Satellite mapping of land use land cover (LULC) changes and NDVI in the Subansiri river basin of eastern Himalayas and the Alaknanda river basin of western Himalayas: A comparative study based on spatial analysis

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Abstract
This study attempts to analyse and interpret the land use and land cover changes in two Himalayan river basins viz. the Subansiri and the Alaknanda of eastern and western Himalayas respectively using Remote Sensing and GIS technologies with the help of LANDSAT imageries and standard procedures. It is found from the study that the vegetation cover had declined by 1.81% and barren land by 3.82% in 14 years in case of the Subansiri basin, while in case of the Alaknanda basin, the corresponding values work out to be 4.24% and 3.54% in 13 years.

The reason for the decline of the forest cover and barren land may be due to the increasing agricultural practices, population pressure and construction activities in the basins. There are positive changes in agricultural lands by 6.39% and 6.40% in the Subansiri and the Alaknanda basin respectively to fulfil the needs of rising population and their livelihood. The NDVI shows high vegetation indices in both the basins (0.97 in Subansiri and 0.91in Alaknanda). From the study, anthropogenic activities are found to be comparatively more pronounced in the Alaknanda basin as compared to the Subansiri basin.

Keywords: Land use and Land cover (LULC), Himalaya, Subansiri, Alaknanda, NDVI.

Introduction

Land use/Land cover is an important component in understanding the interactions of the human activities with the environment. The Himalaya is a unique mountain system of the world with their lofty snow capped summits and rich biodiversity. Water is very vital for nature and can be a limiting resource to human and other living beings.[12] The Himalaya is the main source of water for the rivers in the Indo-Gangetic plains and has significant water yielding capacity. The Himalayas constitute the largest reservoir of snow and ice in the world excluding the polar regions. Water is a precious gift of nature and a river is an open system that has a great influence on settlement pattern, land use and socio-economy of the area. Land Use/Land Cover (LULC) change detection is one of the most significant parameters to detect the population pressure on a specific area. It reflects not only the human interventions on the land area but also on other resources like forest canopy, wetlands and other water bodies and biodiversity. LULC change detection is very much informative in case of the river basins that are located geologically complex terrain and are affected not only by human interventions but also by frequent natural calamities.

The Subansiri basin of eastern Himalayas and the Alaknanda basin of western Himalayas are also not exceptions from these characteristics. The Subansiri basin located in seismically active zone V frequently experiences earthquake, erosion, landslides and flood hazards while landslides and flash floods (due to Glacial Lake Outburst Flow) are very common in the Alaknanda basin which also falls in seismically active zones both IV and V. The observed patterns of the Subansiri river channel dynamics and consequent land use changes in its lower part within Assam in the recent decades have tremendous effects on human settlement and have thrown newer environmental challenges.[7,9]

In the Alaknanda basin, the impediments related to the developmental processes are due to the adverse geo-environmental conditions.[13] The Alaknanda river profile has changed notably after June 2013 flood.[4]

Land use and vegetative cover play an important role in watershed runoff and stream flow discharge patterns over time including peak flows. Increased human interventions have caused rapid transitions in land cover, adversely affecting the watershed processes and hydrological cycle in the long run.[3] Anthropogenic changes in land use, mostly deforestation and conversion of pastures into agricultural lands, are being increasingly recognised as critical factors influencing global change.[16]

The forests of the Himalayan region have a pervasive influence on the ecosystems, environment and the lives of people. During the period (1967–1997), the forest cover in Garhwal Himalaya has been altered drastically due to increasing population pressure (both human and animal), increased agricultural activities and extraction of natural resources.[18] In the mountains, the terrain complexity complicates the interpretation of spectral signatures influenced by elevation, aspect and slope; this could lead to similar objects showing different reflectance and/or the different objects presenting the same reflectance, especially in dark shadow areas.[17]

Study area

The study area covers parts of the western Himalayan region represented by the Alaknanda river sub-basin of the Ganga basin and parts of the eastern Himalayan region represented by the Subansiri river sub-basin of the Brahmaputra basin (Figure 1). The river Subansiri originates in the south of the Po Rom Peak in Tibet (China) at an elevation 5059 meters. The extension of the basin in India is 26°57 N' - 28°40' N and 92°40' E - 94°47' E. It is a perennially snowfed trans-Himalayan river that passes through the Miri Hills in Arunachal Pradesh, enters the plains in Assam and flows through them before meeting the mighty river Brahmaputra near Jamuguri. The drainage area of the Subansiri River in India covers approximately 27,280 sq.km and it contributes about 7.92% flow of the river Brahmaputra at Pandu near Guwahati.

