Geospatial Analysis of Land Use Land Cover Change Modeling in Phewa Lake Watershed of Nepal by Using GEOMOD Model

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Abstract : *Improper practices of land use/ land cover (LULC) are deteriorating watershed conditions. Remote sensing and GIS tools were used to study LULC dynamics using GEOMOD Model and predict the future LULC scenario for years 2015 and 2020, in terms of magnitude and direction, based on past trend in Phewa Lake watershed, Kaski district, Nepal. Due to the proximate and underlying causes, land use and land cover change has become the main challenge of the present world The analysis of LULC pattern during 1995, 2000, 2005 and 2010 using satellite-derived maps has shown that the biophysical and socio-economic drivers including slope, road network and settlements proximity have influenced the spatial pattern of the watershed LULC. These lead to an accretive linear growth of Medium to Fairly Dense Forest, Open Forest, Waste Land and Built-up Land but decrease in other LULC classes. Annual rates of increase from 1995 to 2010 in Medium to Fairly Dense Forest, Open Forest, Waste Land and Built-up land were 75.15, 32.7, 10.14 and 24.2 ha/year respectively, while the rates decrease in Dense Forest, Terrace Agriculture, Valley Agriculture and Bush/Scrub land were 42.58, 58.17, 27.46 and 2.48 ha/year respectively. The predicted LULC scenario for 2015 and 2020, with reasonably good accuracy would provide useful inputs to the LULC planners for effective management of the watershed. The study is a maiden attempt that revealed the expansion of Waste and Built-up Land, which is the main driving force for loss of Agriculture Land and Grass Land, and an increase in Medium to Fairly Dense Forest and Open Forest leading to decrease in Dense Forest and Bush/Scrub Land in the watershed.*

Keywords: GIS, Watershed, Biophysical drivers, Socio-economic drivers, Open Forest, Built-up land.

1. INTRODUCTION

Land use and land cover are the outcome of interaction between man and environment. Some of the land uses are directly related to cultures, and social and economic conditions of the people (Vink, 1975). Land use is the human use of land and land cover refers to physical and biological cover on the surface of land (Rimal 2011). The land use/ land cover (LULC) pattern of a region is an outcome of natural and socioeconomic factors and their utilization by man in time and space. Knowledge of land cover and land use change is important for many planning and management activities (Lillesand and Kirfer 1999). In the mountain geography, micro level accurate mapping on the surface of parameters, such as surface morphometry, land use, land cover resources and population parameters is often a big problem, but mandatory for watershed management (Poudel 2010). Factors driving LULC change include an increase in human population and population response to economic opportunities (Lambin et al., 2001). Despite the social and economic benefits of LULC change, this conversion of LULC usually has an unintended consequence on the natural environment. For example, LULC change has been shown to have negative effects on stream water quality (Zampella et al., 2007; Tang et al., 2005), quantity (White and Greer, 2006) and stream ecosystem health (Wang et al., 2000; Wang et al., 2001). Changing land use has also been shown to influence weather patterns (Stohlgren et al., 1998) and the generation of stream flow (Bronstert et al., 2002; Weng, 2001). Also, a number of studies have shown that change in agricultural land use has direct consequences on sedimentation, nutrients and pesticides in streams (Osborne and Wiley, 1988; Soranno et al., 1996). The capability of GIS to analyze temporal and spatial data helps in quantifying the land use changes (Awasthi et al., 2002). In Nepal, forestry and land use change alone contribute about 85% of national account of green house gases emission. These complexities necessitate a systematic approach to find out the proper utilization techniques and sustainable management plans (Gautam et al. 2003).This paper focuses on analysis of LULC change using remote sensing and GIS techniques in Phewa Lake watershed of Nepal. Accurate information on land cover change and the forces behind it is essential for designing a sound environmental planning and management. The present study attempts to analyze LULC change modelling for years 2015 and 2020 by applying and adopting satellite remote sensing and GIS techniques with the use of Geomod model at Phewa Lake Watershed of Nepal.

