Drivers and Dynamics of Land Use Land Cover in Phewa Watershed, Kaski, Nepal

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Abstract

Geospatial tools play an important role in monitoring Land Use Land Cover (LULC) dynamics. This study assessed the extent of LULC changes during 2003, 2010 and 2018 using temporal satellite imageries, computed the rate of change in area of Phewa Lake and explored the drivers of LULC change and lake area change in Phewa watershed. It used Landsat Imageries for 2003, 2010 and 2018 and carried out purposive household survey (N=60), key informant survey (N=5), focus group discussion (N=4) and direct field observation to explore the drivers of LULC change and lake area change. It generated LULC maps by using supervised classification and computed LULC change by applying post classification change detection technique. On screen digitization was done to find the area of Phewa Lake during 2010 and 2018. Agricultural land and urban areas were found to have increased by 11.63% and 1.46% respectively while forest area, barren land and water bodies were found to have decreased by 9.21%, 3.56% and 0.5% respectively between 2003 and 2010. Forest area, urban areas and barren land were found to have increased by 5.9%, 3.28% and 5.02% respectively while agricultural landand water bodies were observed to have decreased by 7.83% and 0.16% respectively between 2010 and 2018. During 2010-2018, rate of change in lake area was found to have decreased by 0.61% with periodic annual decrement by 2.59 ha. The drivers responsible for LULC change were alternative form of energy, community forestry, promotion of private forestry, migration for foreign employment, inadequate market price of agricultural products, road construction, soil erosion and population pressure. Lake area was found to have decreased due to sedimentation, encroachment and road construction. Further study is important to know the exact contributions of these drivers of LULC change and lake area change for the sustainability of Phewa watershed.

Keywords: Geospatial,Land Use Land Cover, Phewa watershed, Landsat, Supervised

Introduction

Land use refers to the purpose that land is utilized while land cover is the combination of biological and physical condition of land (Steffen *et al.*, 1992; Turner *et al.*, 1995). Land use land cover (LULC) change refers to numerical change in a specified LULC either in increasing or in decreasing trend within the planet. Mouat *et al.* (1993) defined change detection as the phenomenon of finding numerical dynamics in a body or process by viewing it at different time periods. Land use land cover change (LULCC) is a changeable phenomenon which brings vital dynamics in environment on global scale (Emilio, 2010). Watershed condition can deteriorate due to improper LULC practices which impacts on soil, water resources, biodiversity, microclimate and declined CO_2 absorption (Lambin *et al.,* 2001) and affect natural resources (Awasthi *et al.,* 2002). LULCC has negative impacts on weather patterns (Stohlgrenet *et al.,* 1998) and generation of stream flow (Bronstert *et al.*, 2002; Wang, 2001). LULCC has negative consequences on stream ecosystem structures and functions (Wang *et al.*, 2000), its water quality parameters (Tang *et al.*, 2005; Zampella *et al.*, 2007) and quantity (White and Greer, 2006). Alkharabsheh *et al.* (2013) revealed that LULCC can be applied in many areas like research, planning, geography and policy formulation sectors. Changes in LULC practices have been regarded as one of the key influencing factors at present and many environmental problems are associated with the LULCC in the watershed. The study of LULCC helps to explain the interior mechanism of inter-activities of man-land environments. So, the study of LULC has been the backbone of integrated research of environment (Omernik *et al.*, 1981).

As quantification of spatio-temporal process is not feasible by traditional techniques, temporal satellite imageries can be used to obtain important data for many GIS applications (Rawat and Kumar, 2015). These imageries can provide unavoidable information on land use analysis, soil, vegetation, various aspects of streams and its landforms (Borrough and McDonnell, 1998). At the same time Landsat imageries are mostly used in mapping and monitoring aspects due to their resolution characteristics and free availability (Sadidy *et al.*, 2009). Geospatial techniques can play crucial role in examining, keeping and recovering biological, physical, social and economic aspects of watershed (Awasthi *et al.*, 2002; Sidhu *et al.*, 2000).

Phewa Lake is a master piece of nature in Pokhara city with national significance and is included in Lake Cluster of Pokhara Valley (included in Ramsar site in February 2, 2016). But human induced activities have negatively impacted on land use which result in deposition of sediments in water resources (Sthapit, 1988). These sediments decrease both depth and area of the lake which inturn affects its life span (Awasthi *et al.*, 2007; Sthapit and Balla, 1998). The annual siltation rate of Phewa Lake has a range of about 175,000-225,000 m^3 (Heyojoo *et al.*, 2009) and at this rate of loss of 80% water volume, the terminal silt trap portion will be detached from the main body of the lake in upcoming 20-25 years and the lake will actually "die" in the following 135-175 years (Sthapit and Balla, 1998). Deforestation, uncontrolled grazing and unsuitable farming caused landslides and erosion which in turn resulted in siltation in Phewa lake until mid-1970s (Fleming and Fleming, 2009; Paudyal *et al.*, 2017b) and led to intensive heavy siltation in Phewa lake, the second largest lake and prominent tourist destination in Nepal (Paudyal *et al.*, 2018).

Population rise, irregular economic growth and government policies supporting urban areas economic development are the major drivers of LULCC in Nepal (Jorgensen and Volleweider, 1989; Rimal *et al.*, 2018 a; Rimal *et al.*, 2018b). Mainly soil erosion, deforestation, unplanned rural road construction and rapid changes in LULC are degrading Phewa watershed (Regmi and Saha, 2015).

