Spatiotemporal dynamics of land use pattern response to urbanization in Biratnagar Sub-Metropolitan City, Nepal.

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Abstract -- In Nepal, speedy urbanization took place in the last two decades due to population growth. The dynamics of urban landscape systems of Nepalese cities is driven by complex political, social and economic systems. This study examines the spatiotemporal pattern of urbanization in Biratnagar Sub-Metropolitan city of Nepal using remote sensing and GIS. Biratnagar, the second largest city and gateway of Nepal-India border in the eastern part of Nepal, has been rapidly getting urbanized since the 1990s. In the analysis four pairs of cloud-free Landsat images (1976, 1990, 1999 and 2009) have been used. Supervised image classification system has been applied to classify the images to different land use categories. Four land use classes are identified: Urban (Built-up), water body, forest cover and cultivated land. The quantitative evidences presented here showed that there were drastic changes in the temporal and spatial dynamics of land use/land cover. Urban and industrial areas are very much enlarged and cultivated and forest areas considerably decreased during the study periods: 1976 to 2009. The central part of the city has dense settlement area and cultivated land has occupied the southern and western part of the city. The total amount of urban land has increased from 5.03%, 12.68%, 25.71% and 39.16% during the examined time periods 1976, 1990, 1999 and 2009.In the mean time cultivated land decreased from 84.84% to 55.75% .

Keywords: Land use change, urbanization, spatiotemporal pattern, remote sensing,

1. INTRODUCTION

Urbanization is a process of increase of modernization system which modifies the socioeconomic activities and revolutionizes the land use practice according to time frame [1]. By the middle of 2009, the number of people living in urban areas, more than 50% (3.42 billion) had surpassed the number living in rural areas (3.41 billion) and since then the world has become more urban than rural. Northern America, Latin America and the Caribbean, Europe and Oceania are highly urbanized. According to the report 70.2 percent people are living in urban in Oceania, 81.9 percent in Northern America, 79.3 percent in Latin America and the Caribbean, 72.5 in Europe, 41.7 in Asia and 39.6 in Africa respectively [2]. Nepal is predominantly a land of villages and one of the least urbanized countries in the world. **.** Central Bureau of Statistics has released the preliminary result of the national population census 2011 on September**,** according to the statistical report of central bureau of statistic, the urban population of Nepal increased from 2.9 percent in 1952/1954 to 17 percent in 2011. The number of urban centers in Nepal grew from 10 to 95 between the years 1952/54 and 2011. Only 61 among the 75 districts of the country had municipal areas in 2011, while the urban population increased from 0.2 million to 4.5 million (this increased urban population refers only in terms of the previously declared 58 municipalities), that is an increase by a factor of 19 times in the same period [3]. Continuous migration from rural areas to urban areas largely contributed to rapid urbanization of Nepal.

Urban growth, particularly the movement of residential and commercial land use to rural areas at the periphery of metropolitan areas, has long been considered a sign of regional economic vitality [4], [5], [6]. The broader concept of urban development implies changes, growth or decline. The term includes the physical, socio-economic and environmental dimensions. Physically and functionally, urban development includes both new development and urban redevelopment [7]. Persistent dynamic land use change processes are expected to accelerate in the next several decades. Worsening conditions of crowding, housing shortages, insufficient infrastructure, and increasing urban climatologically and ecological problems require consistent monitoring of urban [8], [9].

Remotely sensed data become much more useful when they are integrated into decision support system with GIS. Spatial data from GIS will provide significant benefit for remote sensing image processing by proposing map-guided stratification, enhancing accuracy and efficiency of auto-classification, and conducting post-classifier sorting [10]. Urban growth remains a major topic concerning GIS and remote sensing applications. Remote sensing and GIS have proved to be effective means for extracting and processing varied resolutions of spatial information for monitoring urban growth [11], [12]. Dating back to the 1960s, remote sensing can also provide consistent historical time series data. Because of the lack of temporal and spatially consistent datasets in other forms for the valley, multi-temporal satellite images with high resolution (CORONA, SPIN, and IKONOS) to moderate resolution (LANDSAT MSS and TM) were processed to identify the temporal changes in landscape patterns since

