The Himalayan Review XLV (2024)

Changing Pattern and Drivers of Land Use and Land Cover in Bagmati Province of Nepal

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Submitted: May 26, 2023, Accepted: March 27, 2024, Published: July 26, 2024

DOI: https://doi.org/10.3126/hr.v45i1.68163

Abstract: Land use and land cover (LULC) represents the physical component of the Earth's environment, and often changes as a result of natural and anthropogenic activities. This study carried out changing patterns and orientations of LULC types of Bagmati province of Nepal by using satellite images between 1996 and 2016. The study applied a classification scheme through support vector machines (SVM) for the period from 1996 to 2006, and 2006 to 2016. Our study explored that built-up area expansion was the major change witnessed which increased from 85.25 km^2 in 1996 and sharply increased and labeled 250.06 km^2 in 2016. Similarly, the forest land of the province increased by 329.02 km^2 between 1996 and 2016. The status of cultivated land was found slightly decreasing trend, which was noted at 6113.50 km^2 in 1996 and labeled at 5725.82 km^2 in 2016. The shrubland of the province declined by 272.03 km^2 from 1851.67 km^2 in 1996 to 1579.64 km^2 in 2016. However, the status of snow/ ice cover found at fluctuated form, which was noted 774.27 km^2 in 1996, 1297.43 km^2 in 2006, and 828.92 km^2 in 2016. The increasing population trend is the main driver of the high rate of built-up area expansion and contraction of the cultivated land. Community forestry programs highly supported the expansion of forest cover. The proper implementation and improvement of the existing policy are the major concerns for sustainable LULC management in the province.

Keywords: Land use/land cover change; driving factors; Bagmati province; Nepal

1. Introduction

Land use land cover (LULC) change is one of the major causes of global to local area environmental change (Ellis et al., 2010, Gao et al., 2015, Song et al., 2018) and is driven by multiple natural and social factors (Gobin et al., 2002, Feng et al., 2013). Natural factors determining land use distribution include slope, aspect, altitude, soil, landform (Wubie and Assen 2020), natural hazards (Khan et al., 2015), and geomorphological processes (Fort et al., 2018). Anthropogenic determinants (Daye and Healey 2015) include urbanization (Seto et al., 2012), industrialization (Li et al., 2010), deforestation, forest degradation, and fragmentation (Lambin et al., 2001, Foley et al., 2005, Ostapowicz et al., 2006, Nobre et al., 2016), agricultural intensification (Ramankutty and Foley 1999, Wubie et al., 2016, Garrett et al., 2018), migration (UNDESA 2019), population pressure (Khan et al., 2015), and government policies (Feng et al., 2013). However, anthropogenic driving factors are active than biophysical driving factors varying over space and time. Studies have pointed human activities to have exerted greater effects on LULC change than other factors in recent decades (Lambin et al., 2001, Foley et al., 2005, Ostapowicz et al., 2006). Such changes impact ecology (Cai et al., 2016), climate change (Aguilár and Ward 2003), and pose threats to sustainable food security (Ruel et al., 2017) soil, biodiversity, and ecosystem service loss (Wang et al., 2015, Hu et al., 2019).

The changes of the major land use and land cover in the Asian country show high level of agricultural land converted into the urban and built-up area (Estoque and Murayama 2015, Schneider et al., 2015). This is also very common in South Asian countries (Pandey and Seto 2015, Bhat et al., 2017), including Nepal (Paudel et al., 2016, Bare et al., 2018). Studies have revealed that the greatest destruction, brought by the expansion of urban spaces, has been to agricultural lands (Wubie et al., 2016, Garrett et al., 2018). Besides, land cover changes were a result of several culminating factors like soil weathering, shrinking of water bodies, vegetation pressure, and other anthropogenic activities in west Africa (Reij 2009). Furthermore, road network, waterbodies (lake) elevation of a specific area is other factors of land use land cover change determination (Du et al., 2014). Reductions in farmland for crops cultivation have direct impacts on ecosystem productivity and services, a problem which is referred to as “ecosystem disservice” (Ramankutty and Foley 1999). As a result of migration to the city center, major farmlands of rural and urban-fringe remain abandoned (Ramankutty and Foley 1999, Khanal et al., 2016, Bhattarai and Conway 2021) while outskirts of city farmland transform into industrial and urban centers (Bhat et al., 2017, Rifat and Liu 2019). The conversion of farmland into the city may create food insecurity in developing countries (Chen 2007).

Nepal is a developing country with tremendous urban growth for the past decade. In Nepal, various studies at national and sub-national levels also indicate the major land use cover change issue combines with socio-economic conditions (Rijal et al., 2020), population growth, economic activities, land market, and infrastructure (Bhattarai and Conway 2021), urban sprawl (Bare et al., 2018), climate change, and natural hazards (Subedi 2017, Bhattarai and Conway 2021), agricultural practices (Paudel et al., 2016, Subedi 2017, Bhattarai and Conway 2021), government plan and policies (Subedi 2017, Bhattarai and Conway 2021). The built-up area has been rapidly increasing since 2010, 0.32% in 2010 (Paudel et al., 2016). Moreover, urban expansion is concentrated around old cities, national highways, and the southern Tarai region (Rimal et al., 2018), mostly eliminating cultivable lands. Studies portray increasing cultivated land until 2010, since, declining after 2010 (Paudel et al., 2018). The declining trend of forest cover (the 1970s – 1991) however has reversed with the implementation of the community forest program, GC et al., 2016). The forest cover declined to 52% in 1991, gradually increasing to 61% by the end of 2011 (GC et al., 2016). The snow and ice cover, however, have been noticed declining in past recent years, creating increased barren land in the country (ICIMOD 2014).

Bagmati Province is one of the most fast-changing landscapes of Nepal incorporating a total of 45 urban municipalities. The province includes the rapidly urbanizing Kathmandu valley accommodating 10% of the national population (SFD 2020). Besides the province is home to two major metropolitans in Bharatpur and Lalitpur with Heatuda and Bhaktapur being other major urban centers of the country. Meanwhile, the study area is characterized by the fragile geography witnessing and at severe risk of several natural hazards such as landslides, floods, glacial lake outburst flood (GLOF), droughts, and soil erosion which eventually result in the change in LULC (Subedi 2017, Bhattarai and Conway 2021). Along with various densely populated urban centers, forest cover (59.73% with grassland) is the dominant land cover of the area and 1 conservation areas, 4 national parks, and their buffer zones are integrated with the region which is important in terms of various ecosystem services and biodiversity. The cultivated land cover in the southern plains and valleys is an important ‘food basket’ of the region however is under extreme pressure from numerous anthropogenic factors (Bhattarai and Conway 2021). To this end, exploring the LULC change of the Bagmati province is highly imperative.