Therefore, for sustainable development and management of the watersheds, spatial inventories of the trends of LULCC and their prediction status are vital (Regmi and Saha, 2015). So this paper assesses the extent of LULC changes during 2003, 2010 and 2018 using temporal satellite imageries, computes the rate of change in area of Phewa Lake during 2010 and 2018 and explores the drivers of the change of LULC and lake area in Phewa watershed. Understanding LULC dynamics of Phewa watershed plays a vital role in designing proper land use plan for sustainable productivity and benefits. Therefore, this paper, with its information on potential environmental impacts, can be important for formulating policies and planning strategies for effective land management for the sustainability of Phewa watershed and Phewa Lake.

Materials and Methods

Study Area

Phewa watershed is situated in the south-western corner of Kaski district covering rural as well as urban area. It expands from 28°11'39" North to 28°17'25" North latitude and 83°47'51" East to 83°59'17" East longitude. The altitude of the area varies from 789 to 2508. 81 m above msl in the west with the highest peak at Panchase which is biologically rich. The watershed area

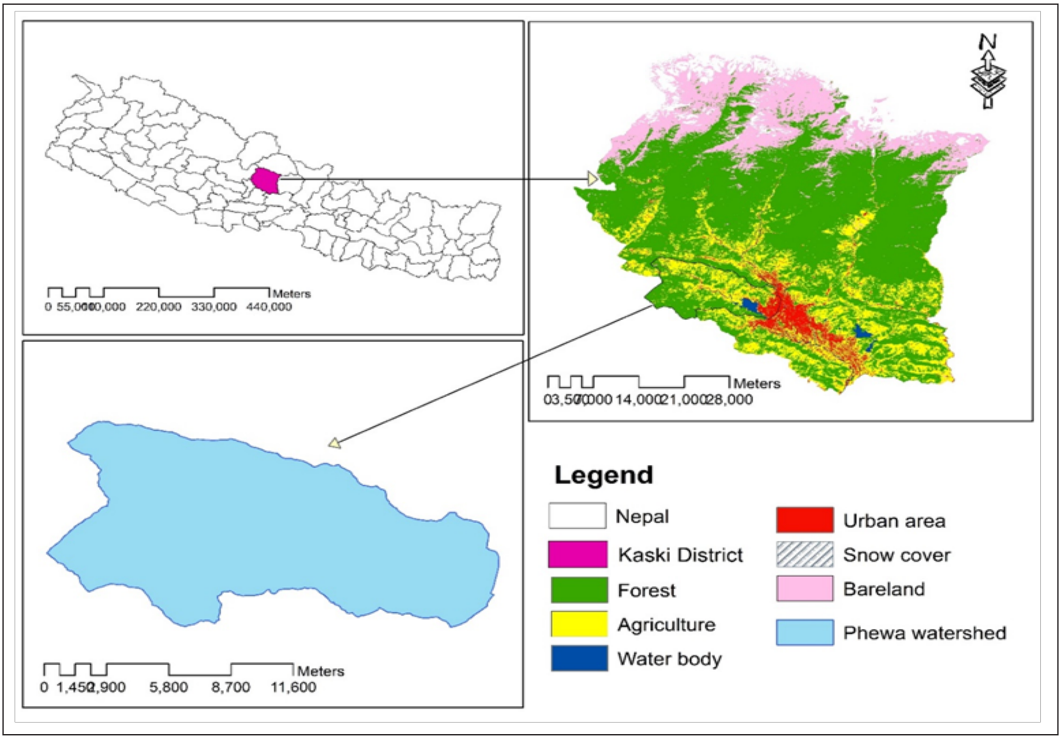

Figure 1: Map of the study area

possesses moderate subtropical to the cool temperate type of climate.

Phewa Lake extends from 83°55’44” to 83°58’10” East latitude and from 28°11’44” to 28°13’40” North longitude with average elevation of 794 m from mean sea level.

Landsat TM for 2003, 2010 and OLI_TIRS for 2018 imageries was analyzed for assessment of LULCC. The LULC classes used for the classification were forest, agricultural land, barren land, water bodies and urban areas.

Table 1: Data specification of satellite imageries used in LULC classification

Satellite	Years	Sensor	Total bands	Temporal resolution	Spatial Resolution (m)	PAN Band	Date of acquisition
Landsat 5	2003	TM	1-7	16 days	30*30	Nil	30-Nov-2003
Landsat 5	2010	TM	1-7	16 days	30*30	Nil	1-Nov-2010
Landsat 8	2018	OLI_TIRS	1-11	16 days	30*30	15m,B-8	23-Nov-2018

Methods

The primary data related to the drivers of LULC change were collected through direct field observation, purposive household survey (N=60), key informant interview (N=5) and focus group discussions (N=4) while the secondary data viz Landsat TM for 2003, Landsat TM for 2010 and Landsat OLI_TIRS for 2018 imageries were freely downloaded from USGS website (earthexplorer.usgs.gov). Aster DEM from USGS website (earthexplorer.usgs.gov) was used for boundary demarcation of the watershed.

LULC Analysis

Radiometric, Atmospheric and Sun angle corrections of respective Landsat imageries were carried out. LULC maps for change detection analysis were generated using supervised classification with maximum likelihood classifier (Lillesand *et al.*, 2004). Digital supervised classification of

Rate of Change in Lake Area

The rate of change in lake area was assessed by the given formula.