The Alaknanda is a Himalayan River in the State of Uttarakhand. It is one of the major headstreams of the Ganges and originates at the water divide between Satopanth and Bhagirath glaciers situated in the southern slopes of the outer Himalayas. The river basin lies between 30° 0' N- 31° 3' N and 78°37'E - 80°2' E covering a basin area of 10,936 sq. km. and carrying an average discharge of 439.36 m^3/s. Several high mountain peaks such as Nanda devi, Kamet, Trisul, Chaukhamba etc. are located here.

Methods

The remote sensing technology along with GIS is a widely used tool in recent times to identify, interpret and map various types of lands associated with different landform units. LANDSAT imageries of the years 2000 and 2014 for the river Subansiri and of 2000 and 2013 for the river Alaknanda were used for interpretation of land use/land cover and field study. Digital data were imported into the image processing system and enhancement was performed. Separately, from making observation on the individual bands, FCC was generated using bands 2, 3 and 4 by transmission of blue, green and red combination. Image classification procedures are used to classify multispectral pixels into different land cover classes. The input for the classification is multispectral bands and textural patterns computed from the multispectral data. Primary methods used for LULC are supervised and unsupervised classifications. LANDSAT imageries are downloaded from Global Land Cover Facility (GLCF) and USGS websites and are classified in level I classification.[1]

The classes were generated by the unsupervised classification based on spectral properties taking isodata algorithm with hundred (100) classes and iteration six (6) for accurate classification. The classified map is validated with the imagery using visual interpretation technique and finally a classified map was prepared. The Normalized Difference Vegetation Index (NDVI) is calculated under GIS platform using 9.3 version of the software using the same LANDSAT imageries of the year 2000 for both the basins.