Ever-evolving satellite images provide primary data for remote sensing applications (Phiri and Morgenroth 2017). Remote sensing and time-series Landsat satellite images have been successfully used to evaluate Land cover studies for more than 40 years (Jensen and Cowen 1999, Hansen and Loveland 2012, Uddin et al., 2015b), and help in identifying attributes in dynamically changing environment including forest change (Frantz et al., 2016, Zhao et al., 2016), urban monitoring (Feng et al., 2017), ecological studies (Zedadra et al., 2019), disaster management (Tiwari et al., 2017) and assessment of ecosystem services (Rimal et al., 2019). The previous studies in different regions of the province were conducted in small and some specific areas using remote sensing technology (Gautam et al., 2003, Thapa and Murayama 2009, Thapa and Murayama 2011); however, to our knowledge, there is the dearth of studies which have attempted to investigate the LULC change of this region in the province level. Thus, this study aims to fulfill this research gap by investigating the spatio-temporal change of LULC change in the Bagmati province of Nepal between 1996 and 2016.

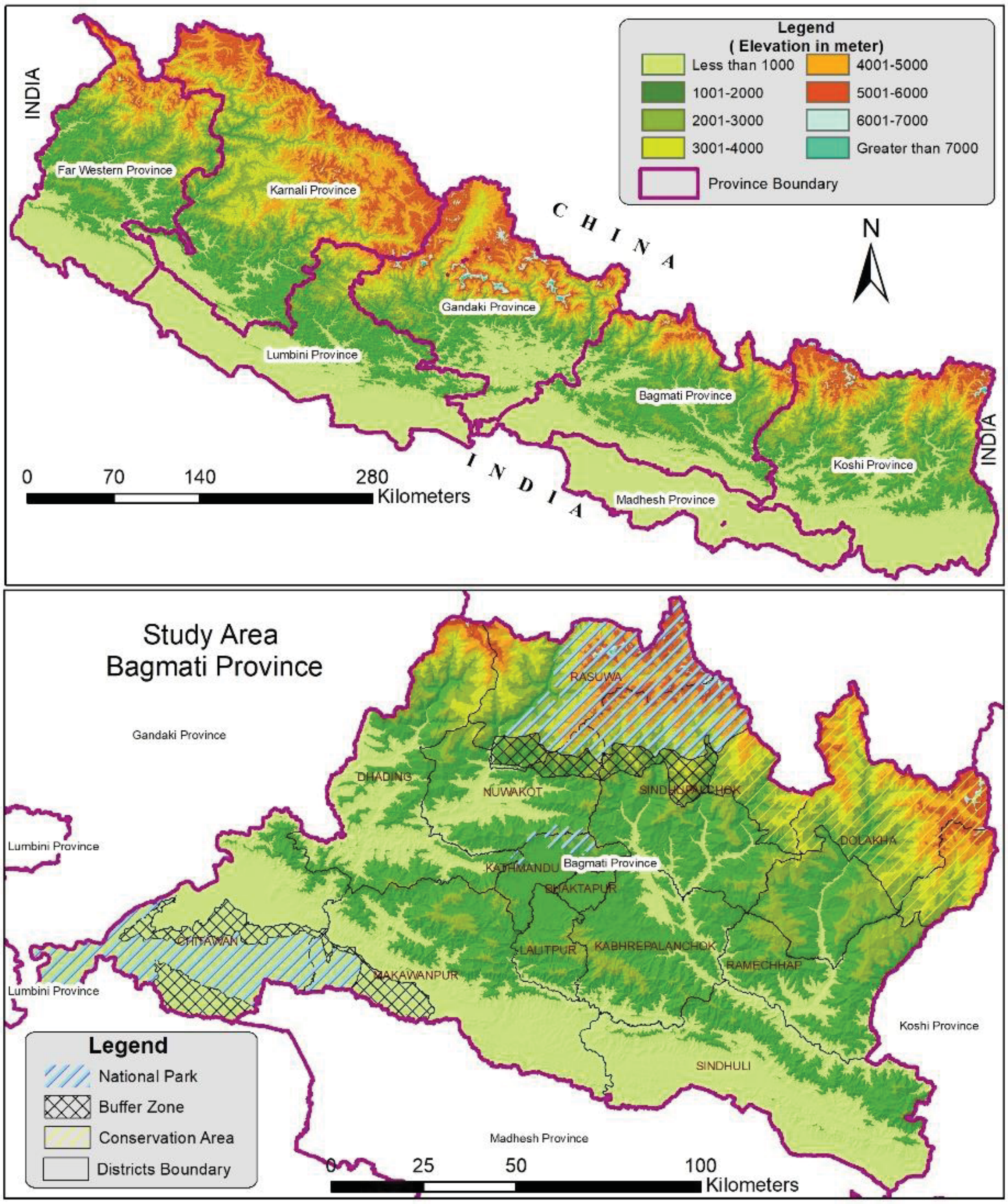

Figure 1. Administrative and geographical details of the study area (Bagmati province, Nepal)

2. Materials and Methods

2.1. The Study Area

The study area, Bagmati province, is geographically located in the central part of Nepal within 26 º.916- 28º. 391 north latitude and 83º.919-86º.575 eastern longitude (Figure 1) covering 20369 km^2. Administratively, the province covers 13 administrative districts (Sindhuli, Ramechhap, Dolakha, Rasuwa, Sindhupalchok, Kavre, Dhading, Kathmandu, Bhaktapur, Lalitpur, Nuwakot, Makawanpur, Chitwan) including the densely populated Kathmandu valley (Capital city of Nepal) and Hetauda city (Provincial capital), 3 metropolitan cities, 1 sub-metropolitan, 41 urban municipalities and 74 rural municipalities accommodating 6,116,866 population (NSO 2021). The elevation of the province ranges from 141 meters above sea level (masl) (Golaghat, Chitwan) to 7422 masl (Gaurishankar Himal). Siwalik Hills of Madhesh province and India borders the province in the south, mountains borders in the north with China, Gandaki province (Trishuli river) in the west, Koshi province and Sunkoshi river borders the province in the east. India on the southern side, and Koshi river on the eastern side with Koshi province. The Koshi river, Bagmati river, Kamla River, Lakhandevi river, and Bishnumati river are the main rivers of Madhesh province.