the 1960s (Thapa and Murayama,2009) [9]. Effective analysis and monitoring of land cover changes require a substantial amount of data about the Earth‘s surface. This is most widely achieved by using remote sensing tools. Remote sensing provides an excellent source of data, from which updated land use/land cover (LULC) information and changes can be extracted, analyzed, and simulated efficiently. LULC mapping, derived from remotely sensed data, has long been an area of focus for various researchers [13], [14]. Many remote sensing change detection methods have been developed to monitor land cover change and to build spatiotemporal patterns of change, in order to derive better understanding of causes and consequences of the change, and to model the tendency of the change. In general, remote sensing change detection methods can be divided into two broad classes, termed as bi-temporal change detection and temporal trajectory [15], [16].

The increasing population pressure caused the spatial pattern of urbanization to be highly dynamic. Urbanization is the social process whereby cities grow and societies become more urban. Modeling of urbanization requires spatially explicit factors. There are many factors which influence the urbanization like population growth, good prospects for livelihood, good availability of facilities etc. Land use change is influenced directly by infrastructural development, where all types of human facilities are concentrated and people develop their all qualities and spend luxuries life. The day by day development of infrastructural facilities, natural land cover gets converted into the urban area which promotes the urbanization process.

However, due to un-controlled urbanization, it is common to come across industrial sides within the urban areas. Industrial sites are distributed irregularly at the urban area. Industrial and residential growths occurred in areas close to the main roads. Deforestation, decline of the cultivated land and rapid population growth are the main causes of the urban development in city. Thus, research on this subject is important in order to understand patterns of LULC change as well as their social and environmental implications at different spatial and temporal scales. The main objective of this article is to examine the spatiotemporal pattern of urbanization in the Biratnagar city using remote sensing and GIS.

2. MATERIAL AND METHODS

A. Study Area

Biratnagar was established as town in the year 1914 AD when the headquarter of Morang district was transferred from Rangeli to Biratnagar. Biratnagar, which lies in south eastern part of Nepal in Morang district of Koshi zone, is a historical town of Nepal, made town municipality in 1953 and it Sub-Metropolitan City in 1995 with 22 administrative wards. This city is located between 26° 24’30’’ to 26° 30’ 00’’ north latitude to 87° 15’ 00’’ to 87° 18’ 55” eastern longitude (Figure 1). The study area covers 58.46 Km².Being the industrial area of Nepal and second largest city after the Kathmandu and the get way of Nepal India border in the eastern part of Nepal it has attracted a large population from the surrounding areas. Biratnagar has been rapidly getting urbanized since the 1990s. It accounts for the highest growth rate of population among the designated towns in the country. Biratnagar Sub-Metropolis is selected as the study area because of its rapid process of urbanization and fast changing land uses of terai *(plain)* region.

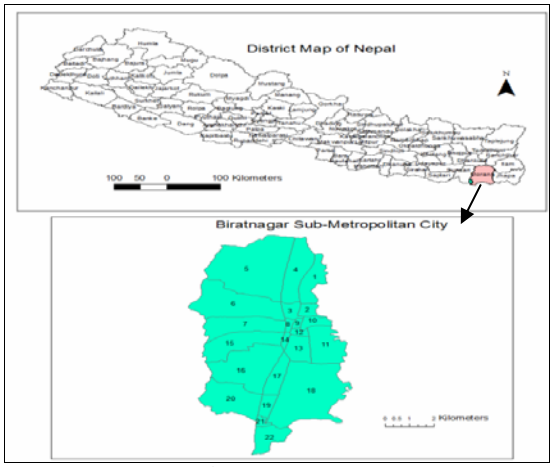

Figure 1. Location map of study area

B. Data sets

This study includes both field survey and map studies and computer based analysis. In primary session, fieldwork was conducted to acquire first hand data required for the research. Most of the essential data for improving mapping accuracies of spatial changes were collected through the fieldwork. Landscape observations, meetings with experts, and structured interviews were conducted in the sub- Metropolitan area. For this study, land use/land cover maps and topographical maps of the study area were necessary. Possible latest topographic maps of the region were acquired. The maps collection from 1978, 1992 and 2001 were selected for change analysis based upon their perceived accuracy and their similarity in general mapping parameters. First, 1976 data are obtained from land use maps the scale of 1:50,000 compiled from ground-verified aerial photographs (1:50,000) by the Land Resources Mapping Project (LRMP), a collaboration between His Majesty‘s Government of Nepal (HMGN) and an external consultant (Kenting Earth Sciences Ltd, Ontario, Canada). Topographical map the scale of 1: 25,000 has been used for the analysis of images was published by Survey Department, government of Nepal on the dated 1997. The map is based on the aerial photograph at the scale of 1:50000 taken in 1992.