Rate of Change (%) = [((b/a) ^ (1/n)-1)*100] (UNDP, RFDTh and FAO cited by Lamichhane, 2008).

PAI=A i+n-Ai/n
Where,
a = base year data
b = end time data
n = number of years
A i+n = Area of $(i+n)^{th}$ year
Ai = Area of i^{th} year
PAI= Periodic annual increment

Data Processing and Analysis

LULC change operation was done in ArcMap 10.3. On screen digitization was done to find the area of Phewa Lake during 2010 and 2018 in ArcMap 10.3. The rate of change in lake area was calculated by above formula. Quantitative data of LULCC and lake area change were analyzed using MS

Table 2: LULC classes used for classification

S.N.	LULC types	Description
1.	Forest	Shrub lands,trees, grassland bushes.
2.	Agricultural land	Cultivation in sloping mountainous areas in terraced fields. Includes both valley and terrace agriculture.
3.	Barren land	Sandy areas, areas exposed after landslides and soil erosion. Quality of soil is poor.
4.	Urban areas	Urban and rural human settlement areas.
5.	Water bodies	Areas with lake and rivers.

Excel 2016.The drivers associated with LULC change and lake area change of Phewa watershed were analyzed on MS Excel 2016.

Results

LULC Dynamics of 2003, 2010 and 2018

The area statistics of LULC for the respective time periods are shown in (Annex 1 and 2 and shown in Figure 2 (A), (B) and (C). There were drastic changes in LULC during these periods in the watershed. Agricultural land covered the largest area in all time periods followed by forest area in study time periods. In 2003, agricultural land covered 5179.86 ha (43.2%) followed by forest which covered 4963.05 ha (41.39%). Barren land, water bodies and urban areas covered 891.99 ha (7.44%), 529.29 ha (4.41%) and 425.34 ha (3.55%) respectively. In 2010, agricultural land covered an area of 6573.78 ha (54.83%) followed by forest which covered 3882.42 ha (32.38%). Urban areas, water bodies and barren land covered 600.03 ha (5%), 468.99 ha (3.91%) and 464.31 ha (3.87%) respectively. In 2018, the agricultural land covered 4914.72 ha (40.99%) followed by forest which covered 4565.88 ha (38.08%). Barren land, urban areas and water bodies covered 1065.87 ha (8.89%), 993.33 ha (8.28%) and 449.73 ha (3.75%) respectively.

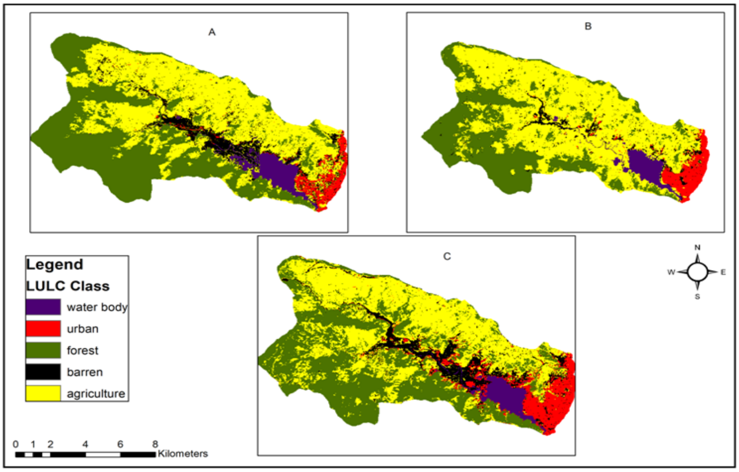

Figure 2 : LULC map for (A) 2003, (B) 2010 and (C) 2018

Accuracy Assessment

Altogether 160 ground truth positions were collected with the help of Google earth image for 2003 and 2010. Additional GPS points combined with Google earth image were utilized to collect ground truth positions of classified LULC map for 2018. Confusion matrix was used for accuracy assessment. The overall accuracy of the classified maps was 85%, 92.44% and 88.1% respectively. The Kappa coefficients were 0.76, 0.9 and 0.84 respectively.

As shown in change/no change map for 2003-2010 is shown in (Figure 3) land use was changed from forest to agricultural land by 12.01%, barren land to agricultural land by 5.3%, agricultural land to forest by 3.62%, urban areas to agricultural land by 0.28% and water bodies to agricultural land by 0.81% (Annex 3).

The change/no change map for 2010-2018 (Figure 4) shows that the land use was changed from agricultural land to forest by 9.72%, forest area to agricultural land by 3.79%, barren land to agricultural land by 1.22%, urban areas to barren land by 0.39% and water bodies to urban areas by 0.26% (Annex 4).

