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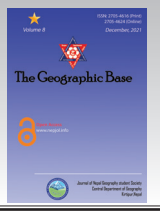

Historical Land Use and Land Cover Change of Eastern Nepal: A Case of Dharan Sub-Metropolitan City

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Abstract

Land use and land cover change (LUCC) has become an essential for monitoring and managing the natural resources, urban planning as well as sustainable development of any place. This study analyzes the historical LUCC during 1986-2020 of Dharan sub-metropolitan city (DSC) of Sunsari district, eastern Nepal. To analyze historical LUCC, LRMP (1986), ICIMOD (1990, 2000, 2010) and Google Earth Image (December, 2020) were used in the study. The results reveal the expansion of built-up areas by 500%, whereas agricultural land and forest cover decreased by 4% and 6%, respectively, during the past 34 years. Mainly the growing built-up area encroached on the agricultural land, forest and river banks. The built-up area is expanded to the south-eastern, north-eastern and western direction from the core area. The built-up area is still likely to increase with high pace in the future, where need to give more attention to future possible urban hazards, urban pollutions and haphazard urbanization while making urban planning and policies.

Introduction

Land use refers to human activities on the landscape and land cover means natural elements, which direct observation on earth within a specific time (Fisher et al., 2005). Land use and land cover (LULC) classes include urban/built-up area, agricultural land, forest cover, snow/ glacier cover, water bodies, etc. LULC is a dynamic process and its relations between physical factors and human activities (Turner et al., 1994; Liu et al., 2002; Li et al., 2016). Land use land cover change (LULC) is the main issue of global change, which is also related to sustainable development and livelihoods (Turner et al., 1994). There are natural and human factors forcing changes on LULC. Human activities are also known as dominant factors to change and shape the LUCC globally (Meyer & Turner, 1994; Deng et al., 2009). People change lands for economic benefit and create new land use (Lambin et al., 2001). These anthropogenic activities have affected climate, global biodiversity, and the sustainability of lands (Mustard et al., 2012). The studies on changes on LULC are necessary to understand climate change, loss of biodiversity, and land management (Ellis and Pontius, 2006; Bagan & Yamagata, 2014).

Globally, the increasing urbanization results in decreasing agricultural land, vegetation which is threatening to local biodiversity and the environment (Seto et al., 2011). Urbanization has been increasing rapidly in Asian and African countries, where the urban population will likely to be reached 64% and 56% by 2050, respectively (UN, 2014). A study has found that population growth has led a significant role to increase urbanization in Asian countries (He et al. 2017), including Chinese cities (Deng et al., 2008; He et al., 2017) and Nepalese cities (Thapa and Murayama 2010, Rimal 2011, Rai et al. 2020). Haphazard growing urbanization is creating natural disasters in major cities of Asian countries such as Kathmandu (Haack and Rafter 2006), Dhaka (Dewan & Yamaguchi, 2009), Delhi (Jain et al., 2015) and many Chinese cities (Peng et al., 2015; He et al., 2017). A study has already alarmed the high risk of floods, earthquakes, landslides, drought and volcanoes in Asian cities in the future (UN, 2016). The rapidly increasing urbanization is challenging to remaining agricultural land and high pressure on the environment in eastern Nepal (Rimal et al., 2019). Globally, the agricultural land expanding at the cost of the primary forest, grassland, and wetland, which enlarged from 3-4 million km^2 in 1700 and 15-18 million km^2 in 1990, while the forest cover reduced from 53 million km^2 in 1700 and 43 to 44 million km^2 (Ramankutty et al., 2006).

Similar to global forest cover loss, the forest covers are also decreasing in Nepal. The forest cover was 76,710 km2 in 1930, which declined to 39,392 km2 in 2014 with a net loss of 37,318 km2 (48.6%) (Reddy et al., 2017). The forest cover also decreased in Kathmandu

valley, which converted to urban areas during 1967-2010 (Thapa & Murayama, 2009; Wang et al., 2020). Dharan is the gradually growing sub-metropolitan city of eastern Nepal. Still, historical studies on LULC are lacking in Dharan sub-metropolitan city. Thus, this study aims to present LULC status and changes of Dharan sub-metropolitan city of Sundari district of eastern Nepal from 1986 to 2020 with focusing on the urban growth and its orientation based on national-level land cover data and Google Earth Images.