Four pairs of cloud-free Landsat images have been used to classify the study area. All images have been collected from the University of Maryland, Global Land Cover

Facility,USAwebsite http://glcf.umiacs.umd.edu/index.shtml, and USGS Global Visualization Viewer: http://www.glovis.usgs.gov, which are mentioned in table 1. All data used in this study were rectified in the Universal Transverse Mercator projection system that is UTM World Geodetic System 1984.

TABLE I. Landsat Satellite Images

Images	**MSS**	**TM**	**ETM+**	**TM**
Dates	1976-11-13	1990-11-21	1999-10-28	2009 /09/29
Path/Row	150/42	139/42	140/42	140/42

The IDRISI GIS Taiga version has been used for the analysis of image. According to the land use classification scheme unsupervised and supervised approach with the maximum likelihood parameter (MLP) system was applied to improve the accuracy of the land use classification for the images for all four dates (1976, 1990, 1999and 2009). The flowchart for the process of study methodology is provided in Figure 2.

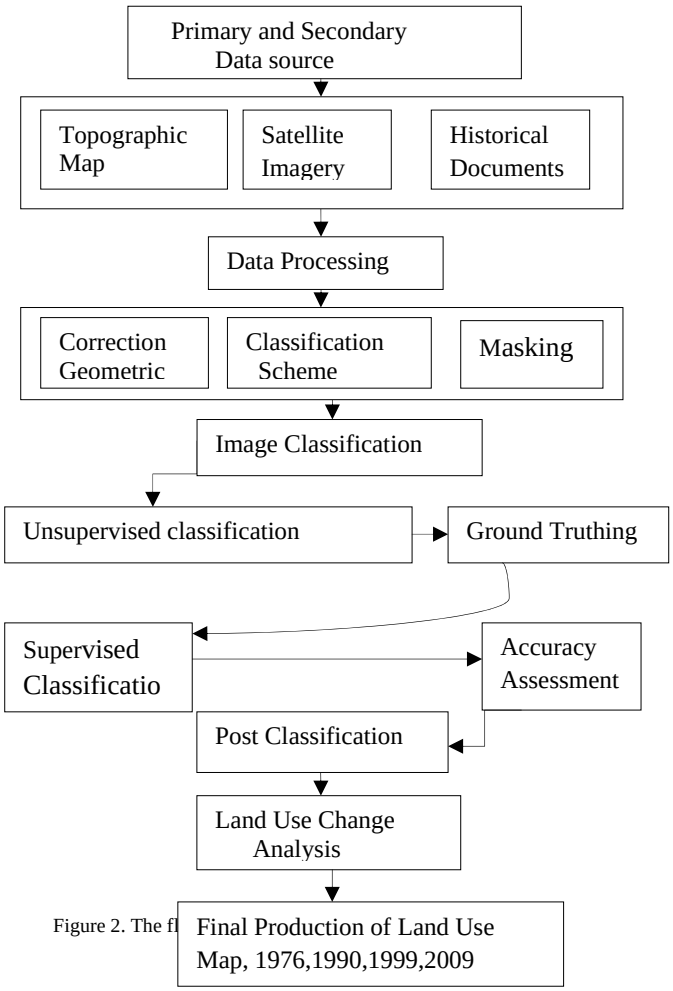

Figure 2. The fl

A proper classification scheme includes classes which are both important to the study and discernible from the data on hand [17]. The classification system utilized in this study is a slightly modified classification system for remotely sensed data as recommended by Anderson et al. 1976. For simplicity, four types of land use classes : Urban/Built-up, Forest, Water body, Cultivated land were selected for the study. Classification accuracy assessment is a general term for comparing the classification of geographical data that are assumed to be true to determine the accuracy of the classification process. A total 100 stratified random sampling point were created for the accuracy of classification. The supervised classification accuracies of 90%, 91%%, 91%, and 90% were achieved for the years, 1976, 1990, 1999 and 2009 respectively.