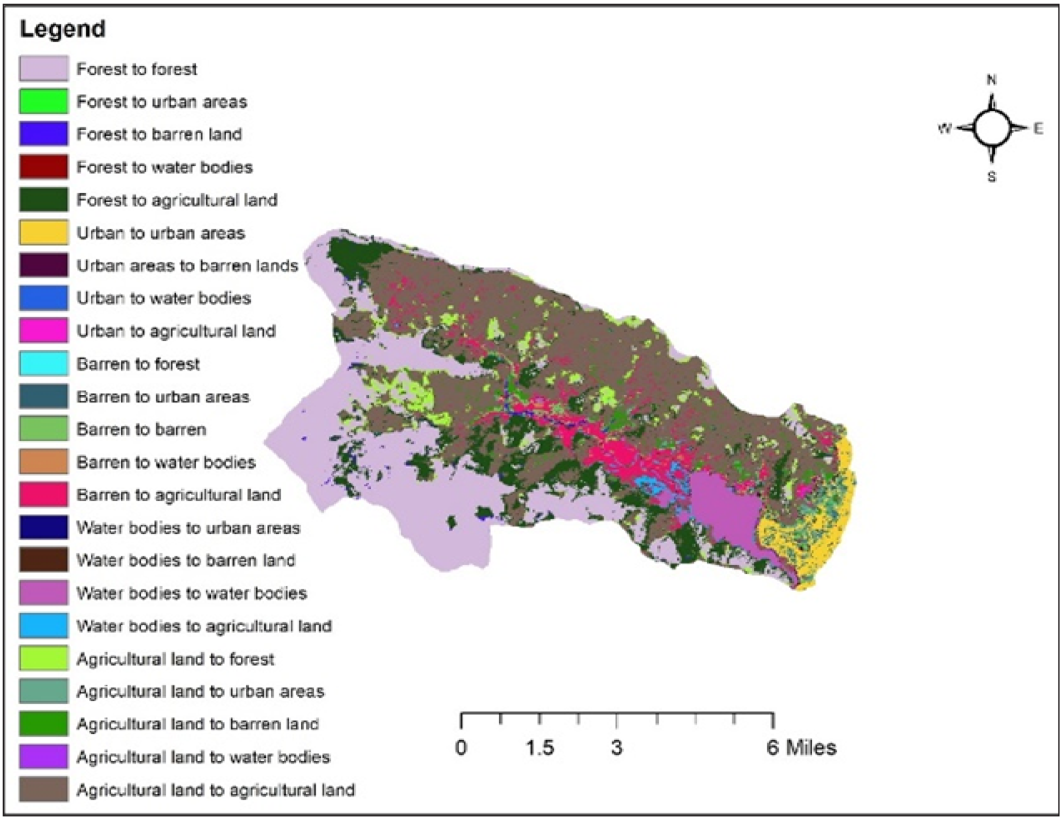

Figure 3 : Change/No change map during 2003 to 2010

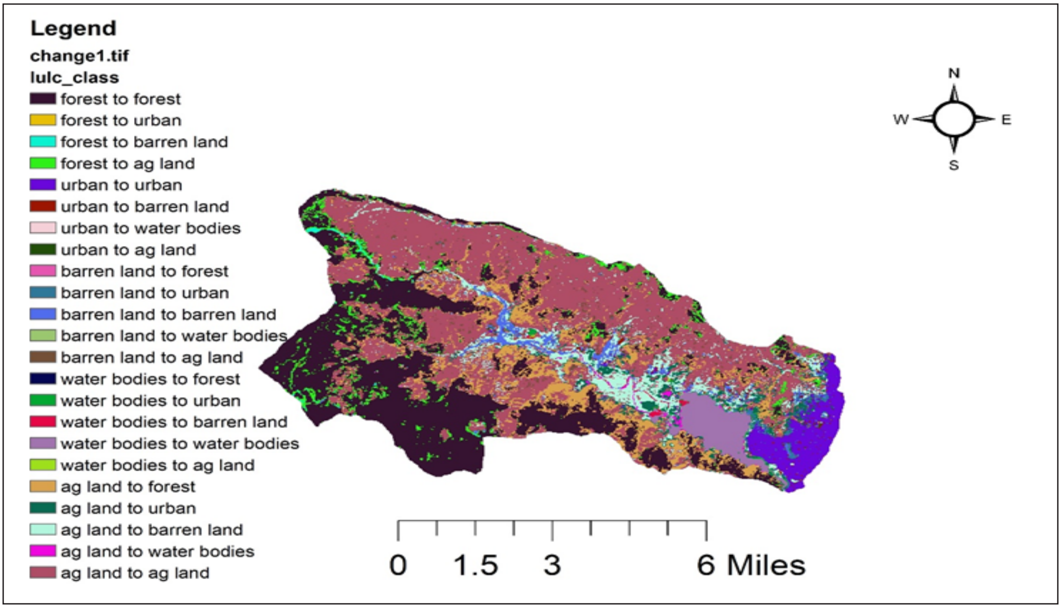

Figure 4 : Change/No change map during 2010 to 2018

Computation of the rate of change in area of Phewa Lake

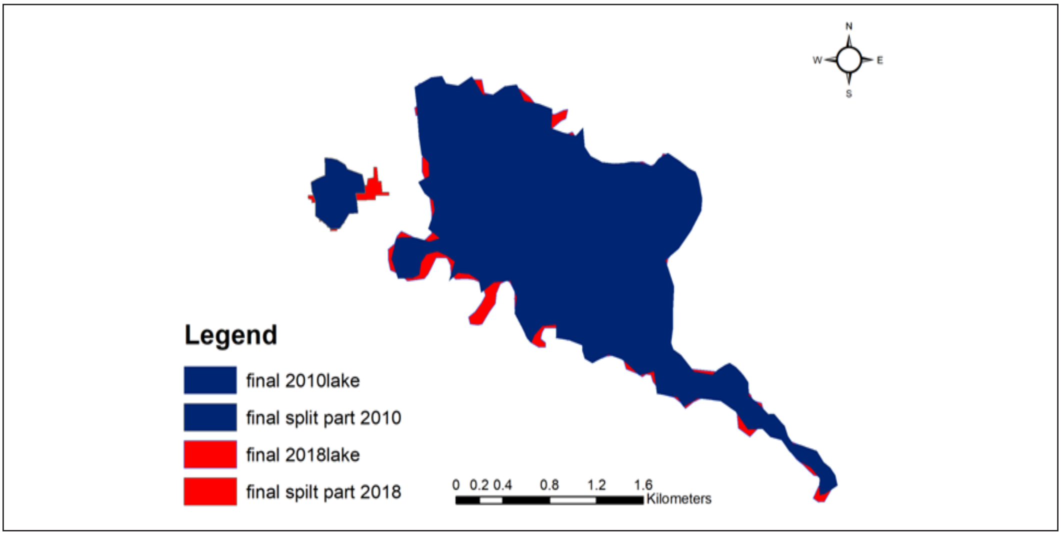

Figure 5 : Lake area change map

From the on screen digitization of Phewa Lake, we found that the lake area was 430.64 ha in 2010 while it was 409.92 ha in 2018 (Figure 5). The periodic annual decrement was 2.59 ha. The rate of change in lake area was found to be -0.61%.

The Normalized Difference Water Index (NDWI) ranges were -0.641791 to 0.419355 and -0.414176 to 0.0906588 in 2010 and 2018 