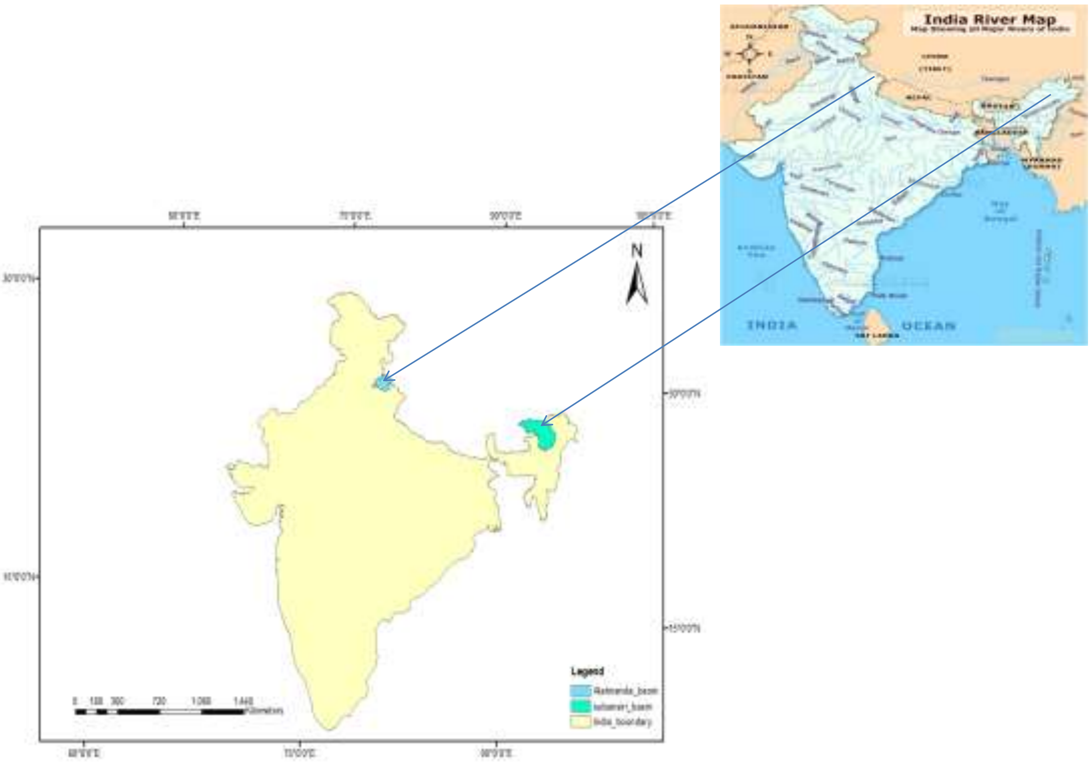
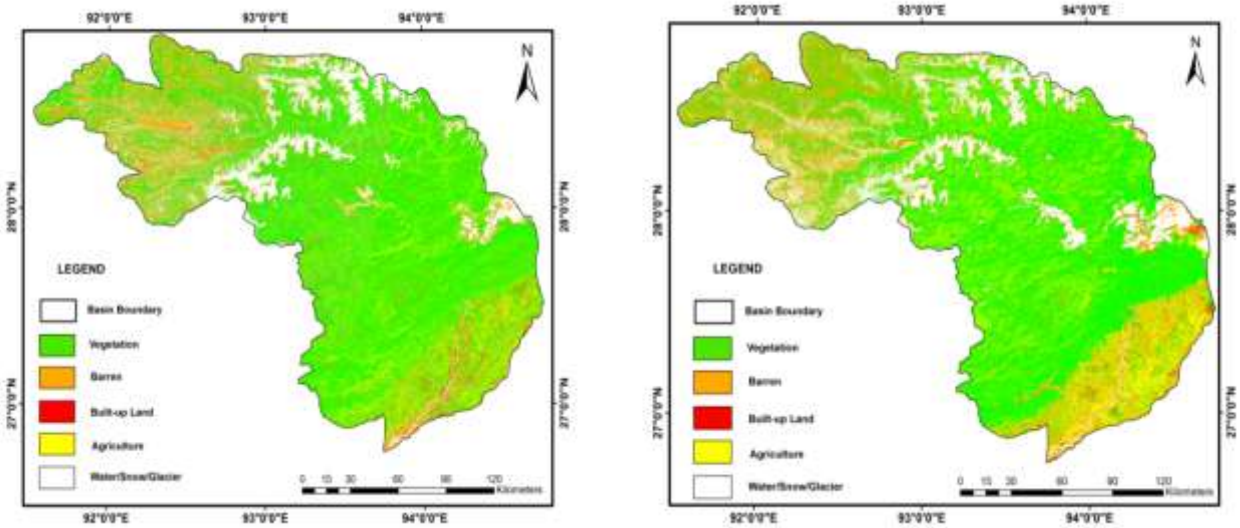