2. MATERIALS AND METHODS

2.1 Study area

Phewa Lake watershed extends between 28°11'39" North to 28°17'25" North latitude and 83°47'51" East to 83°59'17" East longitude (See Map 1). Its covers seven wards of Pokhara Sub-metropolitan city (2, 4, 5, 6, 7, 8, and 17) and a six Village

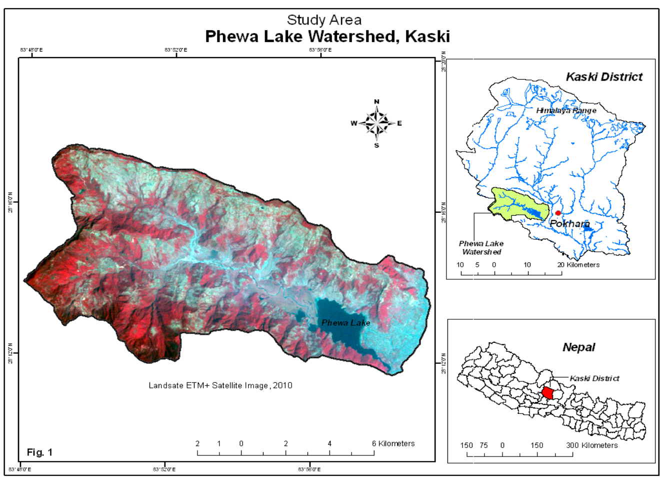

Fig.1: Location Map

Development Committees (Sarangkot, Kaskikot, Dhikurpokhari, Bhadaure-Tamagi, Chapakot and some part of Pumdi-Bhumdi) of the district. Most of the rural area of the watershed is sited on the hilly areas whereas the urban areas are sited on the valley floor of Pokhara. On the whole, study area covers 119.89 Km^2 with its geometrical east-west length of 18.32km and north-south width of 9.53 km. Phewa Lake itself covers about 4.52km^2 (452ha) areas with 23.30meter maximum depth and 11.71meter average depth and or 10.05 meter median depth respectively. The variation of altitude is from 789m to 2508m. in the west at Panchase, the highest summit of the watershed area.

2.2 Methods

2.2.1 *Satellite data*

The main data used in the study included temporal satellite data of Landsat TM / ETM+ of the years 1995, 2000, 2005 and 2010 (15 years with 5 years interval) for LULC mapping (Table 1). All the images were of the month of November. Sufficient GPS points are taken in the entire study area for LULC mapping, which are also used for accuracy assessment. Topographic maps of 1:25,000 scale and digital topographic data with contour interval of 20 m published by the Survey Department, His Majesty´s Government of Nepal (HMGN) were used as ancillary data. The Landsat satellite data provided by Global Land Cover Network (GLCN) was radiometrically and geometrically (orthorectification with UTM/WGS 84 projection) corrected.

Table:1

Year	Satellite	Resolution (m)	Path /row	Band combination	Date of Procurement
1995	Landsat, TM	30	142/040	1.2.3.4.5.6.7	20-Nov-95
2000	Landsat, TM	30	142/040	1.2.3.4.5.6.7	13-Nov-00
2005	Landsat, TM	30	142/040	1.2.3.4.5.6.7	8-Nov-05
2010	Landsat, TM	30	142/040	1.2.3.4.5.6.7	7-Nov-10

2.2.2 *LULC Mapping*

In the present study datasets were geo-referenced in UTM/ WGS 84 projection. The study area was extracted from the acquired satellite images using digital topographical maps of 1:25000 scale and field data from Subset tools in Erdas Imagine. A classification scheme was developed to obtain a broad level of classification to derive various LULC classes, such as Dense Forest, Medium to Fairly Dense Forest, Open Forest, Terrace Agriculture, Valley Agriculture, Bush/Scrub, Grass Land, and Waste land, Water Body, Wetland and Built-up Land. Forests were classified with FCD Mapper software and verified with ground truth for accuracy. The field visits were made to complete reconnaissance survey, ancillary data collection, LULC classification, and validation of sub-watershed area statistics and percentage LULC change. LULC classification was performed using supervised classification technique for years 1995, 2000, 2005 and 2010.