2.2. Data and Sources

This study used maximum (< 10%) cloud-free, terrain corrected (L1T) for the years 1996, 2006, and 2016 and was obtained from the United States Geological Survey (USGS) (website https://earthexplorer.usgs.gov) (USGS 2020) (Table 1). The obtained images are from the period between November and December month. Landsat 5 TM (Thematic Mapper) images for 1996 2006 and Landsat 8 OLI (Operational Land Imager) images for 2016 were used for this analysis. The study used a 30 m resolution Shuttle Rader Topographical Mission (SRTM) digital elevation model (DEM). Google earth images from Google Earth (http://earth.google.com) of multiple dates and topographical maps published by the Survey Department, Government of Nepal, 1995 (scale 1:25,000) (MoLMCPA 1996) were collected. District level population information of 1991, 2001, 2011, and 2021 were collected from the Central Bureau of Statistics, (GoN 2014). Major land-cover change information and road networks were gathered using Global Positioning System (GPS) in course of the field visit and field verification in campaigns.

Table 1. List of Landsat satellite imagery used by the study.

Path/Row	1996	2006	20116
140/41	Dec-30	Nov-8	Nov-3
141/40/41	Oct-18	Nov-15/30-Oct	Nov-10
142/42	Nov-10	Oct-5	Nov-1

2.3. Pre-Processing of Images and Design of Image Classification

Proper land cover analysis requires, preprocessing of satellite images. Preprocessing involves the geometric correction, radiometric correction, atmospheric correction, image mosaicking, and image subsets (Erasu 2017). The geometric correction was used through polynomial transformation fit, while the nearest neighbor algorithm was exercised for resampling and image registrations. The initial negative values in the image were changed to zero, later a 3x3 neighborhood operation was performed to smoothing the image, and negative pixel values were placed by the average value of the pixel. Geometric correction of Landsat images was inspected and processed using ENVI (Modica et al., 2016, Sothe et al., 2017). The images were atmospherically and geometrically corrected using a radiative transfer model-based Fast Line-of-sight Atmospheric Analysis of Hypercubes (FLAASH) atmospheric correction model. The root mean square (RMS) error of geometric rectification was kept below 0.5 pixels. Multiple Landsat images were georeferenced with a pixel-based image mosaic tool in the ENVI environment to cover the study area. The extended pixel of the mosaic image was clipped by the province boundary in the study.

LULC classification has been pursued using several approaches: supervised, unsupervised, pixel-based, sub-pixel, knowledge-based, contextual-based, object-based, or hybrid approaches (Phiri and Morgenroth 2017). The image classification techniques are generally categorized into two: parametric and non-parametric; where non-parametric classifiers do not assume the statistical nature of the data. The most used land cover classifier in Nepal are: Supervised Maximum Likelihood (SML) (Gautam et al., 2003, Mandal 2014), Support Vector Machine (SVM) (Paudel et al., 2016, Rimal et al., 2019), Maximum Likelihood (ML) (Rimal et al., 2018), Object-Based Image Classification (OBIA) (Uddin et al., 2015a) and Machine based GEOBIA (Uddin et al., 2015a).

The SVM is one of the widely used non-parametric widely used in remote sensing data (Huang et al., 2002, Ceamanos et al., 2010). SVM algorithm finds a hyperplane to separate the database based on a predefined number of categories (Mountrakis et al., 2011). SVM can convert a low-dimensional classification problem into a high-dimensional one (Zhu et al., 2019). The SVM can support multi-class classifier strategies and small training samples can draw conclusions with limited training samples (Mountrakis et al., 2011) providing the solution to the problems of a nonlinear, overlearning phenomenon, as well as the local minimum (Chang and Lin 2011). SVM approach is generally organized into four Kernel functions: Linear, Polynomial, Radial Basis Functions (RBF), and Sigmoid (Kavzoglu and Colkesen 2009, Lee et al., 2017). The mathematical representations of each kernel are mentioned in the help section of ENVI version 5.3; whereas, the same mathematical representations are presented by Lee et al. 2017 (Lee et al., 2017) using ENVI version 4.4. The multi-class SVM pairwise classification creates a binary classifier for each possible pair of classes, is available ENVI environment, was used in this study. Modified Anderson (Anderson et al., 1976) land cover classification scheme with nine land covers (Table 2) was defined for the LULC classification.

Table 2. Land cover classification scheme (modified after Anderson, 1976)

Land Cover	Symbol	Description
Snow/ice	S/I	Snow-covered mountain peaks
Grassland	GL	Open pastures, playground, park
Waterbodies	WB	River, lake/pond, canal, reservoir
Sand	SA	Riverine deposits, river bank deposits, and sand
Barren land	BL	Cliffs/small landslide, bare area
Shrub land	SL	Small bushes, levees
Forest land	FC	Forest, trees, Grass fields, degraded forest
Cultivated land	CL	Wet and dry croplands, orchards, all agriculture land
Urban/built-up	UB	Commercial areas, settlements, industrial areas, construction areas, roads, airports, public service areas (e.g., school, college, hospital)

The LULC area of the year 1996 - 2006 - 2016 was analyzed in terms of particular LULC net changes (gross gain, gross loss, or persistence) through LULC transition analysis. The LULC transition analysis was used to ascertain the degree of change and the intensity of change transition. The cross-function in TerrSet, initially developed by Clark Lab (clarklabs.org), has been applied to generate a land cover transition matrix. The transition matrix consists of sets of rows and columns of the land cover category. The transition matrix analysis itself does not postulate how changes occurred and does not show which causal mechanism is driving the change process rather it gives a descriptive quantitative model of vegetation change at the landscape level (Biondini, and Kandus 2006).