respectively (Figure 6). Water bodies were degraded as there was decrease in positive value of NDWI between 2010 and 2018.

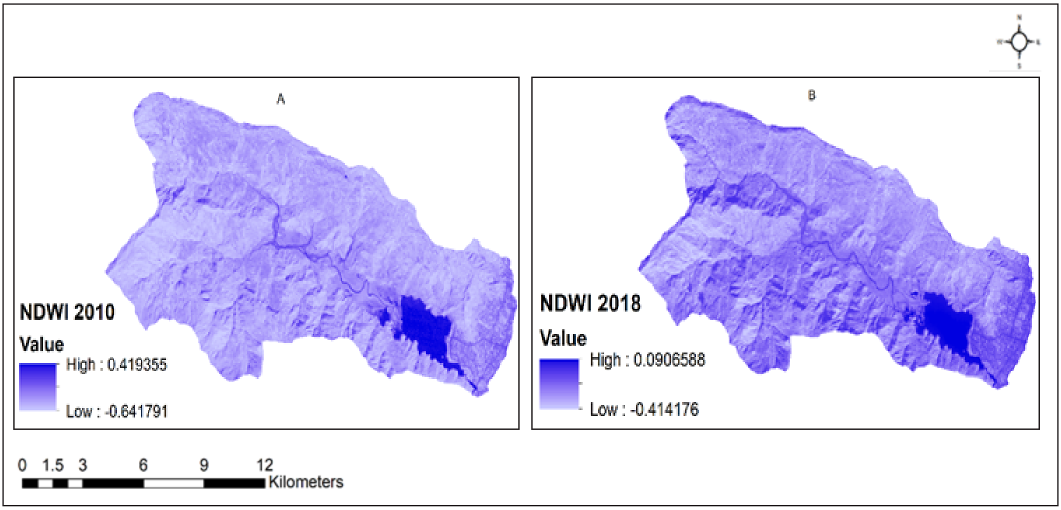

Figure 6: NDWI value range in (A) 2010 and (B) 2018

Drivers of LULC change and lake area change in Phewa watershed during 2010 to 2018

Increase in forest area

As per the opinion of respondents, the major drivers responsible for forest area increase were Community Forestry (CF) Program (18%), alternative form of energy (27%), promotion of private forestry (15%), awareness on importance of forest (11%), forest watchers/Heralu (13%), control burning (5%) and increase of forest in barren land (11%)(Figure 7).