The accuracy for all four classified maps were assessed with the test samples generated from ground truth data against high resolution references. The overall test samples generated were 98 for each of the 1995, 2000, 2005 and 2010 classified maps. Eye bird satellite of high resolution 2010, Google Earth, ESRI online, digital topographic map and other layers were used as references due to lack of high resolution satellite data. The LULC Maps of all periods were imported in ARCGIS 9.3 in which five Sub-watersheds were delineated. The studied watershed was delineated into five sub-watershed considering topographical parameters derived contour lines and drainage system. Preparation of LULC map for four periods using temporal satellite data, identification and quantification of LULC changes was carried out. The spatial layers of ancillary database including different socioeconomic and biophysical drivers of LULC changes were prepared using data from topographic map and relevant information (CBS, 2011).

Land-Use and Cover Change modeling is growing rapidly in scientific field. There are many modeling tools in use but the performance of different modeling tools is difficult to compare because LULCC models can be fundamentally different in a variety of ways (Pontius, 2006). Among the numbers of land use modeling tools and techniques, the commonly used models are Morkov chain, the Cellular Automata Markov, GEOMOD etc. In this study GEOMOD Model was implemented to predict and compare the major land uses for some further period. This may require more advanced spatial techniques supported by the policy makers involving shifting of emphasis from basic geographic data handling into manipulation, analysis and modeling in order to solve the real problem (Ramachandran, 2010). Various attempts have been made to study land use land cover dynamics but only limited work describes the land use land cover change pattern and prediction for future LULC change scenario. The present paper attempts to analyze LULC change modelling for years 2015 and 2020 by applying and adopting satellite remote sensing and GIS techniques with the use of model GEOMOD at Phewa Lake Watershed of Nepal. . This task was accomplished by using IDRISI software package developed in Clark Labs, Worcester, and Mass.