2 .4. Accuracy Assessment

Accuracy assessment of land cover maps was prepared using satellite images and field-level information (Foody 2002). Random stratified sample points were selected for the accuracy assessment. Sample points were validated using ancillary data (High-resolution Google Earth Images), GPS points collected from field verification for the year 2016/2018, and topographical maps developed by the Survey Department of 1996 (scale 1:25000 and 1:50000) (MoLMCPA 1996). Overall accuracy (OA), user's accuracy (UA), and producer's accuracies (PA) were tabulated as a measure of accuracy assessment. The confusion matrix was developed based on the existing ground truth reference data and classified land cover maps.

2.5 Correlation between urban growth, cultivable land, and population increase

Researches have discussed population growth as the driver of urban expansion (Xu 2004, Long et al., 2007, Bhat et al., 2017). Besides, urban expansion has been discussed as a major driver for the loss of cultivable land around the globe (Tan et al., 2005, Dupras et al., 2016, Mohamed and Worku 2019, Peerzado et al., 2019). In Nepal, increasing population has been attributed to increasing urban sprawl and decreasing agricultural land loss (Gautam et al.,, 2002, Paudel et al.,, 2016, Bare et al., 2018, Rijal et al.,, 2020, Bhattarai and Conway 2021). To visualize the correlation between urban expansion, population growth, and cultivable land loss, the annual growth rate of urban growth, population growth will be calculated using the formula:

$$\text{Growth Rate} = [(T_2 / T_1)^{\wedge(1/20)} - 1] * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where T_2 is the second time (2016 here), T_1 is initial time (1996 here). Besides, a correlation between cultivable land and urban growth pursued using R^2 correlation.

3. Results

3.1. Land use and land cover status

This study evaluated the status of land cover for the years 1996, 2006, and 2016 (Figure 2). The study implies a significant increase in urban/built-up, a slight increase in the forest, snow/ice, and water while a rapid decrease in shrubland, sand, and cultivable land. Besides grassland, barren land is almost constant over the 1996-2016 period (Table 3). The overall; classification accuracy for 1996 is 88 %; 90% for 2006, and 90% for the year 2016. The detailed LULC information of Bagmati province during 1996, 2006, and 2016 is presented in Table 3. The land cover analysis for 1996 implies forest land as the major land cover in the Bagmati province with total coverage of 8374 km^2 area of the province. The cultivated land occupied 6113 km^2 area of the province in 1996. Similarly, there was 1793 km^2 area covered by shrub land, 1338 km^2 by barren land, 1103 km^2 by grassland, 773 km^2 by snow/ ice cover 553 km^2 by sand, 233 km^2 by water bodies in 1996. The rest 85 km^2 area was covered by urban/ built-up area in the province in 1996 (Table 3).

Similarly, during 2006, the Bagmati province has almost 8603 km^2 area of forest land and 6050 km^2 area of cultivated land. Further, 1567 km^2 area was covered by shrubland, 1294 km^2 area by snow/ ice cover, 1146 km^2 area by grassland, and 767 are covered by barren land in 2006. In addition, the province had 584 km^2 of sand cover, 220 km^2 water, and 134 km^2 area urban /built-up area in 2006 (Table 3). By 2016, the forest cover had grown up to an area of 8674 km^2 making the forest the largest land over in the province. The Bagmati province had 5726 km^2 of cultivated land, and 1600 km^2 of shrubland in 2016. Similarly, in 2016, the province had 1346 km^2 of barren land, 1270 km^2 of grassland, 828 km^2 of snow/ice cover, 531 km^2 of sand, and 280 km^2 of water bodies. The rest around 250 km^2 area covered by a urban /built-up area in the Bagmati province in 2016 (Table 3).

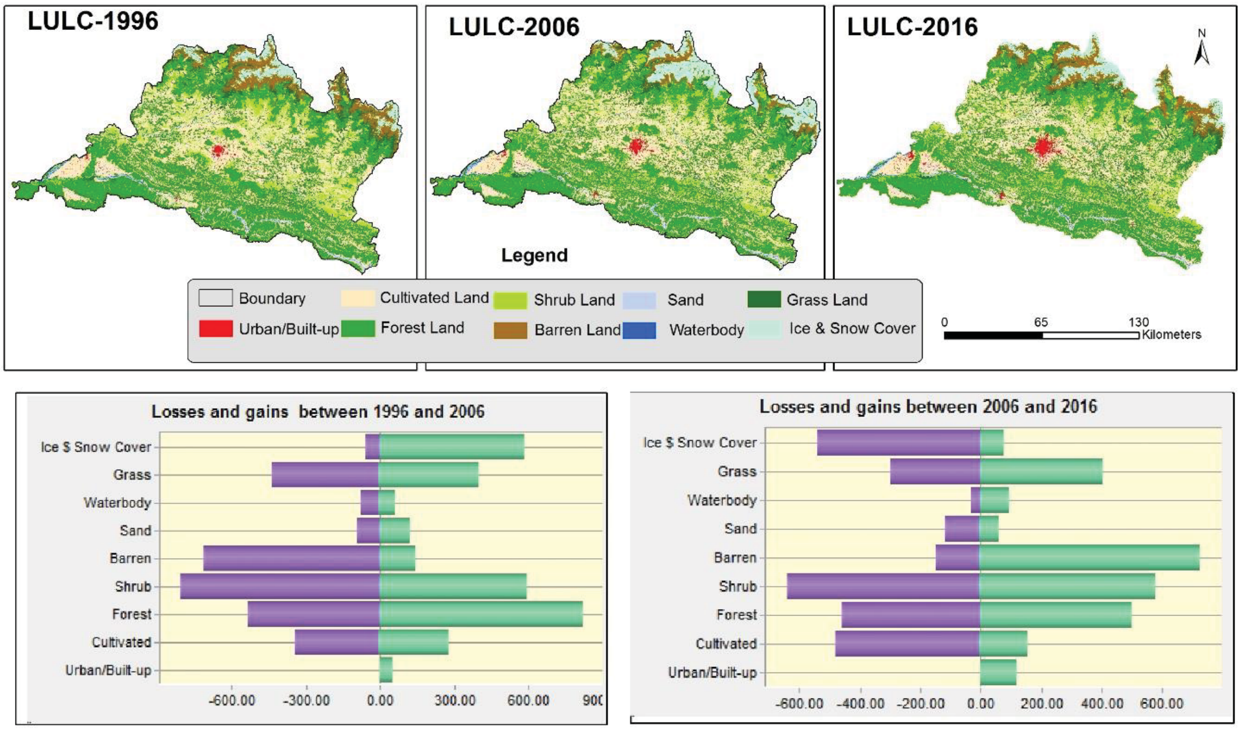

Figure 2. Land use and land cover status of Bagmati province from 1996 to 2016.

