Impact of Land Use Land Cover Change using Remote Sensing with Integration of Socio-Economic Data on rural Livelihoods in case of Nashe Watershed, Ethiopia

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Research Article

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Abstract

Land use/land cover is an important component in understanding the interactions of human activities with the environment and is necessary to recognize the changes in order to monitor and maintain a sustainable environment. This study aimed to analyze changes in land use and land cover spatially and temporally in the Nashe Watershed. since the dam of the Nashe watershed was built in 2012 socio-economic characteristics of the area are used to interpret the causes of land use and land cover changes occurring changes on their life and environment. The socioeconomic data were analyzed with Excel and integrated with biophysical data. For the 2010–2020 ten-year period showed that Cropland and Woodland have been reduced from 73–62% and 18–14%, respectively, and Wetlands have been fully converted to Water Bodies, alternately increasing Water Bodies and Pasture Land from 43.9–54.5% and 0.04–18%. respectively the reason for this discussion of change was the construction of dams without considering the effect on livelihood and the environment. The government could not give these people adequate compensation for their lands conquered by water. These peoples were forced to expand their agricultural lands by cutting and logging trees in order to make a living to get basic needs. Therefore, Nashe watershed is identified as an area highly affected by land use and land cover change and it is necessary to closely monitor land use/land cover to maintain a sustainable environment for future

Introduction

Land use and land cover change is the overall threat that leads to land degradation and negative environmental impacts by threatening the natural environment through desertification, biodiversity loss, habitat destruction and species transfer In particular, its effects are more visible in developing countries, where the economic activity of farmers depends on agriculture (Oluseyi 2006). Some studies suggested that the main drivers of land use and land cover are demographic dynamics, economic factors, socioeconomic factors, and cultural factors. Research carried out in Ethiopia such as (Aredehey, Mezgebu, and Girma 2020), (Abere, Adgo, and Afework 2020), (Sisay, Halefom, and Teshome 2019), (Halefom et al. 2018), (Mekuria et al. 2018), (Tolosa 2018) showed that LULC changes are visible in the country due to different economic activities.

Most of these study results indicated that deforestation and expansion of cultivation to peripheral areas such as steep slopes were the main causes of land degradation, especially in the highlands of Ethiopian country. For example, (Belay Tegene 2002) and (Woldetsadik 2004) reported a serious trend of land degradation resulting from the expansion of cultivated land at the expense of forested areas in Dembecha in northwestern Ethiopia and in the Derekoli watershed in southern Wollo. (Tekle and Hedlund 2000), also reported an increase in open grazing land developing at the expense of scrubland and forests in the Kalu area of north-central Ethiopia. In contrast,, (Woldetsadik 2004) and (Bewket 2002) have reported an increase in forest plots (eucalyptus tree plantations) and arable land at the expense of grazing land in both the Sebat-bet-Gurage country of south-central Ethiopia and in the river divide Chemoga in northwestern Ethiopia. These reports have revealed heterogeneity in changes in the type, pattern, direction, and magnitude of LULC across the country and highlighted the difficulty of extrapolating the known trends to unstudied areas. Therefore, region-specific information on such changes in the LULC is essential for land-use planning aimed at wise resource management and maximizing productivity of both agricultural and non-agricultural land at regional and national scales.

However, in Ethiopia information on these changes is lacking or unavailable for many small tracts of land for which generalizations are extremely difficult or could lead to incorrect conclusions. Many of the above studies were conducted in the north-central highlands of the country. The exceptions are notably that of (Woldetsadik 2004) and (Rembold et al. 2000) study which is probably the only one conducted in the Rift Valley area. This implies that there is a gap in terms of spatial representation in studies of land use and land cover change in the country. Therefore, this study attempted to map the status, extent and direction of land use and land cover between 2010 and 2020 in order to predict and assess possible changes that could take place in certain areas due to the dam constructed in 2010 It was gained an impression of the socio-economic status of rural farmers using geographic information systems/remote sensing and socio-economic data.

Material And Methods

Study area

The Nashe watershed lies between 287530 and 311154 m east and 1065920 and 1084194 m north in the district of Horo Buluk, western highlands of Ethiopia, in the Nile basin of western Ethiopia (Fig. 1) with an elevation of 2094 to 2651 m.a.s.l.