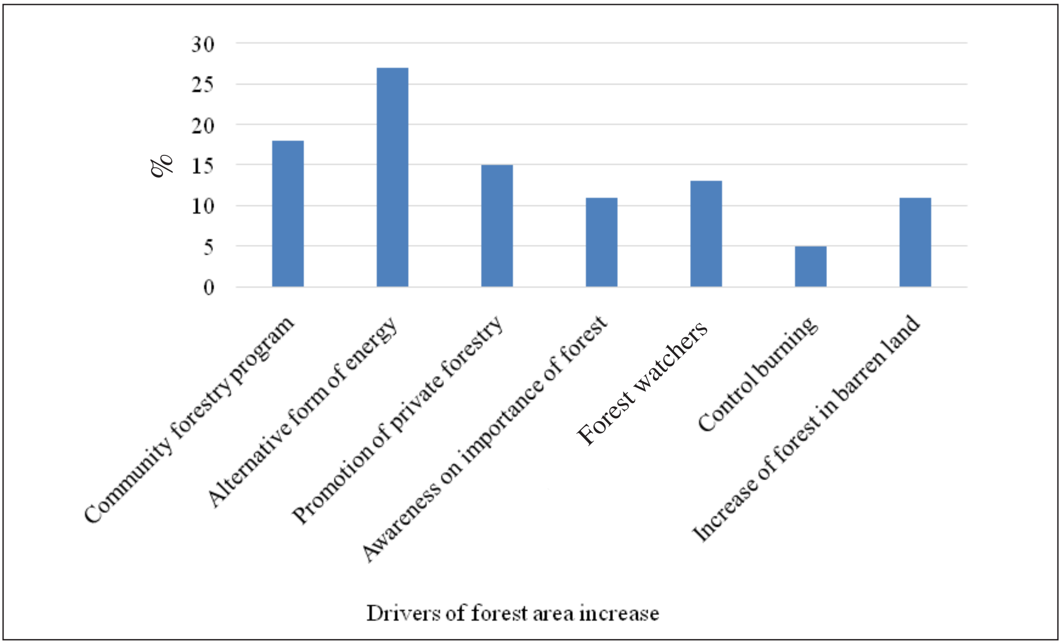

Figure 7: Respondents opinion on drivers of forest area increase

Increase in barren land

As per the view of respondents, the major drivers for barren area increase were lack of manpower (42%), road construction (13%), soil erosion / landslides (16%), lack of market price of agricultural products (20%) and lack of irrigation facilities (9%) (Figure 8).

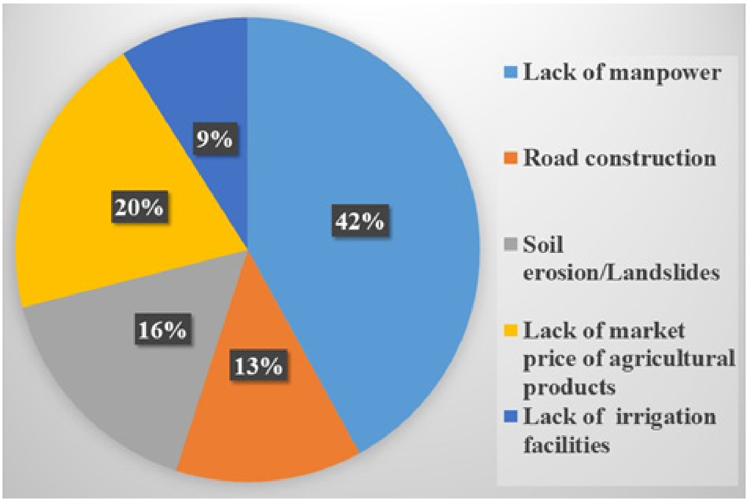

Figure 8: Respondents opinion on drivers of barren land increase

Increase in urban areas

As per the view of respondents, the major drivers for urban area increase were population pressure (69%) and migration to down stream areas (31%) (Figure 9).

Decrease in agricultural land

As per the view of respondents, the major drivers for decrease in agricultural land were soil erosion / landslides (9%), migration for foreign employment (33%), road construction (10%), lack of market price of agricultural products

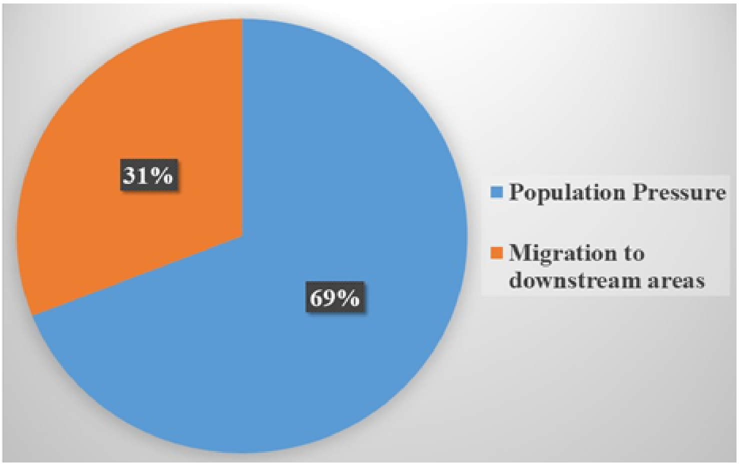

Figure 9: Respondents opinion on drivers of urban area increase

(15%), urbanization / infrastructures (11%), irrigation problem (8%) and excessive use of chemical fertilizers (14%) (Figure 10).

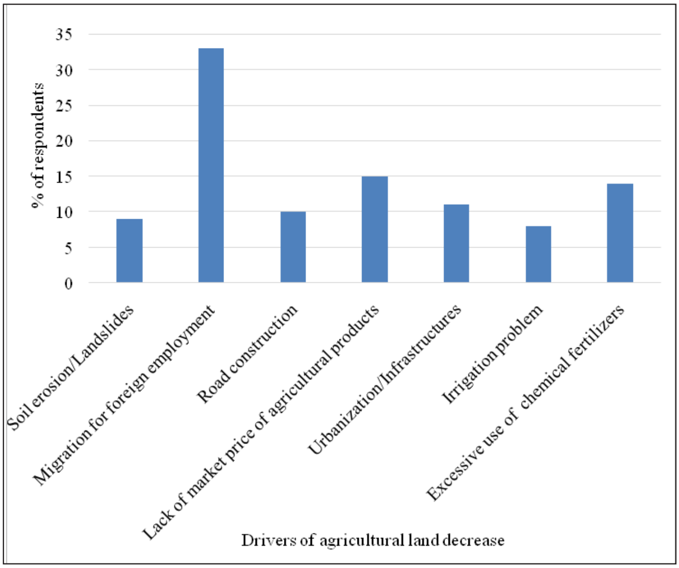

Figure 10 : Respondents opinion on drivers of agricultural land decrease

Decrease in lake area

As per the opinion of respondents, the major drivers responsible for decrease in lake area were sedimentation/soil erosion (45%), encroachment around the lake (24%) and road construction (31%)(Figure 11).