Methods and Materials

Study area

Dharan sub-metropolitan city (DSC) is located in Sunsari district of Province no. 1 Nepal. It is also known as the beautiful and clean city of eastern Nepal. In the past, the city was a market center for eastern districts such as Bhojpur, Dhankuta, Sankhuwasabha, Terhathum. People were used to coming primarily for better goods and services such as to buy salt, clothes as well as receive the pensions of retired armies. The city is the foothills of Himalaya, which is adjoining to Hill and Tarai region of Nepal. In addition, the city is famous for the homes of retired British and Indian armies. The DSM encompasses an area of 193.85 km^2 with 715 population density per km^2, located at northern latitudes 26.8065° and eastern longitudes 87.2846° (Figure. 1). Based on census 2011, a total of 137,705 people (64,671 male and 73,034 female) are living in 32,693 households within the city. DSC is located at the elevation ranges between 64 to 1739 m above the mean sea level. Lower part is covered by built-up areas and forest cover and northern high elevation parts coved with forest and agricultural land. Predominantly, the central part is covered by the built-up area and northern and eastern parts are partially covered by agricultural land. The southern part is almost covered by dense forest, which is also called *Charkoshe jungle/jhadi.*

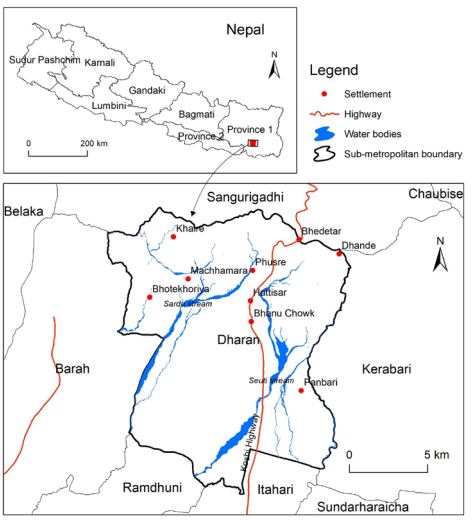

Figure 1. Location map of the Dharan sub-metropolitan city

Data sources

LULC data sources

To analyze the changes in LULC, land cover data from diverse sources, including Land Resource Map (LRMP) of Nepal (1986) (LRMP, 1986) and archived data from ICIMOD (http://rds.icimod.org) were obtained (Table. 1) and very high-resolution images from

Google Earth Images were used. Manual online digitization on the Google Earth environment was applied to prepare the recent land cover for the year 2020. The spatial data such as administrative boundaries, settlement and water bodies, road used in the study were collected from the Survey Department, Government of Nepal. Land cover change analysis and mapping are carried out in ArcGIS software.

Table 1. Details of the LULC data and its sources

LULC dataset	Spatial resolution	Source
1985/86	1:150,000	LRMP
1990	30×30 m	ICIMOD
2000	30×30 m	ICIMOD
2010	30×30 m	ICIMOD
2020	-	Google Earth Images of 2020 December

Results and Discussion

LULC statistics

Predominantly, the forest cover is found in the southern and northern parts, which accounted for 68.13% of DSC, whereas the agricultural land is found in the eastern (ward no 5 and 6) and north-western (ward no 20) parts (Figure. 2). Altogether, the agricultural land occupies 16.09% area of the study area (Table 2). The most central part of the study area is covered by built-up area 16. The built-up area is 10.87%, which is the third-highest area of the DSC.

Table 2. LULC situation of Dharan sub-metropolitan city in 2020

S. N.	LULC types	Area (km^2)	Percentage
1	Agriculture	31.20	16.09
2	Built-up	21.07	10.87
3	Forest	132.07	68.13
4	Water body	9.51	4.91
Total		193.85	100.00

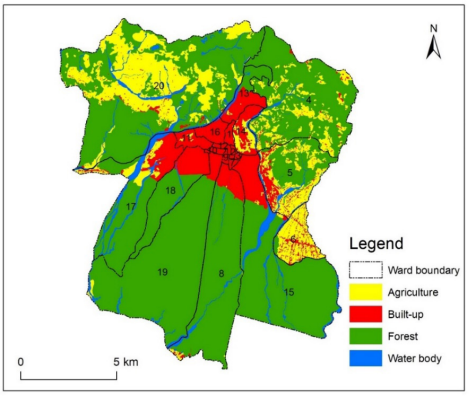

Figure 2. Spatial distribution of LULC in DSC, 2020

LULC change: The results of the study show the important changes in LULC over the last 34 years (between 1986 and 2020). During the 34 years, built-up and forest cover have significantly changed within the DSC.