The study is characterized by a unimodal precipitation pattern, with an average annual precipitation of 1400 mm and a monthly average temperature between 14.1 and 17.3°C. The study area covers about 22,067 ha and its main land's fall into hilly terrain (15–30%) covering about 32%, hilly terrain (8–15%) covering about 20% and undulating terrain covering about 12% covered. Only small patches of land, accounting for about 1% of the total area, were flatly covered. About 15% of the total country was covered by steeply dissected to mountainous terrain and 2% was also characterized by a very rugged, mountainous and hilly topography with steep slopes. The remaining part of the study area, accounting for 18%, was covered by water.

Table 1
Slope range of the study area in per cent

No	Slope range (%)	classes Name	Area	Slope coverage in %
1	0–2	Flat to almost flat terrain	189.36	1
2	2–8	Gently flat to undulating terrain	2657.328	12
3	8–15	Rolling terrain	4400.212	20
4	15–30	Hilly terrain	7014.339	32
5	30–50	Steep dissected to mountainous terrain	3319.662	15
6	> 50	mountainous terrain	525.0952	2
7	Water body		3961	18

Data sets: In order to achieve the objective of the study, data sets from multiple sources including satellite imagery, climate data and digital elevation models (DEM) were obtained from various sources. The remote sensing data comprised two interval years, namely 2010 and 2020 Landsat imagery (Table 1) downloaded from the United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov/).

Table 2
Landsat images and their characteristics

Sensor Name*	Acquisition date	Scene ID	Path, row	Spatial resolution (m)	Number of MS bands	Cloud cover (%)
Landsat7 ETM$^+$	January14,2010	LT07_L1TP_169053_20100114_20161017_01	169053	30	7	0
Landsat8 OLI	March30,2020	LC08_L1TP_169053_20200330_20200410_01	169053	30	8	0

TM, thematic mapper; ETM+, Enhanced Thematic Mapper plus; OLI, Operational Land Imager; MS, Multispectral. This study was conducted using biophysical data such as aerial photographs and geographic information systems (GIS) in conjunction with conventional techniques. For the conduct of this study, the Land Sat 8 image acquired in December 1990, December 2002 and December 2011 should be used as the main data source. This data was obtained from the Ethiopian Mapping Authority

(EMA). But socioeconomic data was specifically collected from households between three kebele (Alchaya Igu, Sandabo Dongoro and Ejersa Meca) within a watershed. The sample size was determined based on the following formula given by

Yemane (1967).

$$n = \frac{N}{1+N(e)^2}.$$

Where, n is sample size, N is number of households in the district and e is the desired level of precision. So that, the total households in the study area 1222.

$$n = \frac{1222}{1+1222(0.08)^2}. =156$$

Where, n is sample size, N is number of households in the district.

Table3: number of HHs and sample size at study area

Name of kebele	Total number of households	Sample proportion (%)	Sample
Alchay Igu	530	0.44	68
Sandabo dongoro	272	0.22	34
Ejersa Meca	420	0.34	54
Total	**1222**	**100**	**156**
Source: From Horo Buluq district (2021)			

In addition to satellite image data, socioeconomic data which collected from the households' randomly using interview and questioner's method was used for achievement of this paper purpose.

Image pre-processing

1 arc second (~ 30 m) Shuttle Radar Topography Mission (SRTM) Void Filled DEM was also downloaded from the USGS website. DEM and satellite image slice setting out of the bands was performed and image correction was also performed to correct distortions resulting from the image acquisition process and finally the updated image was uploaded to the Universal Traverse Mercator (UTM), Adindan Zone 37, projected north (N) and referenced to World Geodetic System datum 1984 (WGS84).

Image Classification and Change Detection

Image classification for both year intervals (2010 and 2020) was performed by supervised classification using maximum likelihood classifier. The classified images were assigned to the respective classes (i.e., forest, water, cultivated land, wetland, grassland, wasteland, and settlement).

