CONCLUSION

It is observed that the output of the study for ascertaining the snow cover area along with debris covered glacier and clean ice glacier and analyzing the trend for changes depend significantly in the availability of appropriate data. As is seen from the snow cover area data, the maximum snow cover for the year 2003, 2004, 2006 and 2009 were inconsistent with the result of other years. A reason for this inconsistency is due to the improper selection of LANDSAT dataset i.e. data with high cloud cover, data of inappropriate date or combination of both. One of the limitations of conducting the study is the lack of availability of regular month wise data. Because of lack of regular data with tolerable cloud cover, the analysis of trend of change of snow cover could not be properly addressed.

It can be interpreted that, although fluctuating in magnitude, the overall snow cover in the catchment is in depleting trend for periods of low snow cover whereas the overall snow cover is in increasing trend for periods of high snow cover. It is seen that the variation in magnitude of maximum snow cover over the years is not as significant as the variation in the magnitude of minimum snow cover. In fact, the minimum snow cover is seen to have depleted by about 40% from the year 2000 to 2017. The debris covered glacier in the catchment covers about 5% of the total area while the clean ice glacier covers about 25% of the total catchment.

A quantitative analysis of snow cover, debris covered glacier and clean ice glacier was performed for a catchment in Langtang. NDSI, NDVI and LWM model were used to determine the coverage of snow, debris covered glacier and clean ice glacier. The expediency of remote sensing through software like ERDAS and ARCGIS in monitoring the land use over a large area was realized. Such tools prove to be highly useful for qualitative as well as quantitative evaluation of land use parameters, especially where ground based monitoring is difficult[10]. However, the accuracy of the result obtained from these tools is dependent upon the availability, suitability and reliability of image data.

REFERENCES

(1) Tariyal, K.; Bartwal, D. M.; Melkania, U. Glacial Melting in Himalaya: Local Impacts of Climate Change on Mountain Ecosystems and Livelihoods. *J. Adv. Lab. Res. Biol.* **2013**.

(2) Bajracharya, S. R.; Mool, P. K.; JoshiI, S. P. Spatial Database Development of Glaciers and Glacial Lakes in the Identification Potentially Dangerous Glacial Lakes of Nepal Using Remote Sensing and Geographic Information Systems. In *Proceedings of 23rd Asian Conference on Remote Sensing held from 25 - 29 November 2002*; 2002.

(3) Kang, S.; Xu, Y.; You, Q.; Flügel, W. A.; Pepin, N.; Yao, T. Review of Climate and Cryospheric Change in the Tibetan Plateau. *Environmental Research Letters*. 2010. https://doi.org/10.1088/1748-9326/5/1/015101.

(4) Shrestha, U. B.; Gautam, S.; Bawa, K. S. Widespread Climate Change in the Himalayas and Associated Changes in Local Ecosystems. *PLoS One* **2012**. https://doi.org/10.1371/journal.pone.0036741.

(5) R. BAJRACHARYA, S. Glacial Lake Outburst Flood Disaster Risk Reduction Activities in Nepal. *Int. J. Eros. Control Eng.* **2010**. https://doi.org/10.13101/ijece.3.92.

(6) Shrestha, A. B.; Aryal, R. Climate Change in Nepal and Its Impact on Himalayan Glaciers. *Reg. Environ. Chang.* **2011**. https://doi.org/10.1007/s10113-010-0174-9.

(7) Development, S. M. *Draft Regional Report Hindu Kush – Himalaya Sustainable Mountain Development*

Hindu Kush Himalaya (HKH) Region; 2011.

(8) Matambo, S. T.; Shrestha, A. B. *World Resources Report Case Study. Nepal: Responding Proactively to Glacial Hazards*; 2011.

(9) Koboltschnig, G. R.; Schöner, W.; Zappa, M.; Kroisleitner, C.; Holzmann, H. Runoff Modelling of the Glacierized Alpine Upper Salzach Basin (Austria): Multi-Criteria Result Validation. In *Hydrological Processes*; 2008. https://doi.org/10.1002/hyp.7112.

(10) Jha, L. K.; Khare, D. Detection and Delineation of Glacial Lakes and Identification of Potentially Dangerous Lakes of Dhauliganga Basin in the Himalaya by Remote Sensing Techniques. *Nat. Hazards* **2017**. https://doi.org/10.1007/s11069-016-2565-9.