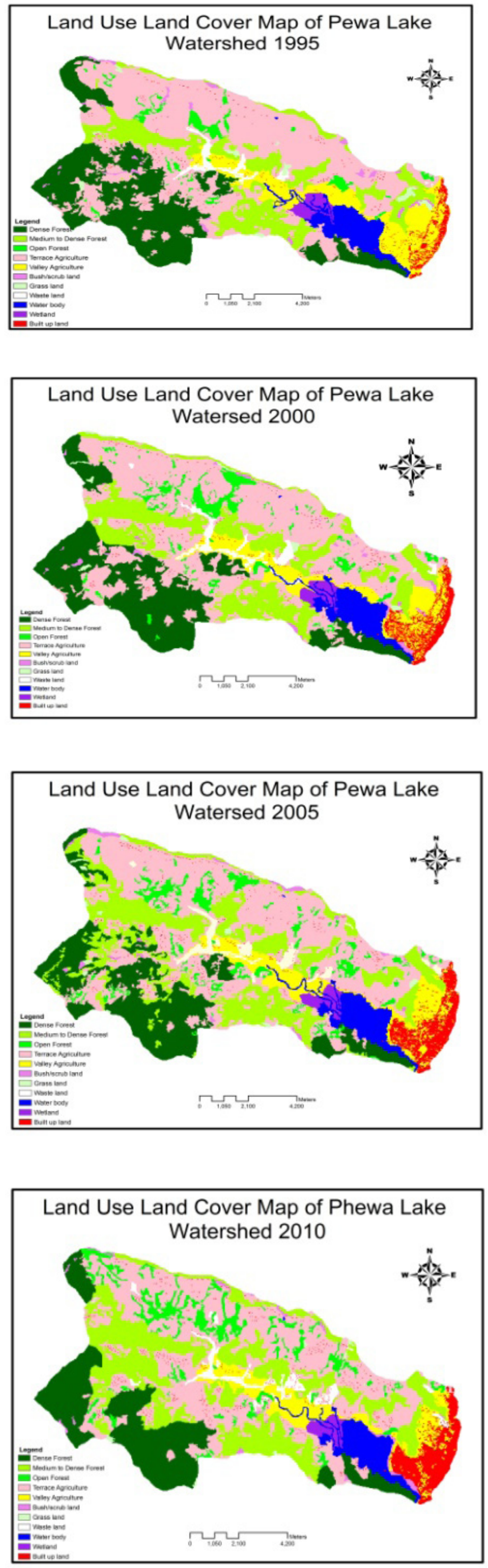

Figure 2: LULC Classifications for years 1995, 2000, 2005 and 2010

GEOMOD Model

GEOMOD is the model that has been used frequently to analyze baseline scenarios of deforestation for carbon offset projects, as called for by the international agreements on climate change, such as the Kyoto Protocol (Pontius and Chen, 2006). It is a grid-based land-use and land-cover change model, which simulates the spatial pattern of land change forwards or backwards in time. It simulates the change between exactly two land categories denoted as 1 and 2 for “non-developed” and “developed” respectively, but 1 and 2 could represent any two categories for any particular application. The user must supply a map of a beginning time and information concerning the number of grid cells of each category at an ending time, and then selects the location of the grid cells to classify as one of the two categories for the ending time. If there is a net increase in the developed category as the simulation proceeds from a beginning time to the ending time, then it will search among the non-developed grid cells in order to select the cells that are most likely to be converted to become developed during the time interval. Conversely, if there is a net increase in the non-developed category as the simulation proceeds from a beginning time to a ending time, then it will search among the developed grid cells in order to select the cells that are most likely to be converted to non-developed during the time interval (Eastman, 2009).It requires only one beginning land-use map for calibration, while some algorithms for other popular models require maps from four times for calibration (Silva and Clarke, 2002) The GEOMOD, however is a grid-based (Pontius and Chen, 2006) land use change modeler and simulates the change between two land uses category only. Therefore, it was best suited to simulate the built up and non-built up land classes. Therefore in this study GEOMOD modeling was employed for comparing dominant LULC classes (Dense Forest, Medium to Fairly Dense Forest, Open Forest, Terrace Agriculture, Valley Agriculture, Waste land, and Built-up Land) obtained by change detection process for the predicted LULC 2010, 2015 and 2020 (fig 8). GEOMOD was supplied with the beginning time map 2000 and ending 2005 for prediction of 2010 and similarly for 2015 and 2020. The result of area statistics of predicted LULC by GEOMOD are presented in table (6).

3 MODEL VALIDATION

After any model generates a simulated map, it is desirable to validate the accuracy of the prediction. Therefore, model validation is one of the important stages in the prediction regime of land uses. The VALIDATE module involves a comparative analysis of the simulated and real maps based on the Kappa Index. However, it is different from traditional Kappa statistics in that it breaks the validation into several components, each with special form of Kappa such as Kno, Klocation, Kstandard, etc. and the associated statistics (Pontius and Chen 2006 and Eastman 2006). The validation result of the projected LULC 2010 against real 2010 map is given below as Kappa measures (Table 2).

Table 2: Validation Result

LULC	GEOMOD Validation Result of Projected 2010			
	Kno	**Klocation**	**Kloc strata**	**Kstandard**
Dense Forest	0.9748	0.9791	0.9791	0.9712
Medium to Fairly Dense Forest	0.9125	0.9212	0.9212	0.9035
Open Forest	0.9414	0.9399	0.9399	0.9256
Terrace agriculture	0.8807	0.8985	0.8985	0.8756
Valley agriculture	0.9751	0.9709	0.9709	0.9685
Waste land	0.9895	0.9897	0.9897	0.9861
Built up land	0.9838	0.9862	0.9862	0.9791

4. RESULTS AND DISCUSSIONS

4.1 LULC dynamics

The LULC change dynamics of Phewa Lake watershed was studied over more than a decade from 1995 to 2010.The results of LULC distribution in 1995, 2000, 2005 and 2010 showed that Terrace Agriculture, Dense Forest and Medium to Fairly Dense Forest were the dominant LULC category (Table 3). Overall, Medium to Fairly Dense Forest, Open Forest, Waste Land and Built-up Land increased, whereas other land uses decreased significantly during all periods (Table 3).