3. RESULT AND DISCUSSION

A. Population Growth and Distribution in Biratnagar

According to population census 1952/54 the total population of Biratnagar Sub Metropolitan was 8060. At present the total population of Biratnagar is 1, 80138 with 94075 male and 86063 female (city profile 2007). According to table II, the annual population growth rate is increasing per year by 33.86% which is considered as the high growth rate. In 1961 and 2.88 in 2001 and 1.29 in 2007.In the last five decades or so the population Biratnagar has increased from 8060 to 180138, that is an increase by a factor of 22.34 times. Biratnagar Sub Metropolitan city is the significant city of Nepal where the all types of development infrastructures such as large to small types of industries, education, health, electricity, financial institutions (Bank and other finance company), transportation, tourism activities, communication, trade and commercial activities, various national and international organizations and other various government services are accessible. Due to the above mentioned facilities, the population of this sub- metropolitan area has been accelerating rapidly in the recent years.

TABLE II. Growth Rate Of Urban Population In Biratnagar 1952/54 -2007

	Urban population of Biratnagar		**Total Urban Population of Nepal**		
Year	Population	Population Growth Rate in %	Urban Population	Percent of Urban Population	Urban Places
1952/54	8060	-	238275	2.9	10
1961	35355	33.86	336222	3.6	16
1971	45100	2.75	461938	4.0	16
1981	93544	10.74	956721	6.4	23
1991	129388	3.83	1695719	9.2	33
2001	166674	2.88	3227879	13.9	58
2007	180138	1.29	4525787 (census, 2011)	17	95

Census of 1952/54 covered two Nepali years, approximately mid April 1952, to mid April 1954. Sources: Sharma, 2003, City Profile of Biratnagar, 2007, CBS,2011.