Table 4
Land Use Land Cover classes and their respective description

Lulc	Description
Water body	Area completely busy by water
Cultivated land	Area used for cultivation, including fallow plots and complex units such as homesteads.
Swampy land	Flat and swampy area during both wet and dry seasons; mainly covered with grass
Grazing land	Area covered with grass, bushes, and trees, and used for grazing
Forest land	Area covered with natural and plantation trees, sometimes mixed with enrichment plantations, forming nearly closed canopies with 70–100% cover.
Bare land	Are never covered by any things
Settlement	Area occupied by peoples

Results And Discussion

Socio-demographic characteristics of the sample households

Table 5
Household demographic, and livelihood Characteristics of the study area

Socio-demographic Characteristics		Ejersa Mecha HHs in frequence	AL/Igguu HHs in frequence	Sandabo DongoroHHs in frequence	Total in %
Gender	Male	48	63	29	89.7
	Female	6	5	5	10.3
Age	40–50	6	9	6	13.5
	50–60	9	19	12	25.6
	60–70	25	21	8	34.7
	70–80	11	16	4	19.8
	Above 80	3	3	4	6.4
Education status	Illiterate	38	37	17	62.1
	Literate	16	21	19	37.9
	Primary	6	11	5	39.3
	Secondary	8	4	9	37.6
	Diploma $ above	2	6	5	23.1
Family size	Less than 4 persons	16	20	14	32.1
	4–8 persons	22	29	10	39
	More than 8 persons	16	19	10	28.9

According to Figure on (Table 5); a large percentage of household heads (89.7%) were men, while women made up the remaining proportion (10.3%). Likewise, large proportions (34.7%) of the households surveyed were between 60 and 70 years old and a minimum of 13.5% were between 40 and 50 years old, while 25.6% and 19.8% of them were between 50 and 60 years old, 70 and 80 years or older, respectively. In terms of family size of respondents, the highest 39% had 4 to 8 household members. About 32.1% of the respondents had between 1 and 4 household members, while 28.9% of them had eight or more family members. Regarding the educational status of the study area, 62.1% of the respondents were illiterate and 37.9% of the respondents were literate. Therefore, relatively speaking, a larger proportion (39.3%) of the respondents could read and write. A small proportion of heads of household (23.1%) had attended grade 10 or above the formal education

Change in Land Use, Land Cover

Table 6
Land use and land cover change Matrix of 2010 and 2020

LULC	Area in 2010		Area in 2020		Area changed from 2010 to 2020		Remark
	ha	**%**	**Ha**	**%**	**ha**	**%**	
Forest land	3911	18	3018	14	-893	-4	Increased
Grass land	348	2	1191	5	843	+ 4	Increased
Cultivated land	16193	73	13723	62	-2470	-11	Decreased
Bare land	284	1	0	0	-284	-1	Decreased
Swampy area	1281	6	0	0	-1281	-6	disappeared
Water body	7	0.04	3961	18	3953	+ 18	Increased
Settlement	43	0.19	174	1	131	+ 1	Increased
Totally	**22067**		**22067**	**100**			

The classified image of 2020 (Fig. 2) shows a clear change in land use and land cover. The greatest changes were noted in cultivated land, swampy areas, forest cover, and grasslands. Cropland, marshland, and forest area were reduced by 2470 ha (11%), 1281 (6%), and 893 (4%), respectively, while water bodies and grassland were increased by 1281 (6%) and 843 ha (4%), respectively or in 2020. Settlement increased by only 1% in 2020. For these reasons, different biodiversity has been migrated to other areas from this watershed due to the change in land use, land cover and part of the livestock to live in good dead due to the environment has been changed. Because of this, this dam construction had an impact on the livelihoods of farmers (Baba and Hirose 1998).

Effect of Land Use Land Cover Change on Rural Livelihoods Communities

According to household responses (Table:7), land use changes occurred due to human intervention and agricultural intensification due to the construction of the Nashe Dam. Accordingly, 88.5% of all households reported the following: After the construction of the dam, swampy area previously used for irrigation and grazing was completely converted into a body of water. Consistent with these, 94.8% of households reported that arable land totaling more than 2,000 hectares had water drained due to the construction of dams. The size of land holdings varied for each household both before and after the construction of the Nashe Dam. The land tenure size of households less than two hectares before the Nashe Dam was 21.8%, while after the dam was built it was 44.2%. This implies that scarcity of land among them were increased. Similarly, 22.4% of households had an area of 2 to 4 hectares before the dam was built, while after the dam was built, 32.7% of households in the study area had an area of 2 to 4 hectares. Accordingly, 36.5% and 17.9% of households had farmed between 4 and 8 hectares before and after the construction of the Nashe Dam, respectively.