Discussion

Increase in forest area

Regmi and Saha (2015) have found that dense forests have decreased during the study periods 2000, 2005 and 2010 and the prediction of 2015 and 2020. They have also observed that medium to fairly dense forests and open forests have increased during these study periods and predicted periods. Our study also shows appreciable increase in forest

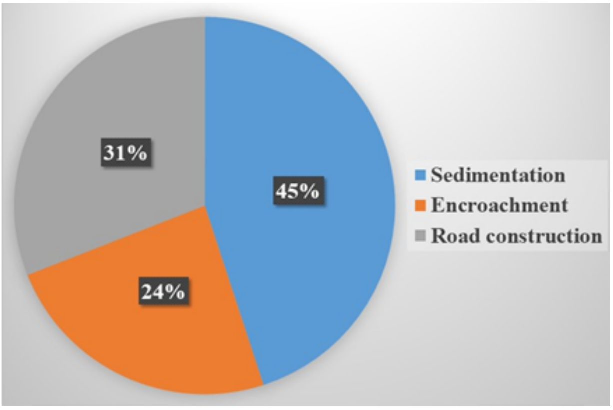

Figure 11: Respondents opinion on drivers of lake area decrease

area of 683.46 ha during 2010 to 2018. Also, more increasing trends in the area were observed under medium to fairly dense forests because of afforestation activities undertaken in large areas under community forest management program implemented in the watershed from mid-1990 as part of Nepal's national program. The agricultural lands can also be considered to have contributed in the increase of forest area in the study area (Annex 4). Local people's participation was noticed after emergence of community forestry in late 1970s and there was considerable increase in forest cover in degraded forest area as they were granted legal rights to utilize forest resources independently (Cronkleton *et al.*, 2017; Paudyal *et al.*, 2017a). There was transformation of eroded pasture, croplands and shrub lands to forestland which resulted in forest rehabilitation (Gautam *et al.*, 2004; Niraula *et al.*, 2013). There is overall increasing trend for uncultivated land, forest and waste land and declining shift of agricultural land in all sub-watersheds of the study area (Javed *et al.*, 2009).

Increase in urban areas

Bhandari (2012) and Khanal and Bastola (2005) have observed that LULC changes and socio-economic dynamics have positive relationship. Rising pressure for energy and food for increasing population results in negative effects on sectors like farmland, grazing land, fuel wood and urban areas. Increase in built-up area was attributed to spatial expansion of existing built-up lands and increasing number of new rural and urban settlements due to high population growth. During 2010-2015, the urbanization rate of Pokhara was 5.21% (UNDESA, 2014). Muzzini and Aparicio (2013) have revealed that fast urbanization can be seen in Pokhara, which was a huge town of mid hill. After declaration of municipality and headquarter of western development region, rapid urbanization can be marked in Pokhara Valley (Rimal, 2011). Regmi and Saha (2015) have explained that population of the Phewa watershed is 198,333 with an average density of 665 persons per km^2. These support our finding that urban areas have increased during our study.

Decrease in agricultural land

The decrease of agricultural land can be attributed to transformation of some portions of this land into forest, barren lands and development of new urban areas (Annex 4). The agricultural land decreased due to socio-political uncertainty, accessible off-farm earning in towns, declining agricultural productivity, lack of labor, dwindling earning from farming and geographical nearness to towns (Paudel *et al.*, 2012; Paudel *et al.*, 2014; Tamang *et al.*, 2014).

Decrease in lake area

Sedimentation has a major role in the decrease of lake area. Natural disaster like soil erosion and debris flows are common in Andheri Khola - a major source of sediment to Phewa Lake (GON, 2015). Harpan Khola, Seti Canal, Phirke Khola and Bulanudi deposit sediments in Phewa Lake whose accumulation rate is in increasing trend. Heyojoo and Takhachhe (2014) have explained that sediment deposition in the lake is induced by human activities like haphazard road construction and unsuitable land use practices in both upstream and downstream areas in the watershed. They have found that the annual decrease rate of the lake was 0.46% with mean annual decrease in lake area around 2 ha (less than 10 ha), while our study shows the annual decrease rate of the lake as 0.61% with the mean annual decrease in lake area as 2.59 ha (Figure 5). This slight variation can be due to low spatial resolution of Landsat imageries for on screen digitization, different study periods considered and also because many drivers of the decrease in Phewa Lake can be more intensive now than before. Shrestha *et al.* (2004) have found that extreme soil erosion is induced bythe factors like land slope, deforestation, uncontrolled grazing, livelihood support farming and population growth combined with high rainfall. All these drivers are controlling the soil erosion phenomenon in Phewa watershed of Nepal.

LULC is a very dynamic phenomenon and there is trade off between LULC classes. Resettlement and land abandonment, alteration in land tenure policy, rapid urban growth and population rise are the dominant factors of LULCC in the mid hills of Nepal (Bajracharya *et al.*, 2014; Paudel *et al.*, 2017; Rimal *et al.*, 2015). The conventional farmers who cannot fulfill the requirements of their households prefer to migrate from that area and gradually leave farming in their agricultural land. Gautam *et al.* (2003) studied Roshi watershed of Kavre district and found that the drivers responsible for LULCC were emergence of community forest and accessibility of off farm earning. Barros (2004) has observed that increase in population and urban areas, less availability of land, demand for additional production and modification of technologies are the drivers of LULC in the world in present situation.