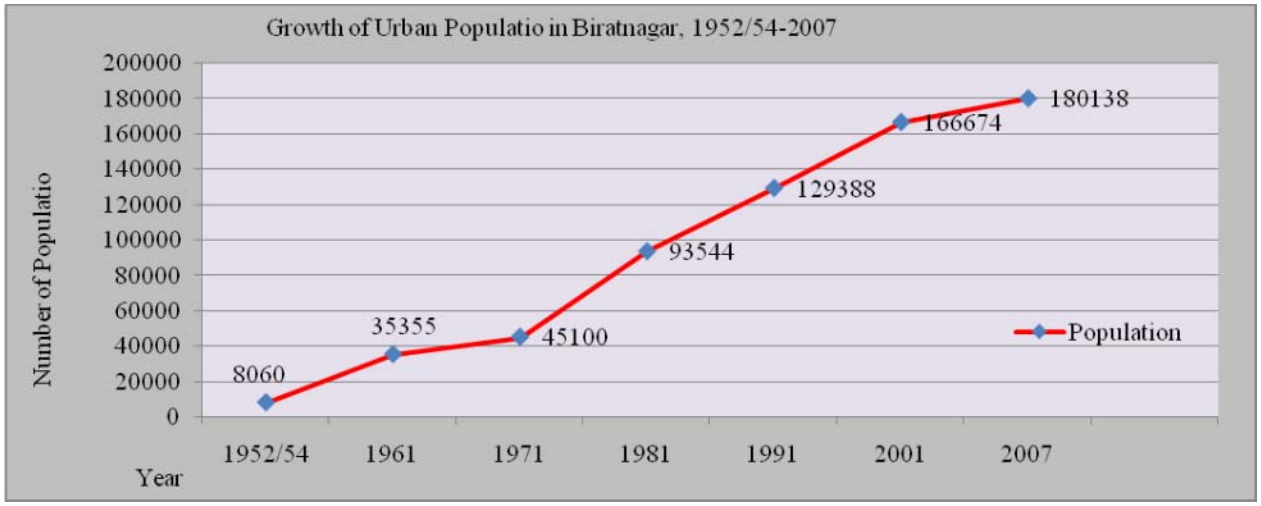

Figure 3. Growth of urban population in Biratangar 1952/54-2007

B. Land Use Change in Biratnagar 1976-2009

Land use statistics and transition matrixes are important information to analyze the changes of land use. The change analysis presented based on the statistics extracted from the four land-use/land-cover maps for the year 1976, 1990, 1999 and 2009. According to the land use statistic Table III, four types of land use covered areas can be observed which were defined by the help of landsat satellite image and topographical map. Urban and industrial areas greatly have increased and cultivated and forest areas significantly have decreased during 1976 to 2009. The central part of the city has dense settlement area and cultivated land has covered the southern and western part of the city. However, due to uncontrolled urbanization, it is common to come across industrial sides within the urban areas. Industrial sites are distributed irregularly at the urban area. Industrial and residential growths occurred in urban areas close to the main roads. As a result, the total amount of urban land has increased from 2.94 km² (5.03%), 7.41 km² (12.68%) 15.03 km² (25.71%) and 22.89 km² (39.16%) during the examined time periods 1976, 1990, 1999 and 2009. Deforestation, decline of the cultivated land and rapid population growth are the main causes of the urban development. In the mean time, forest area seems 2.74 km² (4.69%) in 1976 but it decreased in 1990 and reached to 0.53 km² (0.91%), but this area has improved to 1.25 km² (2.14%) in the year 1999 and decreased in 2009. Water body in Biratnagar covered 3.18 km² (5.44%) in 1976 but it decreased to 1.98 km² (3.38%), 1.72 km² (2.94%), 2.35 km² (4.01%) in 1990 and 1999 and 2009 respectively. We can observe in map central part of the city crossed by canal .The statistic provides that the cultivated land got transformed into other land. More than half of the agricultural land still covers in city, but its area has been fluctuating in different time intervals. The agricultural land decreased slightly from 1976 to 1990, but it decreased rapidly to 40.46 km²

(69.20%) by 1999, and to 32.59 km² (55.75%) in 2009. We can observe the land use/land cover changed in between 1976 to 2009 in figures 5 to 8.

TABLE III. Land Use Statistic of Biratnagar 1976-2009

Years	**1976**		**1990**		**1999**		**2009**	
Land use type	Km²	%	Km²	%	Km²	%	Km²	%
Urban/ Built up	2.94	5.03	7.41	12.68	15.03	25.71	22.89	39.16
Forest Cover	2.74	4.69	0.53	0.91	1.25	2.14	0.63	1.08
Water Body	3.18	5.44	1.98	3.38	1.72	2.94	2.35	4.01
Cultivated Land	49.60	84.84	48.54	83.03	40.46	69.20	32.59	55.75
Total	58.46	100	58.46	100	58.46	100	58.46	100