However, the number of households larger than 8 hectares before the dam was not very large, 17.9% of households owned larger than 8 hectares, while after the dam construction it decreased to 5.1% of households. The resulting dam-engineering deforestation has been heavily practiced to expand farmland and grazing land. This implies that the extent of spatial and temporal land use and land cover change was clearly visible in the study area. The assessment made showed that the land use land bay change was highly developed subsequent dam building with the main factors being the expansion of arable land and grazing land. As a result, many (73.1%) of the households indicated that the income level of the study area's households was observed before (2010) the construction of the Nashe Dam than after the Nashe Dam (2020), representing 26.9% of the respondents is equivalent to. This implies that the stakeholders were negatively affected by the construction of the Nashe Dam as their farmland was affected. Therefore, without considering environmental impact assessment of environment and socio economic of western of Ethiopia are affecting still now their sustainability in all aspects which hinder sustainability development in general(Adugna 2015).

Table 7
Impact of Socio-economic characteristics of households of the study area by LULCC

Socio-demographic Characteristics	**Land holding size both before and after Nashe Dam construction**		**Ejersa Mecha HHs in frequence**	**AL/Igguu HHs in frequence**	**Sandabo DongoroHHs in frequence**	**Total in %**
Land holding size	Less than 2 hac	Before	17	12	5	21.8
		After	27	28	14	44.2
	2–4 hac	Before	8	14	13	22.4
		After	16	26	9	32.7
	4-8hac	Before	27	18	12	36.5
		After	11	9	8	17.9
	Above 8 hac	Before	2	22	4	17.9
		After	0	5	3	5.1
Cause of LULCC	Scarcity of land		4	6	4	8.9
	agriculture expansion		20	21	12	33.9
	due to Nashe project dam		30	41	18	57.0
Income level of HHs	Before nashe dam (2000)		42	52	20	73.1
	After Nashe dam (2010)		12	16	14	26.9
Human encroachment	Yes		49	57	30	87.2
	No		5	11	4	12.8
Swamy area converted to water body	Yes		45	61	32	88.5
	No		9	7	2	11.5
Cultivated land converted to water body	Ye		53	63	32	94.8
	No		1	3	2	3.8
Forest land converted to cultivated land	Yes		50	54	29	85.3
	No		4	14	5	14.7

Effect of dam construction and Land Use Land Cover Change on Environment

Dam construction is one of human activities that exercised on the land which led to change of land use land cover our us, especially, in wetern Ethiopia due to FAN project (Finca'a Amerti Nashe project) almost there is alteration of founa and flora in this area. This alteration was happened for the reason of absence of EIA (Environmental impact assessment) before the construction of Nashe Dam construction. As it known that EIA was a new instrument that started in Ethiopia in recently, in 1997. However, any activities which has as positive consequences, it has adversely affected our environment either directly or indirectly on living things. As interviewed and identified in the study area for the reason of disturbances of Nashe dam construction about 182 cows took by water and 65 antelope were emigrate to other area and around 18 were killed as soon as due to off of their places especially swampy area of Nashe watershed. Similarly, three human beings took by water bodies and most of forest tree and where fertile land were lost by these activities directly. Those all phenomena were rising conflicts and crises within and among different living things(Gubena 2016).

Conclusion

Remote sensing methods with accurate input data and monitoring results can support the assessment of the further behavior of LULC processes. The results showed that the LULC of the Nashe watershed changed significantly within 20 years after the construction of the dam. After dam construction; Farmland and woodland have been reduced, while wetlands have disappeared entirely and been converted to water bodies. Since the construction of the dam in 2012 were done without assessment of EIA, the area of water and pasture has increased in the study area. The direct drivers of land use and land cover were the expansion of cropping and grazing. This LULC change affected the livelihoods of rural households, particularly the former swampy area used for conventional irrigation and grazing was fully converted to a body of water and resulted in biodiversity loss, poverty and some households less land. The resulting LULC maps from this study would be further used for the government agencies and stakeholders to create land use planning for watersheds to prevent natural hazard losses and moreover, the results obtained can help to achieve the sustainable development of the whole region Provision of the required input data.