- During the past 34 years (1986-2020), the forest has decreased from 74.21% to 68.13% at the annual rate of –0.25% within the study area.
- The agricultural land has decreased within the study area. In 1986, the area under agricultural land was

19.66%, which decreased to 16.09% at the annual rate of –0.53% over the past 34 years (Table. 3 and Figure 3).

- The built-up areas have increased significantly over the years, which increased from 2.65% to 10.87% between 1986 and 2020. Overall, the built-up area increased by 9.12% yearly between 1986 and 2020 (Table. 3).
- Water bodies have slightly increased within the study area. The area of water bodies increased from 3.28% to 4.91% between 1986 and 2020.

Table 3. LULC statistics between 1986 and 2020 in DSC (area in km^2)

LULC types	1986		1990		2000		2010		2020		% change/ year
	Area	%	Area	%	Area	%	Area	%	Area	%	
Agriculture	38.11	19.66	27.08	13.97	25.66	13.25	22.97	12.09	31.20	16.09	–0.53
Built-up	5.14	2.65	7.50	3.87	9.20	4.78	15.89	8.20	21.07	10.87	9.12
Forest	144.23	74.41	153.50	79.17	149.79	77.23	148.00	76.78	132.07	68.13	–0.25
Water body	6.36	3.28	5.80	2.99	9.20	4.74	6.96	2.93	9.51	4.91	1.46
Total	193.85	100.00	193.85	100.00	193.85	100.00	193.85	100.00	193.85	100.00	

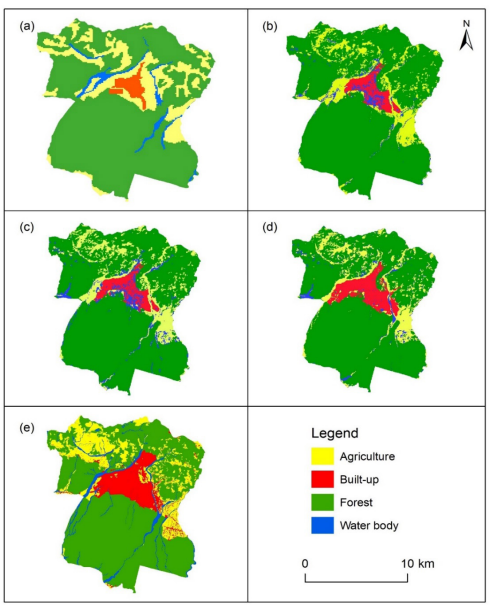

Figure 3. Changes in LULC during 1986-2020 in DSC; (a)-1986, (b)-1990, (c)-2000, (d)-2010 and (e) 2020

Land use land cover transformation

This study has analyzed the LULC transition between 1986 and 2020. The agricultural land has been changed into forest and built-up areas. Based on LULC data, a total of 11.43 km^2 of agricultural land was converted into forest and 9.33 km^2 into the built-up area (Table. 4 and Figure. 4). Likewise, the built-up area is gained from the forest and agricultural land. The large coverage of the forest is converted to agriculture, built-up and water bodies over the past 34 years which accounted for 14.72, 5.55 and 5.35 km^2, respectively (Table. 4).

Table 4. LULC transition matrix within the DSC between 1986 and 2020 (area: km^2)

1986	2020			
	Agriculture	Built-up	Forest	Waterbody
Agriculture	14.57	9.33	11.43	2.46
Built-up	0.23	4.84	1.5	0.02
Forest	14.72	5.55	117.50	5.35
Water body	1.42	1.14	2.08	1.67

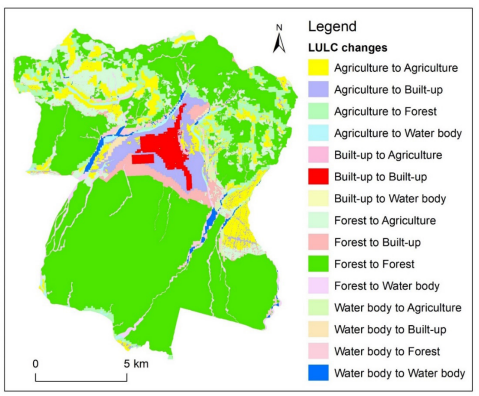

Figure 4. LULC changes between 1986 and 2020

Urban growth and orientation

The built-up area has increased significantly from the core area. Based on the results, the built-up area expanded and focussed to the south-eastern (i.e., Thingabari, Khoriyabasti, Panmari, Chaukidada and Dashghare), north-eastern (i.e., Shivadhara, Bhorleni, Dhande, Basantatar, and Hardiya), and western (i.e., Patnali, Khaireni, Dadaghopa, Talloghopa, etc.) direction of the DSC. The built-up areas increased from 1.23 km^2 to 6.13 km^2 and 0.73 km^2 to 4.13 km^2 to south-eastern and western directions, respectively (Figures. 4 and 5). Likewise, the built-up area has increased 1.06 km2 to 3.50 km2 in the north-eastern direction during the past 34 years in DSC.