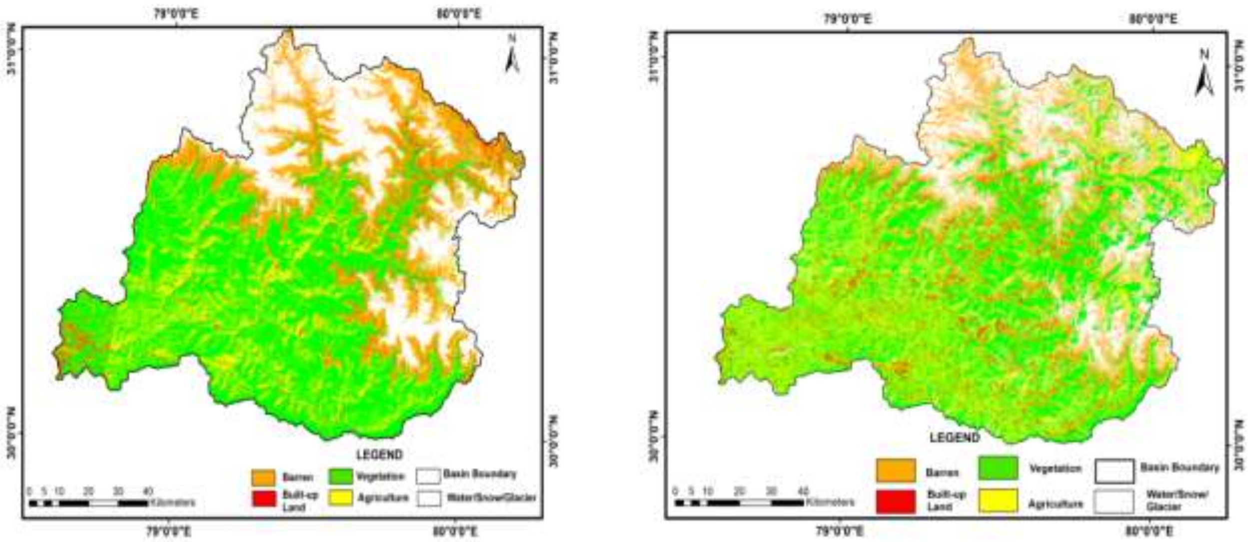
Figure 1: Location map of the study area

Land Use /Land Cover analysis of the Subansiri and the Alaknanda basins: The Land Use /Land Cover (LULC) analysis of the Subansiri and the Alaknanda basins has been carried out based on the LANDSAT imageries of the following years as shown in the figures (Figure 2 and 3).



(a) (b)

Figure 2: LULC map of the Subansiri basin for (a) 2000 and (b) 2014



(a) (b)

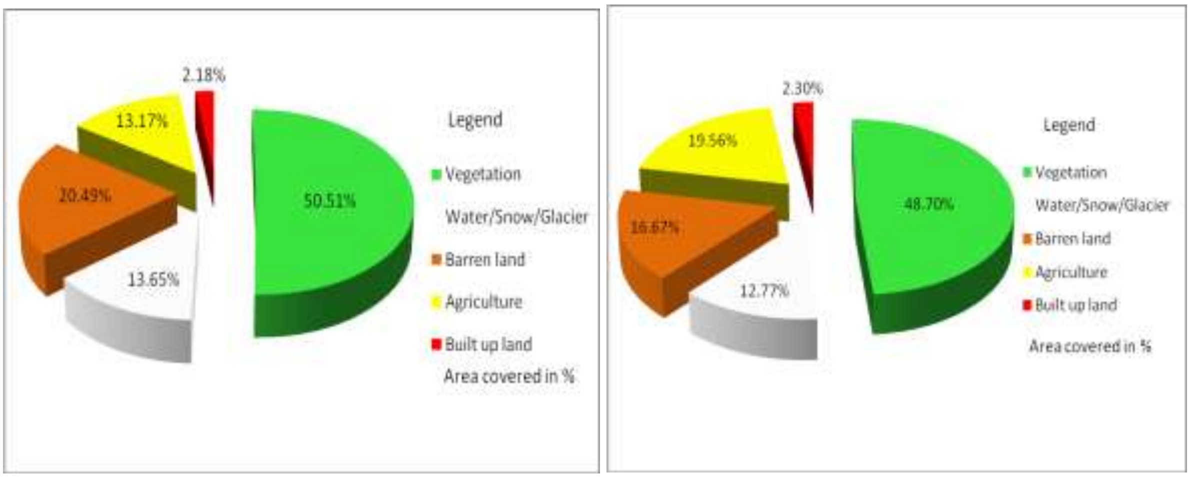
Figure 3: LULC map of the Alaknanda basin for (a) 2000 and (b) 2013

Table 1
Changes of Land use/Land cover pattern in the Subansiri and Alaknanda basins
(Between 2000-20014 and 2000-2013)