Declarations

Funding

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Competing interests

The authors declare that they have no competing interests.

Availability of data and material

All data generated during manuscript analysis are included in the article. Additional datasets are available from the corresponding authors upon request.

Authors' Contributions

The corresponding authors, both Gelana Fikadu, play a major role in the data collection, processing and analysis and initiate the research idea, review relevant literature, design the methods, field data collection, data cleansing, analysis, interpretation and preparation of Manuscript drafts for publication.

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Figures

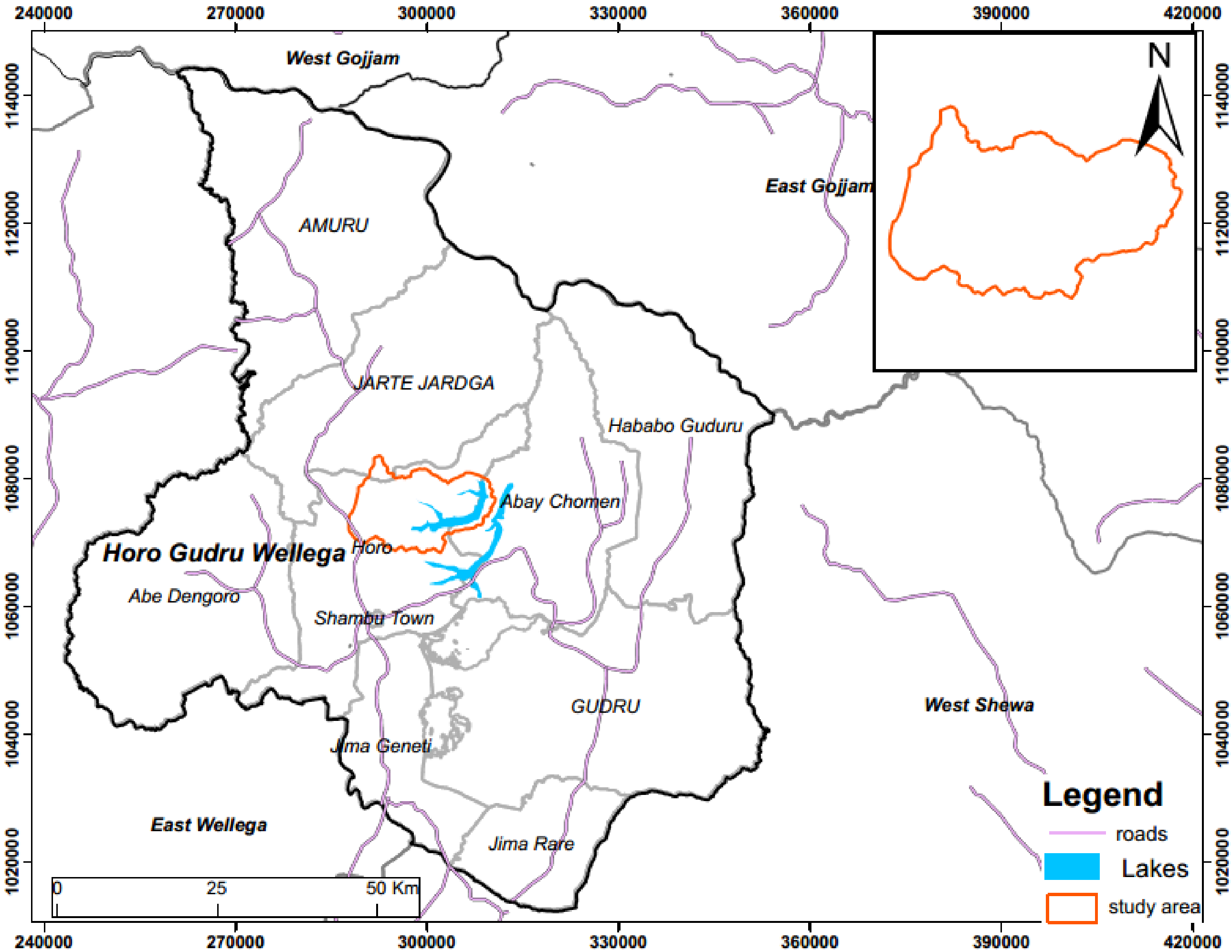
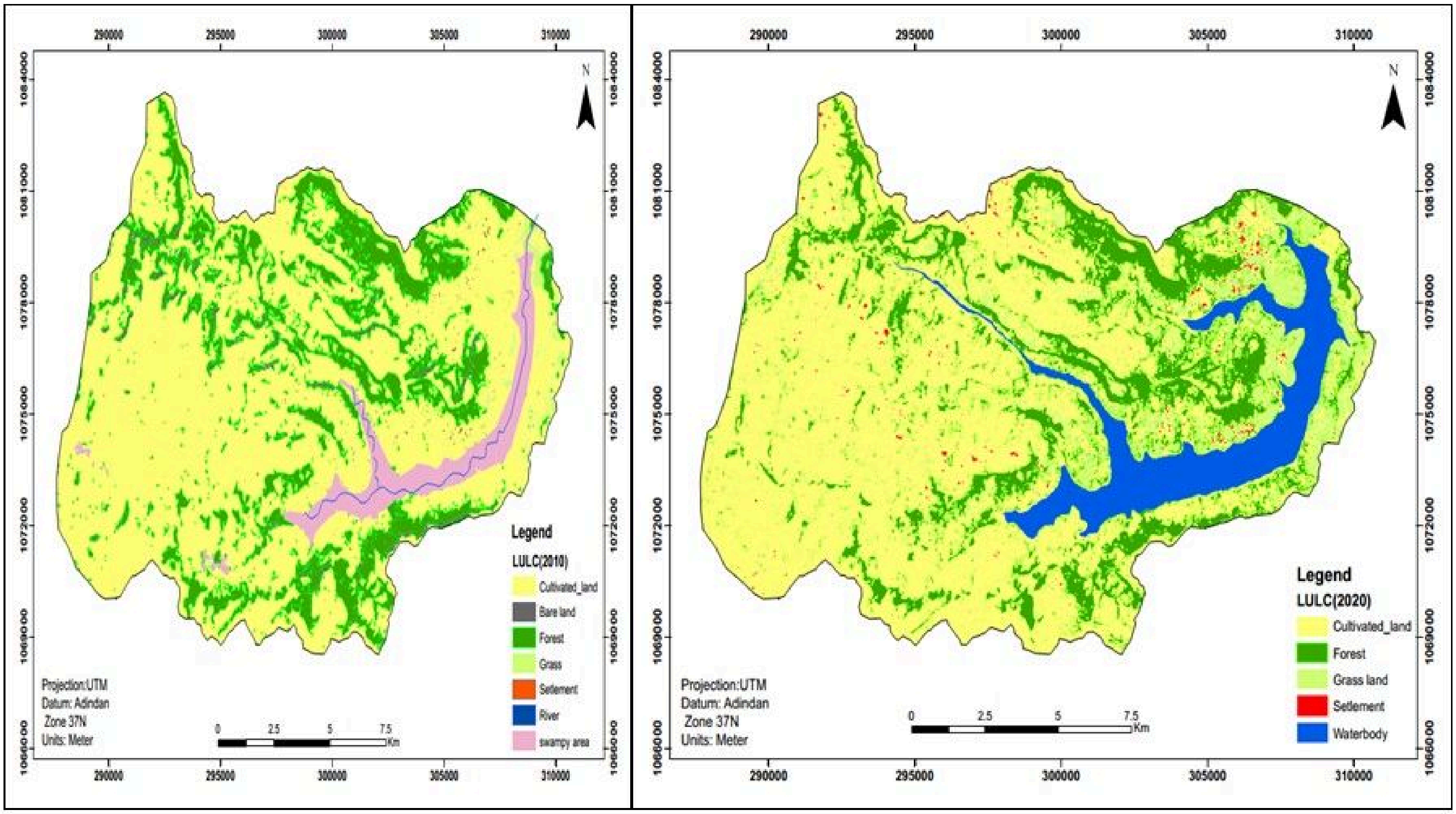


Figure 1

Location map of Nashe Watershed



Before Dam construction after dam construction

Figure 2

Land use and land cover of 2010 and 2020 of Nashe watershed