Table3: LULC Distributions in 1995, 2000, 2005 and 2010

LULC Class	1995		2000		2005		2010	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Dense Forest	2667.42	22.25	2474.10	20.64	2126.34	17.73	2028.60	16.92
Medium to Fairly Dense Forest	1684.35	14.05	2114.82	17.64	2570.40	21.44	2811.69	23.45
Open Forest	296.19	2.47	523.08	4.36	620.46	5.18	786.78	6.56
Terrace Agriculture	4878.18	40.69	4604.58	38.41	4343.67	36.23	4005.63	33.41
Valley Agriculture	1151.01	9.60	830.25	6.92	765.45	6.38	739.08	6.16
Bush/Scrub	141.21	1.18	123.12	1.03	112.77	0.94	103.95	0.87
Grass Land	99.90	0.83	73.08	0.61	61.65	0.51	25.65	0.21
Waste Land	170.91	1.43	244.35	2.04	284.85	2.38	323.01	2.69
Water Body	560.07	4.67	511.92	4.27	496.62	4.14	485.19	4.05
Wetland	130.77	1.09	120.51	1.01	111.33	0.93	107.37	0.90
Built- up Land	209.52	1.75	369.72	3.08	495.63	4.13	572.58	4.78
Total	11989.53	100.00	11989.53	100.00	11989.53	100.00	11989.53	100.00

Overall classification accuracy for all the four time period maps was more than 85% (Table 4). Medium to Fairly Dense Forest, Open Forest, Waste Land and Built-up Land increased by 75.15, 32.7, 10.14 and 24.2 ha/year, respectively from 1995 to 2010, while Dense Forest, Terrace Agriculture, Valley Agriculture, Bush and Grass Land decreased by 58.17, 27.46, 2.48 and 4.95 ha/year, respectively (Table 5).

Table 4: Accuracy Assessments of Classified LULC Maps in 1995, 2000, 2005 and 2010

LULC classes	1995		2000		2005		2010	
	PA	UA	PA	UA	PA	UA	PA	UA
Dense Forest	88.67	88.89	88.64	88.78	88.67	88.89	88.89	88.89
Medium to Fairly Dense Forest	94.21	85.21	85.89	85.21	88.24	88.95	88.24	88.95
Open Forest	88.24	78.95	100.00	89.47	93.75	78.95	85.71	94.74
Terrace Agriculture	91.24	91.89	92.11	94.59	86.49	86.49	97.14	91.89
Valley Agriculture	85.92	85.00	85.82	100.00	100.00	100.00	100	87.50
Bush/Scrub	50.00	50.00	50.00	50.00	50.00	50.00	50	50.00
Grass -Land	50.00	50.00	50.00	50.00	50.00	50.00	50	50.00
Waste- Land	50.00	100.00	50.00	100.00	50.00	100.00	75	75.00
Water Body	100.00	100.00	100.00	100.00	100.00	100.00	100	100.00
Wetland	100.00	100.00	100.00	100.00	100.00	100.00	100	100.00
Built up- land	100.00	100.00	100.00	100.00	100.00	100.00	100	100.00
Year	1995		2000		2005		2010	
Overall Classification Accuracy (%)	84.69		85.71		87.76		90.82	
Overall Kappa Statistics	0.85		0.86		0.88		0.92	

Note: UA=User Accuracy, PA=Producer Accuracy

The changes in Open Forest, Valley Agriculture, Bush/Scrub, Water Body, Wetland and Built- up Land classes during 1995 to 2000 were very high when compared with the change between 2000 and 2005, and 2005 and 2010 while the change of Dense Forest and Medium to Fairly Dense Forest were very high in 2000 and 2005. Also the change of Terrace Agriculture was high in 2005 and 2010 (Table 5).

Table 5: Area Estimates of LULC Change

LULC Class	Change area in (ha) %				Annual rate of change (ha/year)
	1995-2000	2000-2005	2005-2010	1995-2010	
DF	-193.32 (-7.24)	-347.76 (-14.05)	-97.7 (4 -4.59)	-638.82 (-23.94)	-42.588
MF	430.47 (25.55)	455.58 (21.54)	241.29 (9.38)	1127.34 (66.93)	75.156
OF	226.89 (76.60)	97.38 (18.61)	166.32 (26.80)	490.59 (65.63)	32.706
TA	-273.6 (-5.60)	-260.91 (-5.66)	-338.04 (-7.78)	-872.55 (-17.86)	-58.17
VA	-320.76 (-27.86)	-64.8 -(7.80)	-26.37 (-3.44)	-411.93 (-35.78)	-27.462
BA	-18.09 (-12.81)	-10.35 (-8.40)	-8.82 (-7.82)	-37.26 (-26.38)	-2.484
GS	-26.82 (-26.84)	-11.43 (-15.64)	-36 (-58.39)	-74.25 (-24.32)	-4.95
WS	73.44 (42.96)	40.5 (16.57)	38.16 (13.39)	152.1 (48.99)	10.14
WB	-48.15 (-8.59)	-15.3 (-2.98)	-11.43 (-2.30)	-74.88 (-13.36)	-4.992
WE	-10.26 (-7.84)	-9.18 (-7.61)	-3.96 (-3.55)	-23.4 (-17.89)	-1.56
BU	160.2 (76.46)	125.91 (34.05)	76.95 (15.52)	363.06 (73.28)	24.204