LULC Class	Subansiri basin (Area in square km)		Alaknanda basin (Area in square km)	
	2000	2014	2000	2013
Vegetation	18175.58	17525.17	4483.1	3975.69
Water/Snow/Glacier	4910.76	4595.59	2334	2428.79
Barren land	7374.35	5996.74	1852.6	1450.02
Agriculture	4737.63	7036.70	1837.4	2509.24
Built-up land	784.74	828.79	422.23	446.17

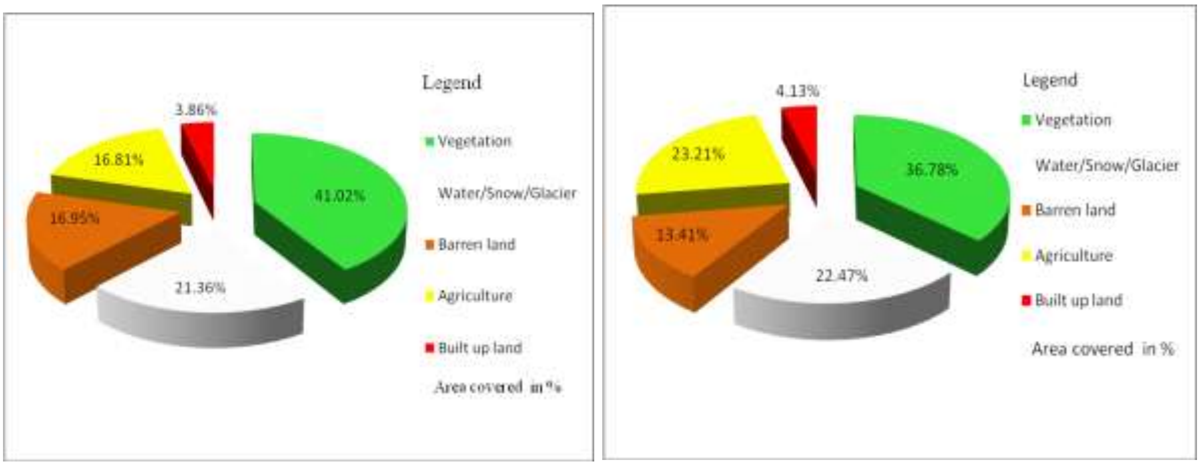
Table 2
LULC Change detection in the Subansiri and the Alaknanda basins

LU/LC Class	**% of Total Area in Subansiri**		**% of Total Area in Alaknanda**		**% change of area in Subansiri basin in 14 years**	**% change of area in Alaknanda basin in 13 years**
	2000	**2014**	**2000**	**2013**	**2000-2014**	**2000-2013**
Vegetation	50.51	48.70	41.02	36.78	-1.81	- 4.24
Water/Snow/Glacier	13.65	12.77	21.36	22.47	-0.88	1.11
Barren Land	20.49	16.67	16.95	13.41	-3.82	-3.54
Agriculture	13.17	19.56	16.81	23.21	6.39	6.40
Built-up land	2.18	2.30	3.86	4.13	0.12	0.26



(a) **(b)**

Figure 4: Graphical presentation of LULC map of the Subansiri basin for (a) 2000 and (b) 2014



(a) **(b)**

Figure 5: Graphical presentation of LULC pattern of the Alaknanda basin for (a) 2000 and (b) 2013

In case of the Subansiri basin (Table 1), it is seen that the vegetation cover and barren land have declined from 18175.58 sq. km. to 17525.17 sq.km. and from 7374.35sq.km. to 5996.74 sq.km. respectively in 14 years. The area covered by water/snow/glacier was calculated to be 4910.76 sq. km. in 2000 while it was 4595.59 sq. km. in 2014 showing a negative change. Agricultural area increases from 4737.63 sq. km. to 7036.70 sq. km and built-up land slightly increases from 784.74 sq. km. to 828.79 sq. km (0.12%). On the other hand, in case of the Alaknanda basin (Table 1), it shows that the vegetation cover has declined from 4483.1 sq. km. to 3975.69 sq. km. and barren land from 1852.6 sq. km. to 1450.02 sq. km. in 13 years. But the agricultural area increases from 1837.4 sq. km. to 2509.24 sq. km. and built-up land increases from 422.23 sq. km. to 446.17 sq. km. in the basin. Water/Snow/ Glacier covered areas have increased from 2334 sq. km. to 2428.79 sq. km. in 13 years.