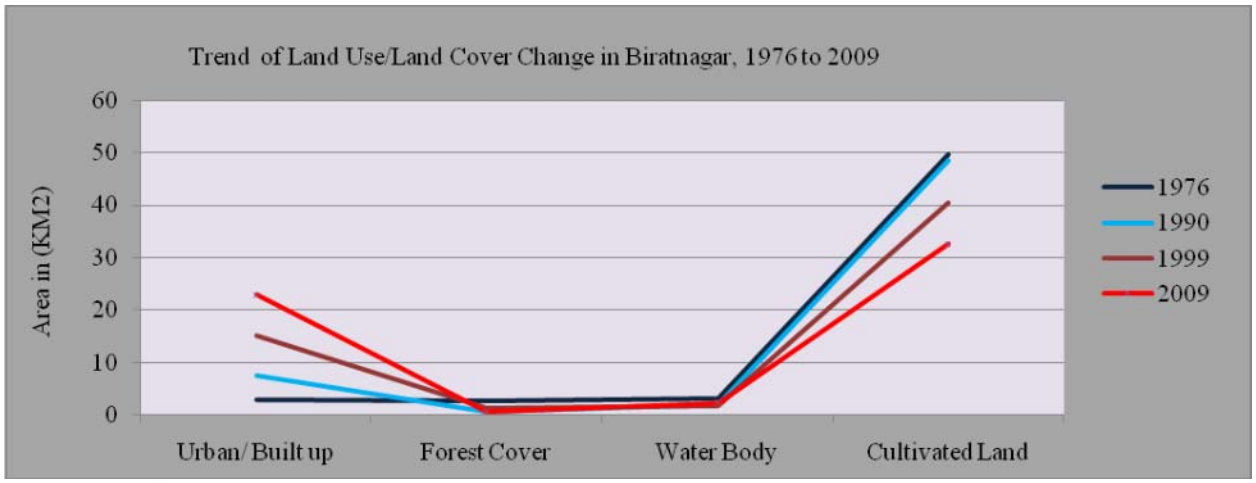

Figure 4. Trend of land use change in Biratnagar 1976-2009

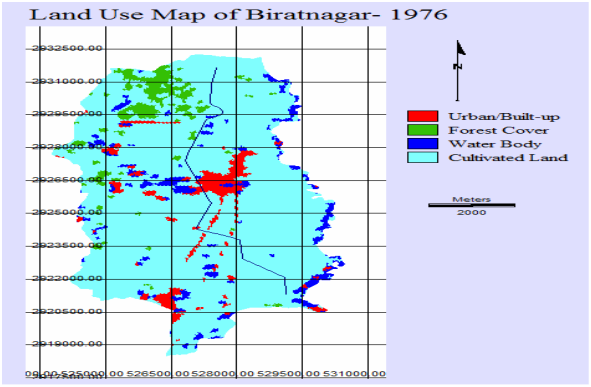

Figure 5. Land use map of Biratnagar – 1976

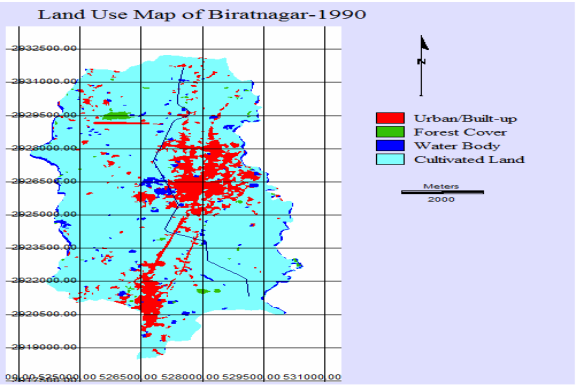

Figure 6. Land use map of Biratnagar - 1990

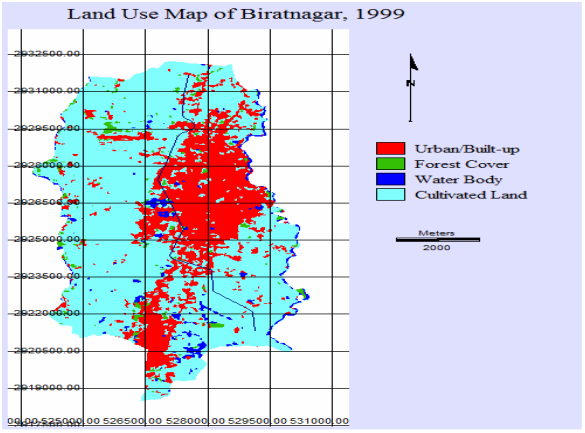

Figure 7. Land use map of Biratnagar, 1999

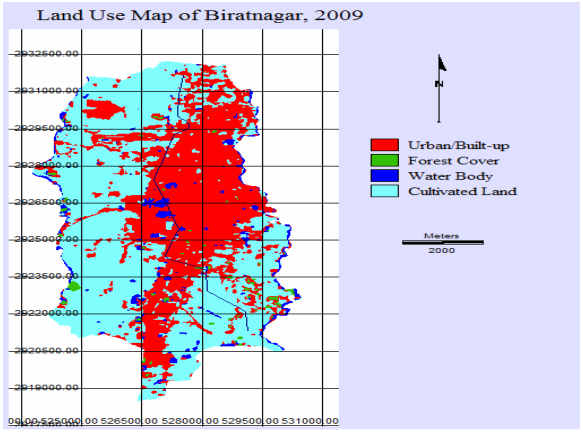

Figure 8. Land use map of Biratnagar - 1976

1) Land Use Change in 1976 to 1990

Mentioned land use and land cover transition Table IV and figures 9 of Biratnagar 1976 to 1990, notes that 1.51 km² area remained in urban land in 1976 but and 1.26 km² area transformed into cultivated land. The analysis pointed that in 1990, cultivated land had decreased in minor ratio. In the same period, 2.45 km² forest area has been converted into cultivated land. Likewise, 0.40 km² water covered area has been transformed into urban, 0.02Km² in forest, 2.33 km² into cultivation in the period of 1976 to 1990. So it is a highest ratio of change from one to another land use classes from 1976 to 1990.