Deforestation, uncontrolled grazing, commercial farming, population growth, over cultivation and rural development policies are the major factors for soil erosion in the middle mountain of Nepal (Shrestha, 1997; Tamrakar, 1993). Bygone and present farming activities, topography in the mountains and hills, severe rainfall and fast urban growth are the major drivers of destructive soil erosion in the Phewa watershed (Awasthi, 2004; Bhandari, 2012).

The reasons behind LULC dynamics were related to the lack of integrated LULC management policies and heterogeneity in the socio-economic conditions of the watershed. This was also revealed by many researchers in their studies (Awasthi, 2004; Khanal and Bastola, 2005; Poudel, 2000; Sharma, 2012). They have also observed that the lack of appropriate land use laws, policies and by laws is responsible for LULCC in Phewa watershed. Similarly, land tenure systems and government policies have also been considered as the main drivers of LULC dynamics in Phewa watershed.

Conclusion

The assessment of LULCC of Phewa watershed in western Nepal and its associated drivers was performed using geospatial tools and social survey techniques.The use of temporal satellite imageries is very useful, time saving and cost effective for the generation of LULC maps and change detection process.

There was a drastic change in LULC in Phewa watershed during the study periods. The obtained LULC maps summarized the highest coverage in the study area by agricultural land and forest followed by other three LULC classes in all study periods. Agricultural land and urban areas were found to have increased by 11.63% and 1.46% respectively while forest area, barren land and water bodies were found to have decreased by 9.21%, 3.56% and 0.5% respectively between 2003 and 2010. Forest area, urban areas and barren land had increased by 5.9%, 3.28% and 5.02% respectively while agricultural land and water bodies were observed to have decreased by 7.83% and 0.16% respectively between 2010 and 2018. The analysis of change process using Landsat imageries showed compromise among various LULC classes.

Phewa Lake is an important tourism asset with its economic, socio-cultural and ecological significance. During 2010-2018, the rate of change in lake area was found to have decreased by 0.61% with periodic annual decrement by 2.59 ha. In the western part of the lake, there is decrease in are are sulting in detachment of a part of lake from its main body. Phewa watershed consists of plenty natural resources but due to various drivers they are at severe risk. The drivers responsible for LULC change in Phewa watershed were alternative form of energy, community forestry, promotion of private forestry, migration for foreign employment, inadequate market price of agricultural products, road construction, soil erosion and population pressures. Lake area was found to have decreased due to sedimentation, encroachment and road construction. Various biophysical and socio-economic drivers were dominating LULC dynamics in the study area.

Thus, application of geospatial tools should be expanded for natural resource management and it's monitoring for up to date updates. Further study is important to know the exact contributions of these drivers of LULC change and lake area change for the sustainability of Phewa watershed.

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Conflict of Interest

The authors declare no conflict of interest.

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Annex 1: Area Statistics of LULC for 2003 and 2010

LULC classes	Area (ha) in 2003	Area (ha) in 2010	Change in LULC area (ha)	% change	Remarks
Agricultural land	5179.86	6573.78	1393.92	11.63	Increased
Forest	4963.05	3882.42	-1080.63	9.21	Decreased
Barren land	891.99	464.31	-427.68	3.56	Decreased
Urban areas	425.34	600.03	174.69	1.46	Increased
Water bodies	529.29	468.99	-60.3	0.5	Decreased

Annex 2: Area Statistics of LULC for 2010 and 2018

LULC classes	Area (ha) in 2010	Area (ha) in 2018	Change in LULC area(ha)	% change	Remarks
Agricultural land	6573.78	4914.72	-1659.06	7.83	Decreased
Forest	3882.42	4565.88	683.46	5.9	Increased
Barren land	464.31	1065.87	601.56	5.02	Increased
Urban areas	600.03	993.33	393.3	3.28	Increased
Water bodies	468.99	449.73	-19.26	0.16	Decreased

Annex 3: Change/no change matrix in percentage of 2003-2010

Years 2003/2010	Forest	Urban areas	Barren land	Water bodies	Agricultural land	Total area in 2003 %
Forest	28.76*	0.04	0.52	0.06	12.01	41.39
Urban areas	*****	2.96*	0.27	0.04	0.28	3.55
Barren land	0.01	0.8	1.12*	0.22	5.3	7.45
Water bodies	*****	0.01	0.06	3.53*	0.81	4.41
Agricultural land	3.62	1.2	1.9	0.06	36.43*	43.21
Total area in 2010 %	32.39	5.01	3.87	3.91	54.83	100%

NOTE: '' represents the no change in area of specific LULC used.*

Annex 4: Change/no change matrix in percentage of 2010-2018

Years 2010/2018	Forest	Urban areas	Barren land	Water bodies	Agricultural land	Total area in 2010 %
Forest	28.29*	0.03	0.27	*****	3.79	32.38
Urban areas	*****	4.51*	0.39	0.01	0.1	5.01
Barren land	0.05	0.7	1.84*	0.07	1.22	3.88
Water bodies	0.02	0.26	0.26	3.34*	0.03	3.91
Agricultural land	9.72	2.78	6.14	0.33	35.85*	54.82
Total area in 2018 %	38.08	8.28	8.9	3.75	40.99	100%

NOTE: '' represents the no change in area of specific LULC used.*