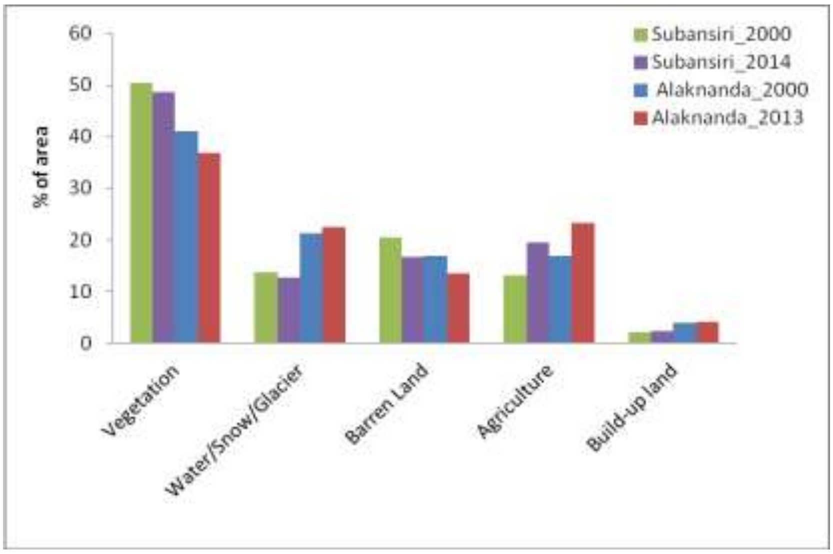


Figure 6: Graphical presentation of LULC categories of Subansiri and the Alaknanda basins 2000 – 2014

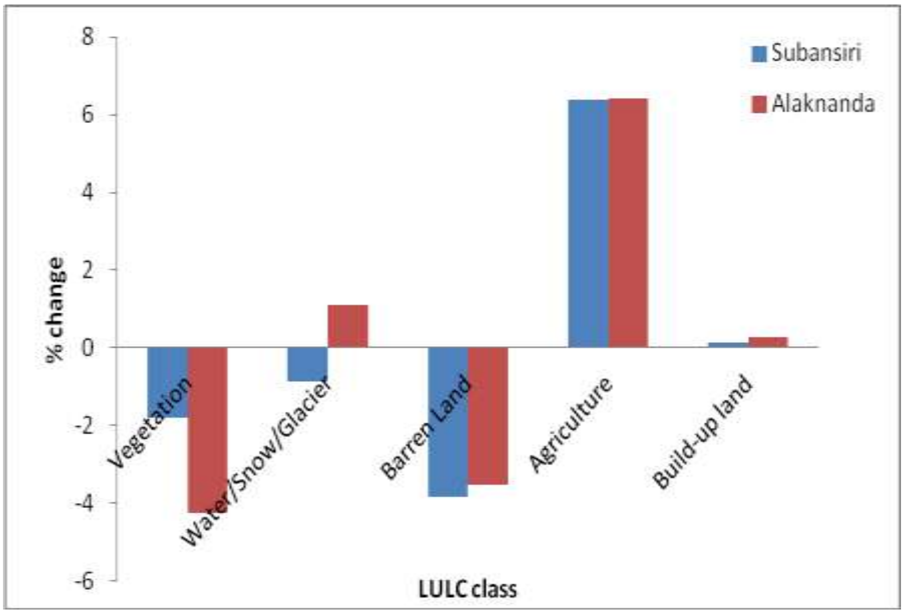


Figure 7: Graphical presentation of LULC change detection of the Subansiri and the Alaknanda basins