TABLE IV. Land Use Transition in Km² (1976-1990)

Year	**1990 Km²**					**Total**
1976 Km²		Urban	Forest	Water	Cultivated	
	Urban	1.51	0.01	0.16	1.26	2.94
	Forest	0.07	0.18	0.04	2.45	2.74
	Water	0.40	0.02	0.44	2.33	3.19
	Cultivated	5.43	0.32	1.34	42.50	49.50
Total		7.41	0.53	1.98	48.54	58.46

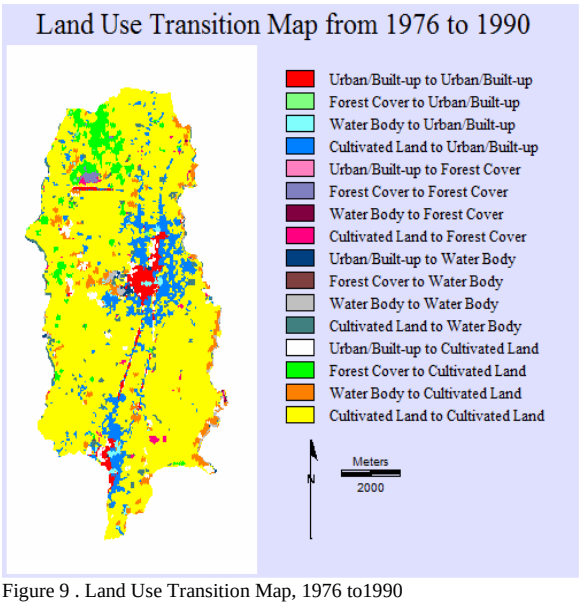

Figure 9 . Land Use Transition Map, 1976 to1990

2) Land Use Change 1990-1999

Mentioned transition Table V and figures 10 of the study area 1990-1999 describes that the transition and overlay of urban in between 1990 to 1999. In total 6.33 km² area has remained in urban and 0.03 km², 0.05 km² and 1.00 km² urban area has been altered respectively in forest, water and cultivated land. Forest and water cover area have been decline and changed into other land use area in significant ratio than previous decade 1976 to 1990. Although cultivated land turn down and 8.30 km² has been converted into urban, 0.95 km² in forest and 0.83 km² in water body by 1990-1999, most of the agricultural lands in the municipal areas were transformed into urban/built-up lands, whereas water and forest lands were converted into agricultural lands elsewhere in the rural periphery.

TABLE V. Land Use Transition in Km², (1990-1999)

Year	1999 Km²					Total
1990 Km²		Urban	Forest	Water	Cultivated	
	Urban	6.33	0.03	0.05	1.00	7.41
	Forest	0.05	0.18	0.02	0.29	0.53
	Water	0.35	0.10	0.83	0.71	1.98
	Cultivated	8.30	0.95	0.83	38.46	48.54
Total		15.03	1.26	1.72	44.46	58.46