(*Note: DF=Dense Forest, MF = Medium to Fairly Dense Forest, OF=Open Forest, TA=terrace Agriculture, VA= valley Agriculture BA=Bush/Scrub land, GS =Grass Land, WS=Waste Land, WB=Water Body, WE=wetland, BU=Built-up Land*).

4.2 LULC prediction and validation

The results of area distribution for predicted LULC 2015 and 2020 by Geomod showed that the major change was found in Dense Forest, Medium to Fairly Dense Forest, Open Forest, Terrace Agriculture, Valley Agriculture, Waste Land and Built-up Land. Dense Forest, Terrace Agriculture, Valley Agriculture, Bush and Grass Land decreased by 66.24 ha, 156.78 ha, 34.39 ha and 7.2 ha respectively, and Medium to Fairly Dense Forest, Open Forest, Waste Land and Built-up Land increased by 148.95 ha, 51.84 ha, 23.85 ha and 57.06 ha respectively from 2010 to 2015. Similar rates of changes are predicted from 2010 to 2020 (Table 6).

Table 6: Area statistics of predicted LULC

LULC Class	Area in (ha)		
	2010	2015	2020
Dense Forest	2028.6	1960.36	1890.88
Medium to Fairly Dense Forest	2811.69	2962.64	3106.19
Open Forest	786.78	840.62	891.92
Terrace Agriculture	4000.63	3843.85	3690.4
Valley Agriculture	737.08	712.69	691.36
Waste- Land	325.01	348.86	373.16
Built- up Land	575.58	632.64	689.34
Total	**11989.53**	**11989.53**	**11989.53**

The Real 2010 LULC map was used as the base map for estimating future LULC scenario for 2015 and 2020, which are shown in Figure 3.