Normalized Difference Vegetation Index (NDVI) of the Subansiri and Alaknanda basins: The Normalized Difference Vegetation Index (NDVI) is based on the property of the leaves of green between near-infrared (NIR) and visible (VIS) reflectance values normalized over the sum of the vegetation to absorb incident solar radiation in the red (RED) spectrum band through the chlorophyll and scattered in the near-infrared (NIR) spectrum band through the spongy mesophyll. It is calculated using the following formula:

NDVI= (NIR−VIS)/ (NIR+VIS)

NDVI is generally recognized as a good indicator of terrestrial vegetation productivity. Environmental factors such as soil, geomorphology and vegetation all influence NDVI values. Variations in climatic factors, in particular precipitation and temperature, have a strong influence on variation in NDVI for a given site.[19] The growing population has increased the pollution and there is a negative correlation of aerosol optical depth and NDVI in different regions of the Ganges basin.[10] The NDVI is mainly dependent on the rainfall showing spatially very strong relationship in north east and southern part of India.[6]

The Normalized Difference Vegetation Index (NDVI) has more relevance in land use/land cover study in recent times as it helps in analysing vegetation stress in a specific area. NDVI is largely used for vegetation studies in regional as well as global levels due to its simple calculation. The combination of NDVI and land surface temperature (LST) provides very useful information for agricultural drought monitoring and early warning system for the farmers.[15]

Many researchers have done valuable studies related to NDVI on the western and middle Himalayan regions but there is an urgent need of this kind of studies specially in the eastern Himalayan region.