Table 3. Land use/ land cover status (km²) of the Bagmati province between 1996 and 2016

	1996	2006	Change % 1996-2006	2016	Change % 2006-2016
Urban/built-up	85.36	134.05	57.04	250.16	86.62
Cultivated	6113.18	6050.48	-1.03	5726.09	-5.36
Forest land	8374.22	8603.40	2.73	8674.99	0.83
Shrub land	1793.65	1567.84	-12.59	1600.52	2.08
Barren	1338.12	767.19	-42.67	1346.20	75.47
Sand	553.93	584.45	5.51	531.62	-9.04
Water bodies	233.50	220.12	-5.73	280.99	27.65
Grass	1103.65	1146.64	3.90	1129.80	10.83
Snow/ ice.	773.79	1294.84	67.60	828.92	-36.08
	20369.40	20369.17		20369.29	
	20369.4003	20369.0249		20369.29	

3.2. Spatiotemporal transition of land use/land cover

During 1996-2006, increase in urban/built-up, forest cover, increase in snow cover are three remarkable land cover increases in the study area. Besides, a decrease in cultivated land is also a major land cover change reported. Urban/ built-up area increased by 49 km^2 (57%) which was increased of which 42 km^2 was derived from cultivated land and was sourced from forest cover and sand. Despite the major conversion of 194 km^2 shrubland, cultivated land declined due to the conversions into urban/built-up (42 km^2), forest (21 km^2), shrub (15km^2), sand (21 km^2), water (4 km^2), and grass (224 km^2). But forest cover increased by 229 km^2 (from 8374 km^2 to 8603 km^2) and this increase is mainly associated with the conversion of large shrubland (480 km^2), grassland (110 km^2), and barren land (36 km^2) into forest cover. The detailed transition matrix of the overall land use classes during 1996-2006 is presented in Table 4.

Table 4. Transition matrix of major land use and land cover from 1996 to 2006

	2006										
	LULC	Urban	Cultivated	Forest	Shrub	Barren	Sand	Water	Grass	Snow/ ice	Total
1996	Urban	84.39	0.03	0.49	0.28	0.01	0.07	0.02	0.07	-	85.36
	Cultivated	42.58	5,768	21.59	15.93	8.26	27.82	4.46	224.6	0.02	6,113
	Forest	2.25	29.34	7,933.69	300.63	16.92	18.48	21.57	49.98	1.37	8,374.2
	Shrub	0.80	194.65	490.51	1,065	8.02	5.47	12.12	15.79	1.51	1,793.7
	Barren	0.71	12.90	36.30	51.18	625.86	12.78	6.00	76.52	515.9	1,338.1
	Sand	1.75	23.00	7.68	8.29	7.11	460	10.86	31.56	3.75	553.93
	Water	0.75	13.54	0.84	0.24	4.76	52.31	153.81	3.04	4.20	233.48
	Grass	0.81	9.06	110.23	123.9	46.68	7.08	8.57	742.47	54.8	1,103.7
	Snow/ ice	-	0.03	2.21	2.29	49.58	0.52	2.24	2.60	714	773.79
		134.05	6,051	8,603.54	1,568	767.19	584.5	219.65	1,147	1,296	20,369

During 2006-2016, urban area, barren land, waterbody, and grassland noticeably increased while cultivated land and shrub land continued to decline. Urban/built-up area increased by 116 km^2, from 134 km^2 to 250 km^2 (86. 62%). The increase is associated with the conversion of cultivated land (102 km^2) and forest (4 km^2) into urban built-up. However, cultivated land declined by 324 km^2, (from 6050 km^2 to 5726 km^2) due to its large-scale conversions to urban/built-up, forest (34 km^2), shrub (237 km^2), grass (60 km^2). To its sharp contrast, forest cover area increased by 71 km^2 (0.83%) from 8603 km^2 to 8674 km^2 and the increase is mainly related to the significant conversion from shrub land (209 km^2) and cultivated 34 km^2) land into forest cover. The detailed transition matrix of LULC during 2006-2016 is presented in Table 5.

Table 5. Transition matrix of major land use and land cover from 2006 to 2016

	2016										
	LULC	Urban	Cultivated	Forest	Shrub	Barren	Sand	Water	Grass	Snow/ ice	Total
2006	Urban	132.77	0.64	0.03	0.20	0.12	0.03	0.24	0.01		134
	Cultivated	102.84	5,567	34.98	237.60	13.54	11.57	20.60	60.87	0.03	6,049
	Forest	4.88	25.87	8,361	90.68	50.93	6.62	7.77	53.00	2.53	8,603
	Shrub	2.42	27.50	209.31	1,233	67.99	3.30	1.88	18.00	4.68	1,568
	Barren	0.84	11.67	4.77	3.41	619.6	6.11	3.42	63.40	53.93	767.19
	Sand	2.99	20.13	9.46	7.47	10.80	467.3	55.72	7.89	2.69	584.47
	Water	0.67	1.48	8.82	2.18	5.21	13.46	186.6	1.06	0.69	220.12
	Grass	2.68	71.92	43.49	26.37	101	20.43	2.53	868.5	9.87	1,147
	Snow	-	0.32	2.87	0.15	477	2.80	2.25	56.83	754.50	1,297
		250.10	5,726.	8,675	1,601	1,346	532	281	1,129	829	20,369

Overall, the land use/land cover change matrix shows that the majority of the increased urban/built-up area was sourced from cultivated land in both periods. Such increase in urban/built-up and primary loss in cultivable land can be attributed to the increasing population and the expansion of the urban area (Figure 2). Urban area was increased by 57% in 2006 and 86% in 2016 (Table 3). Cultivated land converted into shrubland was higher in the period 2006 to 2016 (Table 5); which is further explained by increased barren land (75%) in the same period (Table 3). In comparison to other LULC types, barren land has decreased significantly (-42%) in 2006 while just opposite it has increased by 75% in the year 2016. The increase in barren land and decrease of snow cover has mainly happened in norther area where snow cover occurs. Change in cultivated land is mainly attributed to socio-economic, topographic, and climatic factors in Nepal (Paudel et al., 2016).