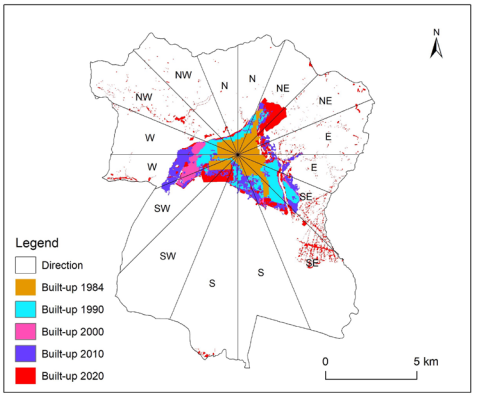

Figure 5. Spatio-temporal distribution of built-up area in DSC

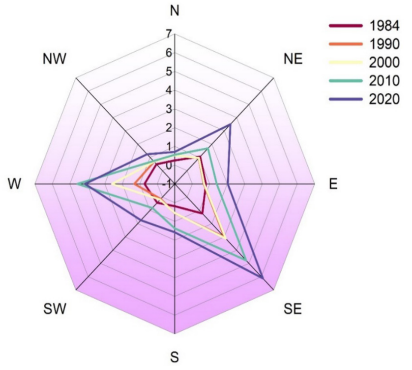

Figure 6. Built-up area expansion and their orientation between 1986 and 2020.

1, 2, 3…7 indicate distances (km) from the central area of the city. Abbreviations: N–north, NE–north east, E–east, SE–south

east, S–south, SW–south-west, W–west, NW–north-west

Historical LULC changes

Globally LULC has been changing due to anthropogenic or natural causes. There is an increasing trend of cropland and urban areas and decreasing trend of forest cover across the world (Hansen et al., 2013). The land cover change of Nepal is also similar to the global trend. A historical LULC study found that forest cover has been decreasing trend in Nepal, which decreased from 52.10 to 26.80% between 1930 and 2014 (Reddy et al., 2017). However, several studies showed a positive change in forest cover after 1999. The forest cover was 29.0% in 1999 (DFRS, 1999), 40.36% in 2014 (DFRS, 2015) and 44.47% in 2018 in Nepal (MoFE, 2019). Conversely, the forest covers decreasing trend in the major cities of the country. A study based on remote sensing analysis has found that the forest cover (included shrub) was 42.89% in 1967 (Thapa & Murayama, 2009), which decreased to 38.49% in 2010 in the Kathmandu Valley (Wang et al., 2020). The decreasing forest covers primarily converted into agricultural land and built-up area over the 20 years in the Kathmandu Valley (Wang et al., 2020). Other large metropolitan cities of the country, such as Pokhara and Bharatpur, also experienced a decrease in forest cover between 1990 and 2018. Based on satellite images analysis of various years, the forest cover decreased from 202.91 km^2 (43.60%) to 191.33 km^2 (41.11%). Likewise, the forest cover also decreased in Bharatpur, which decreased from 35.48% to 34.57% between 1990 and 2010 (Rai et al., 2020). Similar to the previous studies, the DSC has also experienced a decreasing trend of forest over the past three decades.

Not only forest cover, but the agricultural land also has been decreasing trend in Kathmandu valley. Between 1990 and 2010, the agricultural land decreased from 183.11 (41.73%) to 165.16 km^2 (37.63%), which primarily converted into urban areas (Wang et al. 2020). Likewise, the agricultural land also decreased in Pokhara and Bharatpur Metropolitan city during 1990 and 2018. The agricultural land decreased from 48.43% to 46.20% in Pokhara and and 59.93% to 53.16% in Bharatpur Metropolitan city (Rai et al., 2020). The agricultural land decreased significantly between 1977 and 2010 in Pokhara sub-metropolitan city, which was 60.73% in 1977, and is reduced to 20.27% in 2010 (Rimal, 2013). This study has also found that agriculture has been converting into urban areas in all directions from the core area. However, the agricultural land was increased from 151.2×10^2 to 438.8×10^2 km^2 during 1910-2010 in the country (Paudel et al., 2018). The discrepancies in the results could be due to the spatial coverage and study periods of the study area. Water bodies also increased slightly in the study area. Similar to the present study, other historical studies also found an increasing trend of water bodies. A study