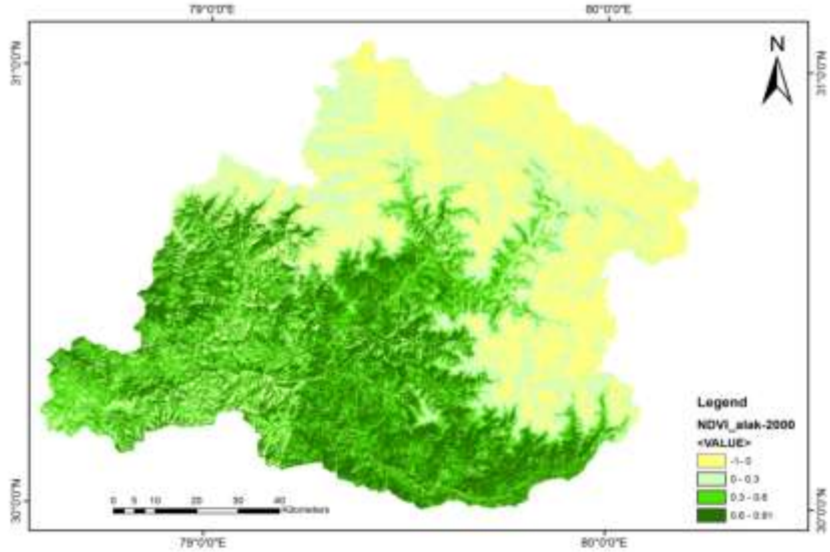


Figure 8: NDVI map of the Alaknanda basin, 2000

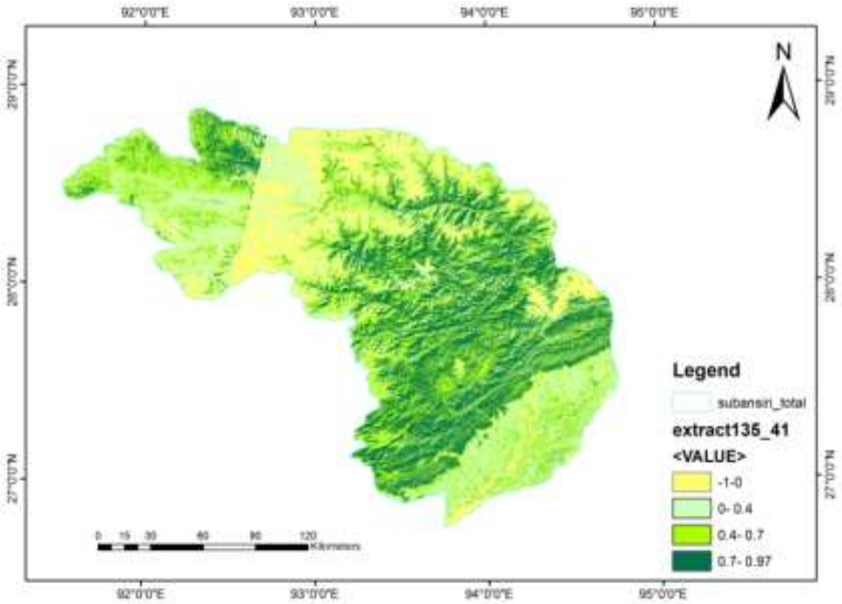


Figure 9: NDVI map of the Subansiri basin, 2000

Results and Discussion

Land use/land cover (LULC) classes have been classified into five LULC categories in level 1 classification.[1] The land use/land cover maps of the Subansiri basin for the years 2000 and 2014 are presented in figure 2, while the same in case of the river Alaknanda for the years 2000 and 2013 are presented in the figure 3. The graphical representations of the LULC maps are given in the figure 4 for the Subansiri while the same is given for the Alaknanda in figure 5. The related calculations for the Subansiri and the Alaknanda basins are presented in table 1 and table 2 respectively.

From the LULC analysis (Table 2) of the Subansiri basin, it is observed that the vegetation cover has declined by 1.81% in 14 years. Reasons for the negative change of forest cover in Subansiri basin of Arunachal Pradesh are primarily due to shifting cultivation practices and biotic pressure (Final report of CWC[2]). Water/Snow/Glacier areas have also decreased by 0.88% and there is a negative change of barren land by 3.82% which may be due to their conversion into agricultural lands. But there is a positive change of agriculture and built-up area by 6.39% and 0.12% respectively to meet the needs of population pressure and their livelihood (Figure 6 and 7).

On the other hand, in case of the Alaknanda basin, it is observed that the vegetation has declined from 41.02% in the year 2000 to 36.78% in 2013, while there is a positive change in case of agricultural practices by 6.4% 9 (Figure 6 and 7). There is a negative change in barren land (3.54%) and positive change in built-up land (0.26%). The water/snow/glacier class indicates a positive change by 1.11% which may be due to the seasonal variation. At the western end of the Himalayas, most precipitation occurs in the form of snow, while in case of the eastern part of the Himalayas, the snowmelt contribution is comparatively insignificant.[8]

For the study area of the Subansiri basin and the Alaknanda basin of eastern and western Himalayas respectively, NDVI is calculated for the year 2000 for both the basins. The NDVI values are found to be 0.97 and 0.91 respectively for the Subansiri and the Alaknanda basins indicating high vegetation index (Figure 8 and 9).

Conclusion

From the LULC study, it is observed that the vegetation cover and barren land decline while there is a positive change in agriculture and built-up land in both the basins viz. the Subansiri and the Alaknanda of eastern and western Himalayas respectively. The reason of the decline of the forest cover may be due to the increasing agricultural practices, population pressure and the construction activities in the basins. A negative change of water/snow /glacier is seen in case of the Subansiri basin of eastern Himalayas. But there is positive change of water/snow/glacier in the Alaknanda basin of western Himalayas which may be due to the seasonal variation or may be due to the glacial lake outburst flood (GLOF). The analysis shows that the LULC study is very much important and useful for realising the land use pattern of both the eastern and western Himalayan regions. Remote sensing data coupled with GIS techniques is useful tool for geo-spatial analysis and better understanding of the hydrologic scenario of a basin having complex and hilly terrain.[5]

Remote sensing and GIS both enhance the databases of such terrain conditions quite effectively. The NDVI values are found to be high for both the Subansiri and the Alaknanda basins, but it is comparatively higher in the Subansiri basin of eastern Himalayas than the Alaknanda basin of western Himalayas which may be due to the more anthropogenic activities causing decline of forest cover in the Alaknanda basin. As the mountains are the effective indicators of global climate change, hence NDVI study especially in the Himalayan region may significantly help in climate change monitoring.

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(Received 10th July 2020, accepted 11th September 2020)