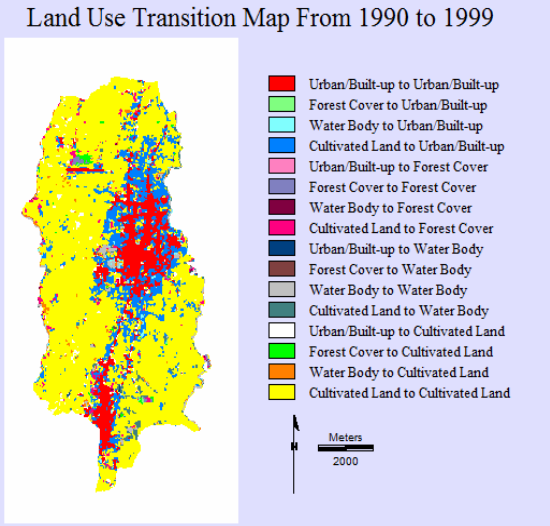

Figure 10. Land Use Transition Map, 1990 to1999

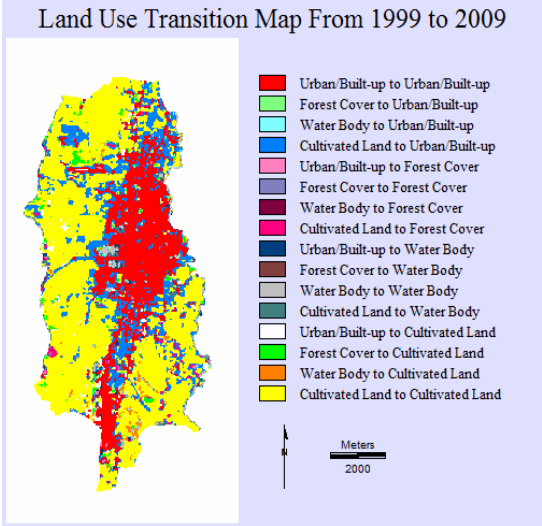

Figure 11 . Land Use Transition Map, 1999 to 2009

Year	**2009 km²**					**Total**
		Urban	Forest	Water	Cultivated	
	Urban	13.27	0.16	0.37	1.22	15.02
	Forest	0.28	0.04	0.11	0.83	1.26
	Water	0.24	0.02	0.91	0.54	1.71
	Cultivated	9.10	0.41	0.96	30.00	40.46
Total		22.89	0.63	2.35	32.59	58.46

3). Land Use/Land Cover Change, 1999-2009

From the cross Table VI and figure 11 the transition of land use statistics in between 1999 to 2009 is described. From the classified image, we can find that, 13.27 km² urban area has been remaining in urban and 0.16 km² area altered in water body, 0.37 km² in forest cover and 1.22 km² area transformed in cultivated land. In 2009, urban area reached to 22.89 km², which had been added from other land use classes. Likewise, forest coverage area has been declined and 0.28 km², 0.11 km² and 0.83 km² area has been transformed in urban, water and cultivated land. Similarly, water area had converted into in urban, forest and cultivated in the mean time. Remarkable cultivated land decreased in this period, 9.10 km² cultivated land alone has been altered in urban area.

TABLE VI. Land Use Transition in Km² (1999- 2009)

4. CONCLUSION

Due to the proximate and underlying causes the land use land cover change is the main challenges of present world. The huge course of urbanization, the major cities of the world are facing the challenging of problem. An unplanned urbanization process becoming the major problem in the develop and development countries. Various causes of the urbanization process brings the unrestrained impact on land use and land cover change. The attraction of people towards the urban area is high and the ratio of land use and land cover change is increasing every day. Urbanization is based mainly in the social development with the specification and characteristics in the specific subject matters such as physical infrastructure development, economic and commercial development. In this study, I have investigated the spatiotemporal patterns of urbanization in the Biratnagar using remote sensing and GIS. This work has exposed that satellite remote sensing provides correct and appropriate geospatial information describing change in land use land cover of urban area. The Urban and industrial areas very much enlarged and cultivated and forest areas considerably decreased during the study periods in 1976 to 2009. The central part of the city has dense settlement area and cultivated lands were at the southern and western part of city. In 1976 the total 5.03% area covered by urban but it seems 39.16% in 2009. This area has been covered 12.68% in 1990 and 25.71 % in 1999. In the mean time cultivated land decreased from 84.84% to 55.75% (1976-2009).

The changing inter-relationship between urban development and land use change in Nepalese cities remains less explored partly because of the lack of systematic data at a fine scale and partly because of the complex nature of the subject matter. It is the high time that the concerned authorities should alert their eyes and ears. The government especially, should immediately pass out some effective rules and drag them into function. For the better and fruitful urbanization, the unproductive

barren lands should be chosen for the residential purpose whereas the fertile land should be used for the cultivation. Formation and implementation of well managed urban plan is necessary for the effective urban development. In terms of physical infrastructure development of the city area, fixed scientific measures should be strictly brought into action .Safety options during construction, should be followed to lessen the loss from the natural disasters. GIS and remote sensing can be helpful tools for the better results. Future research will need to make use of high quality of urban development model for the investigation of urban expansion process and to make the sustainable plan for the sustainable urban development.

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