3.3. Correlation between urban area and population

Historical data shows that the average population growth over the last 20 years (1991 to 2021) (Table 6) has increased by 2.105% in the study area. Likewise, with population growth, the urban area has also been expanding in the region. However, the annual urban area expansion rate (5.528%) was double the actual population growth. This can be attributed to the urban area definition used, which allows merging rural areas into urban centers. On the other hand, annual cultivated land has decreased by -0.327% per year and the annual forest increase is 0.195%.

Table 6. Total population in the Bagmati province

	Population 2001	Population 2011		Population 2021		Growth rate 01-011	Growth rate 011-021
		Number	% change	Number	% change		
Kathmandu	1,081,845	1,744,240	61	2041587	17.05	4.71	1.51
Chitawan	472,048	579,984	23	719859	24.12	2.86	2.07
Kavrepalanchok	385,672	381,937	-1	364039	-4.69	1.73	-0.46
Makwanpur	392,604	420,477	7	466073	10.84	2.22	0.99
Dhading	338,658	336,067	-1	325710	-3.08	1.97	-0.3
Sindhupalchok	305,857	287,798	-6	262624	-8.75	1.59	-0.88
Lalitpur	337,785	468,132	39	551667	17.84	2.73	1.58
Nuwakot	288,478	277,471	-4	263391	-5.07	1.62	-0.5
Sindhuli	279,821	296,192	6	300026	1.29	2.23	0.12
Ramechhap	212,408	202,646	-5	170302	-15.96	1.22	-1.67
Dolakha	204,229	186,557	-9	172767	-7.39	1.65	-0.74
Bhaktapur	225,461	304,651	35	432132	41.84	2.65	3.35
Rasuwa	44,731	43,300	-3	46689	7.83	1.97	0.72
	4569597	5529452		6116866			

The correlation between the urban area and cultivated area, it is negatively correlated ($R^2 = 0.98$) which describes the majority of cultivated land has transferred to the urban area in the study area (Figure 3 and Table 7).

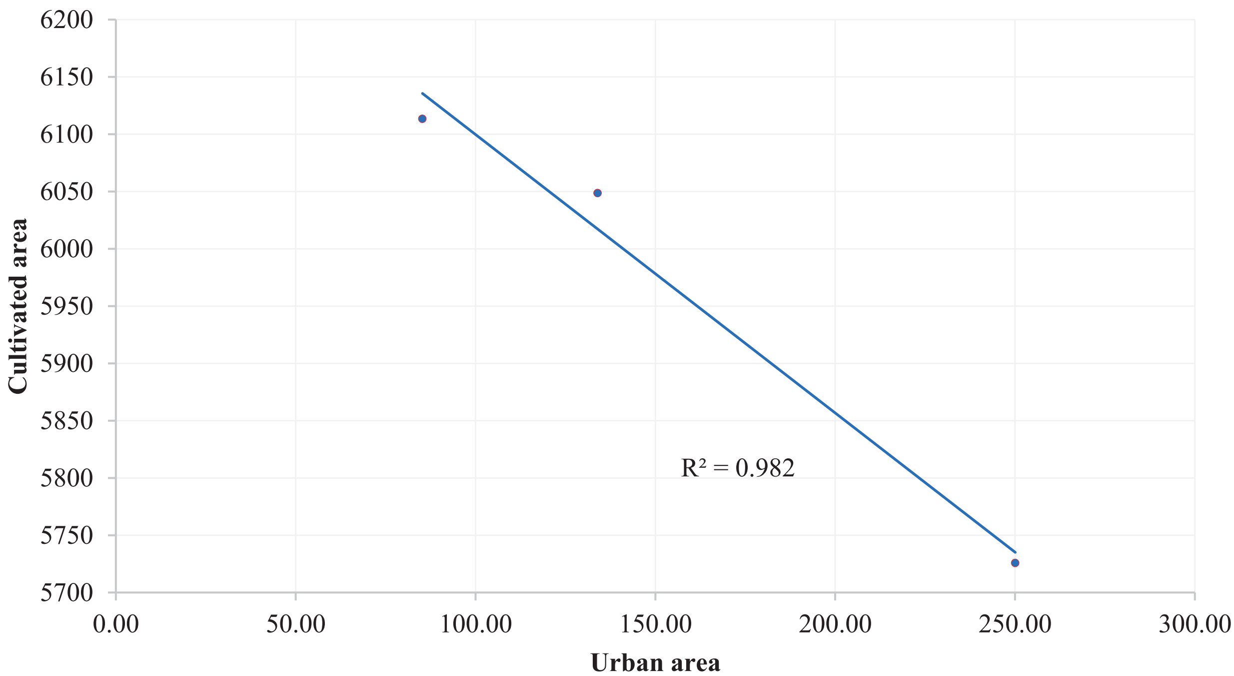

Figure 3. Correlation between cultivated and urban area

Table 7. Cultivated land loss and urban increase correlation analysis

	1996	2006	2016
Urban	85	134	250
Cultivated-land	6113.5	6048.57	5725.82
Correlation			-0.982

4. Discussion

4.1 Land Cover Patterns

The Bagmati province is rapidly urbanizing. Land cover changes are more frequent with several drivers. Major LULC changes witnessed during 1996 to 2016 were a massive increase in urban/built-up area, forest cover, barren land, and continuous decline in cultivated land and shrubland. The increase in urban/built-up area at the cost of cultivated land loss is comparable with similar other studies within Nepal (Rijal et al., 2020) whereas an increase in forest cover is comparable to the case of Gandaki province which reported that forest cover has increased from 52% in 1991 to 61% in 2015 and it is largely due to the community-based forest management practices in the area (Tripathi et al., 2020). Community forest management practices also contributed to forest area changed in this province also.