based on remote sensing has found that the water body increased from 2.49 to 2.95% in Pokhara and 1.57% to 1.66% in Bharatpur Metropolitan city between 1990 and 2018 (Rai et al., 2020).

Urban growth

Historically, the urbanization/built-up area has been growing significantly across the country. The urbanization process starts after the 1950s in the country. During the 1950s (1952/54), there were just ten urban areas (municipality) in the country which increased to 16 in 1971, 58 in 2001 (Poudel, 2013; Shrestha & Rijal, 2017). Recently the government of Nepal has declared the six metropolitans, 11 sub-metropolitan cities, 276 urban, and 460 rural municipalities in 2017 (MoFAGA, 2017). A remote sensing-based analysis were observed increasing trend of built-up area which was 0.22% (329.18 km^2) in 1990 (ICIMOD, 2014a), 0.29% (423.01 km^2) in 2000 (ICIMOD, 2014b) and 0.32% (469 km^2) in 2010 (Uddin et al. 2015). The increasing urbanization is an indicator of development but haphazard increasing urbanization likely to create multiple hazards in the city. A study has notified the high-risk zones along the Seuti and Sardu river banks of multiple hazards (Aksha et al., 2020). The urbanization; increase of built-up area also increased in those areas during this study period.

Population growth and migration are leading to the rapid urbanization process in the major cities of Nepal, such as Kathmandu Valley (Thapa & Murayama, 2009), Pokhara (Rimal, 2011; 2013; Rai et al., 2020), Bharatpur (Rai et al., 2020). Primarily the urbanization has been taking agricultural land in those major cities. Urbanization has been increasing since historical periods, which increased from 2.94% to 14.19% between 1967 and 2000 in the Kathmandu Valley (Thapa & Murayama 2009). A remote sensing analysis has found that the urban area expanded by 87.90 km^2 during 1989-2016 in the eastern Tarai region of Nepal, where around 88 km^2 area is converted into the urban area (Rimal et al., 2019). This study also found the agricultural land converting to urban areas. But the agricultural land converting to urban areas increased negative impact on food security and environmental balance in the Tarai region (Rimal et al., 2019). The current urbanization trend will be a major responsible factor to increase in flood by 40%, which may not control the urban drainage management and infrastructure of Kathmandu Valley (Pradhan et al., 2017).

Urbanization is increasing mainly due to population growth. Historically, the population is in increasing trend in DSC. In 1961, the total population of the DSC was only 13998, which increased to 20,503, 42146, 66,457 and 95,332 and 137,705 in 1971, 1981, 1991, 2991 and 2011, respectively (CBS, 1984, 1994, 2012). Dharan Sub-metropolitan city was formed by merging the existing Panchakanya and Bishnupaduka VDCs.

The total area also increased from 103.38 km^2 (in 2011) to 193.85 km^2 (2020). Redefining of the municipality by the government in 2016 was also a major reason for urban growth (Rai et al., 2020). About 89 km^2 area was gained by DSC after merging two existing VDCs in 2016. Overall, the country also gained an urban population, which was 336,222 in 1961, and it increased to 4523000 in 2011. Urban migration due to various causes also played a key role in urban growth. A ten-year-long Maoist insurgency was also a responsible factor that people migrated to safe urban places from Hills and Mountain regions (Devkota, 2012).

Conclusion

This study examined the land use land cover changes between 1986 and 2020 of Dharan sub-metropolitan city, eastern Nepal. Urbanization is increasing rapidly at the cost of agricultural land and forest cover. The urban land is expanding in south-eastern, north-eastern and western directions from the core area. The large coverage of the forest is decreased over the past 34 years in the study area. Migration from Mountain and Hill region as well as natural population growth are the major responsible factor to increase urban areas within the city (Sharma 2003). The settlement is increasing along both streamside (Sardu and Seuti). The possible flooding may damage buildings as well as human casualties and deaths during the rainy season in the future. Therefore, land use land cover change monitoring is to be considered while designing urban planning.

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