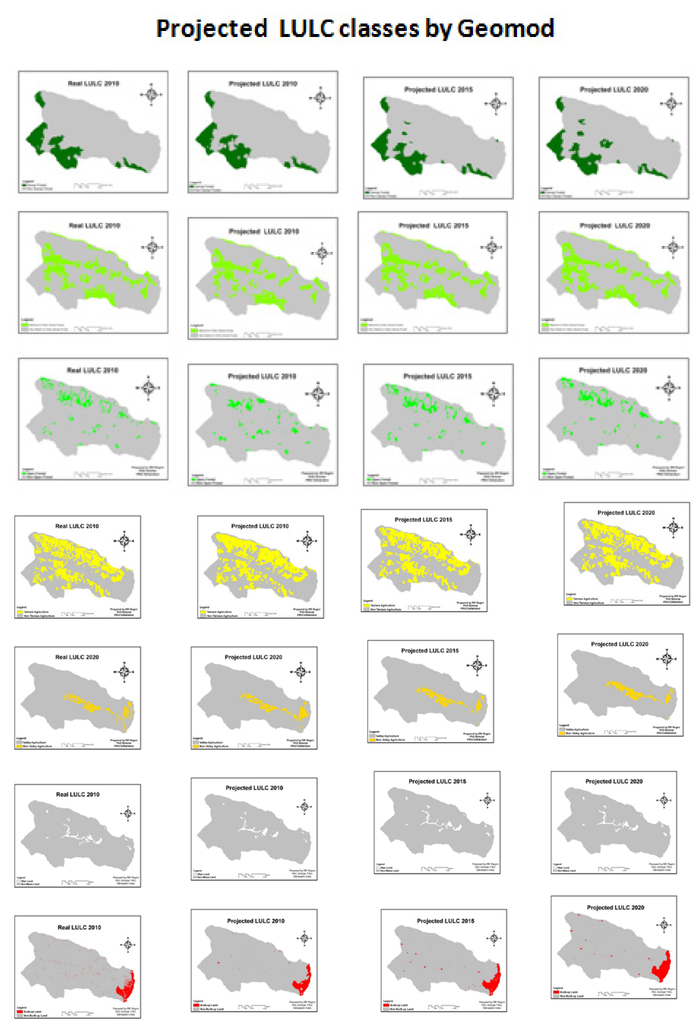

Figure 1 Predicted LULC Maps for 2010, 2015 and 2020

In assessing LULC classification accuracy (Table 4), it was observed that only Water Body, Wetland and Built-up Land provided the highest producer's accuracy (100%) and user's accuracy respectively. The forest and agriculture categories reached above 85% producer's accuracy and user's accuracy. The lowest producer's accuracy and user's accuracy below (75%) were produced by Waste Land, Bush/Scrub Land and Grass Land. It could be due to some overlap between Bush/Scrub and Grass Land. While in Waste Land lower accuracy was observed due to seasonal variations of Waste Land by river course, which results in over prediction of waste land in 2010.

In the prediction of future LULC scenarios, the expected area to change in transition area matrix was observed to be Dense Forest, Medium to Fairly Dense Forest, Open Forest, Terrace Agriculture and Built-up Land. It could be due to settlements expansion, construction of road trials, unscientific agriculture practices and involvement of both socio-economic and biophysical drivers. In multi-criteria decision-making process, different biophysical and socio-economic drivers, and their relative importance for change in watershed dynamics were considered. The present study investigated the human induced LULC patterns, land cover change and hydrologic change in LULC of watershed. It was observed that the expansion of Built-up Land and Waste Land (main driving force) for loss of Agriculture and an increase in Medium to Fairly Dense Forest and Open forest leading to decrease in Dense Forest in the watershed are likely to continue in future.

The prediction of LULC in watershed in 2015 and 2020 was based on change in driver's impact with time and trend of LULC change from 2000 to 2010 and the weight applied for different factors in LULC prediction for years between 2005- 2010 and 2000-2010. It was found that the integration of Markov model and Cellular Automata were effective in projecting future LULC scenario. It produced Kappa value of above 85% when compared to predict LULC map with the real LULC 2010.This is well above the acceptable limit of accuracy (Anderson et al. 1976). Hence, the projected LULC change based on the four time period 1995, 2000, 2005 and 2010 LULC changes (more than five years) and considering the impact of biophysical and socio-economic drivers in watershed showed the potential of modeling exercise for LULC change in the watershed.

5. CONCLUSION

The present study demonstrated utilization of remote sensing and GIS tools to analyze and model the LULC dynamics in Phewa Lake watershed using GEOMOD and predicted the future LULC scenario in 2015 and 2020 with reasonably good accuracy. Future LULC change scenarios were addressed based on the past more than a decade old LULC change trends considering biophysical and socio-economic drivers. Long term land use change analysis from 1995 to 2010 showed that major land use such as Medium to Fairly Dense Forest, Open Forest, Waste Land and Built-up area were in increasing order and other land uses such as Dense Forest, Terrace Agriculture, etc. were in decreasing order for all periods. The integration of the topographic and remotely sensed data within a GIS environment provided an effective means of assessing LULC change modeling within the watershed. This study has demonstrated some guidelines to foresee and examine possible future LULC growth in the watershed with different suitability rankings in multi-criteria decision-making in relation to different environmental, economic, planning and land development settings with effective use of the GEOMOD. It would be helpful for planning and management of watershed resources also for restoring water availability, and improving ecological condition of watershed by the identification of areas suitable for water and soil conservation structures to restore the watershed dynamics. The LULC management prescriptions for the Phewa Lake watershed can include construction of small water and soil conservation structures, such as check dams, percolation ponds, etc.; participation of rural people and stakeholders to prevent further land degradation, and to reduce soil erosion; and improvement in agriculture production following better agricultural practices

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