Urban expansion in the study area shows a pattern of urban agglomeration (Figure 3) (Rifat and Liu 2019). The suburban centers around the major urban area are likely to transform into more urban areas in the future. The result is similar to other researches in the Nepal Himalaya (Thapa and Murayama 2009, Bare et al., 2018). Besides, the rapid urban sprawl, itself would cause other land cover classes to remain under pressure. According to LULC analysis of Tarai districts and Koshi province there was increasing trend of urban –built up area (Rimal et al., 2018). Such an impact would transform other land cover classes, more potently agricultural land cover that is easily changeable.

4.2 Future Drivers of Changing Land Cover

The changes in land cover are influenced by several natural and anthropogenic factors of which population concentration, urban expansion, and natural hazards are highly influential. Socioeconomic factors, migration and population growth, political factors, physical factors, and governmental plans and policies have been recognized as the major influencing factors of urban expansion in the city centers, districts headquarters, Tarai districts (Subedi 2017, Rijal et al., 2020) and Kathmandu valley (Thapa and Murayama 2009,). Some of the arguable drivers for land cover change in the Bagmati Province are:

a) Population Growth: The urban population has increased at an astronomical rate. Although the study (UNDESA 2012) projected one-third of the population to be urban by 2045, a recent report (MoHA 2017) estimates almost half of the population as urban dwellers. The Bagmati province comprising some of the recent urban boom areas is one of the densely populated regions of the country witnessing a gradual population increase; accounting for 18.96% of the national population in 1991, 19.74% population in 2001, and 20.87% in 2011. Expectations are more than one-third of the country's population by the current census, 2021. Kathmandu, Bhaktapur, Lalitpur, Chitwan, Makawanpur, Sindhuli are the districts accommodating the large population, of which, Kathmandu valley alone has incorporated 1,615,091 population in 2001 and 2,517,023 in 2011 (GoN 2014) (Table 7). A recent report places population of the valley to be 3.06 million (SFD 2020), almost 10% of the total population of Nepal. Such an increase in population, not to mention the future growth impacts on future land cover patterns in the province.

b) Migration: Migration is one of the major land cover drivers in the province. The Tarai and Madesh uprising along with better social-economic opportunities has made Bagmati province a woo for every migrant (Bhattarai and Conway 2021). Besides, the Tarai including Hetauda and Bharatpur have been flocked with migrants from the Hilly region increasing urban growth in the area.

c) Infrastructure: Infrastructure and educational facilities are two important factors in the Bagmati province, that will be aiding land cover change for the foreseeable future. The road network, hospitals, industries, and school makes this province an attractive destination for youth to old Nepalese citizens (Subedi 2017, Rijal et al., 2020, Bhattarai and Conway 2021). Infrastructure thus will shape the land cover of the province for the foreseeable future.

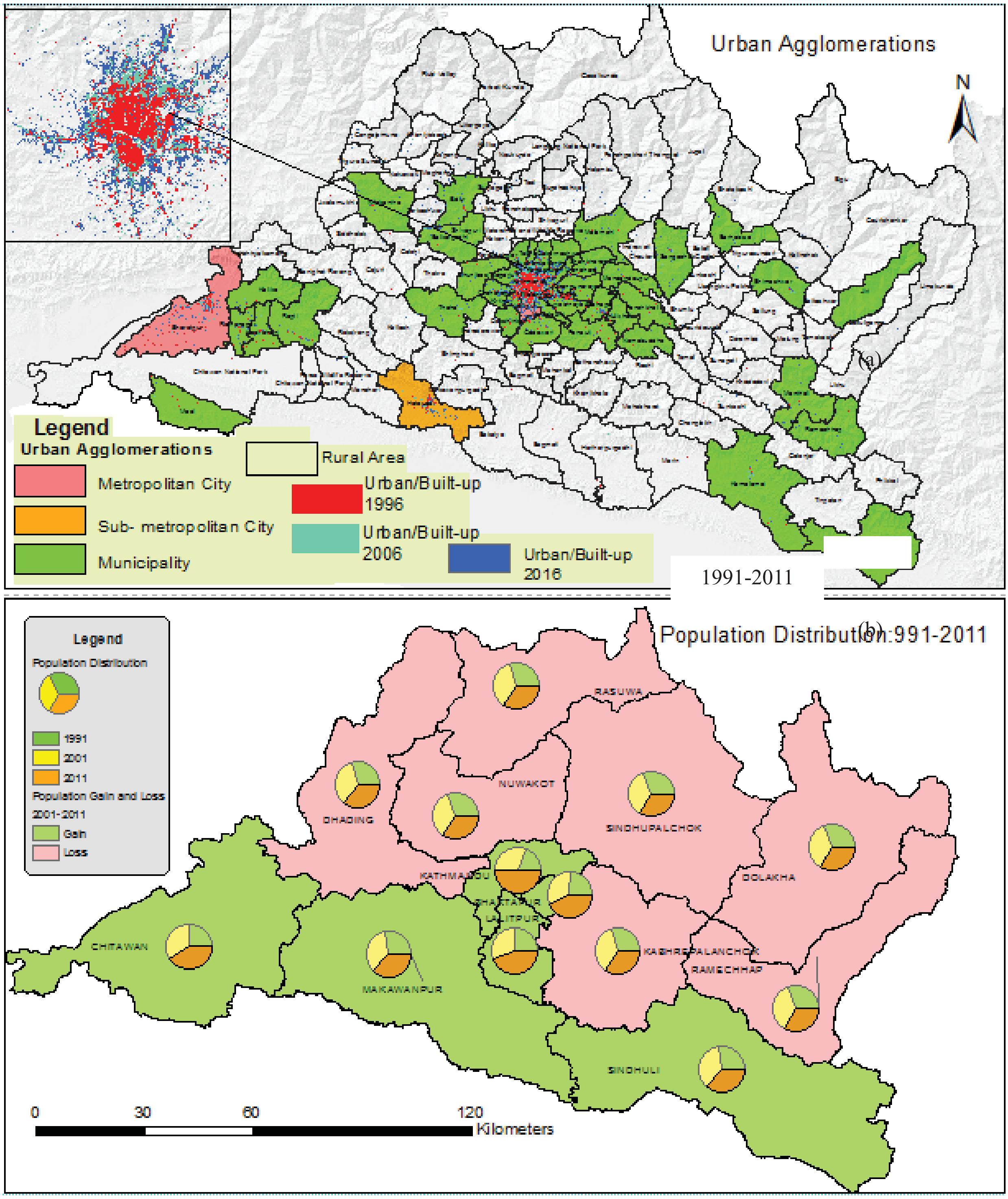

Figure 3. Urban agglomeration in Bagamati province (a), and population trend in Bagmati province during 1991-2011(b).

d) Natural Hazards: Nepal witnessed a massive earthquake of 7.8 Mw on 25 April 2015 and many subsequent aftershocks which not only resulted in the loss of huge lives, properties, and historical monuments but also caused slope failure and landslides (Subedi 2017). The continuous subsequent aftershocks followed by the monsoon season resulted in the failure of slopes and countable landslide events within the fault rupture regions with intensive risks of river blockade (13.5% of the risk), loss of forest cover (18%), residential areas (7.5%) and cultivated land (38%).

Sindhupalchowk district alone witnessed 4919 landslides (Tiwari et al., 2017). Besides, floods, drought, climate change issues are major hazards (Bhattarai and Conway 2021) in the province that can subsequently impact land cover within the province and beyond.

e) Conservation Areas: The study has incorporated 4 national parks (Shivapuri-Nagarjun, Chitwan, Parsa and Langtang national parks), one conservation areas, and their buffer zones. Similarly, the forest resources of the area are being managed after 1990s by community forest users groups (CFUGs) under community forest management. All these management practices are oriented towards the sustainable utilization and management of forest resources, biodiversity, and ecosystem services resulting in the overall increase of forest cover (Rijal et al., 2021).

f) Governmental Policy: Owing to haphazard urban sprawl, food security, and a need for sustainability, several countries have enacted a land-use policy as a major policy guideline; Federal Regional Planning Act (1997)- Germany (Pahl-Weber and Henckel 2008), City Planning Law (1919), Agricultural Land Law (1952), and Law of Construction of Agricultural Promotion Areas (1969) of Japan, Land Zoning in the Netherlands (Jacobs 1997), and Farmland Reform Act (1949) of South Korea (Gurung et al., 2009, Hashiguchi 2014). Although with community forestry Nepal has been getting wonderful results in terms of forest conservation (Tripathi et al., 2020), Nepal has been slowly moving towards land use policy itself with the introduction of Land Use Policy 2015 (MoLMCPA 2015) and Land Use Act 2019 (MoLMCPA 2019). Other conservational practices along with land use policy, plus federalism perhaps will help in sustainable land cover management.

4.3 Future Direction and Management

Studies indicated that the high level of population growth and anthropogenic activities is often playing an important role in land use and land cover change (Meyer and Turner 1992). Many studies at different levels reported that population growth, plan and policy, and conservation practices are the noticeable drivers of land cover change in the south Asian countries (Schneider et al., 2015, Dissanayake et al., 2017, Vadrevu et al., 2017). Further, the results show that forest cover has been ever-increasing, and the expansion of forest cover is highly supported by community forest programs in Nepal (GC et al.,, 2016). Higher rate of farmland abandonment especially in the Hilly and Mountain area in Nepal, and conservation practices supported for expansion of forest cover, and decline of agricultural land in Nepal (Rai et al., 2019, Paudel et al., 2020). The same scenario has in the Hilly and Mountain landscape in Bagmati province, and farmland abandonment has in the favor of forest cover expansion and agricultural land expansion

The expansion of urban / built-up area are good indicators for the overall development of the province, however, without proper planning and management, it will negatively result in ecosystem services, environmental issues, and food security. Besides, land abandonment in the hilly and mountain areas will increase the food insecurity status in the province. In this regard, there was a highly demanded proper management of land use in a scientific way considering with local geography and climate.

4.4 The Policy Implication

Land use act and policy determine the way of sustainable use and management of land resources (Nepal et al., 2020). The land-use zoning concept was introduced in recent years by the government of Nepal (Khanal et al., 2020, Nepal et al., 2020). Further, the government of Nepal adopted a new constitution in 2015. Based on a new constitution, the National Land Use Plan 2013 was reviewed and replaced by the new National Land Use Plan 2015. This plan/policy classified major land use by this way as agricultural, residential, commercial, industrial, mines and minerals, cultural and archeological, rivers–lakes–reservoirs, forests, public use and open spaces, building materials excavation (stone, sand, concrete), and other zones defined as needed

(MoLMCPA 2015). The details land classification scheme and guidelines addressed by Land Use Act 2019 and Land Use Regulation 2022 (MoLMCPA, 2019, MoLMCPA, 2022).

The National Land Use Act 2019 has a long-term vision for the utilization of the maximum land resources through different land classification, their proper use, and management to achieve the national goal (MoLMCPA 2019). In this act address by this law, the local governments themselves can formulate policies or procedures and manage land based on the categorization, which is appropriate at the local level. This act also developed the criterion to control land fragmentation. In this act have the provision to form federal, provincial and local level land use council. In the case of a local government, the respective rural municipality or municipality will act as the local land use council chaired by the respective chairperson/mayor. This council prepares a ward-level land-use plan. Thus, Land Use Act 2019 helped for appropriate management and implementation at the local level for sustainable land use management. Further, the results of this study can use by the provincial level for proper planning of land use and land cover in the Bagmati province in Nepal.

5. Conclusion

Bagmati province's land cover is gradually changing. Urban/built areas are growing at an enormous pace which was observed 85.36 km^2 in 1996 and reached 250.16 km^2 in 2016. Average population growth over the last 20 years (1991 to 2021) has increased by 2.105% in the study area. Forest cover is increasing while agricultural land is shrinking. The scenario will perhaps remain the same in the near future. Agglomeration will lead to larger urban centres especially around the Kathmandu Valley and Chitwan District. Urban centers will be supplanted with decreasing agricultural land. Population growth, migration, and infrastructure are major drivers of land cover in the province. Proper conservation practices, land-use policies will help towards sustainable land cover management in the future. The proper planning and management of land resources at the local level of the province is highly demanding, and this study will facilities towards this direction in the favor of sustainable development. In the future, land cover classification scheme recommended by Land Use Act 2019 is essential to apply for details study of land use in the province. The methods applied in the study and results from this study will be applicable for policy enhancement in this province as well as similar topography of the globe.

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