

Assessment the Land Use Land Cover Change and Urban Sprawl Modelling in Dhanusha District

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Abstract

Background: The global population has shifted from an agricultural rural area to urban cities and metropolis, largely after the industrial revolution in 18th century has created a major wave of urbanization.

Aim and objective: Analysis method using GIS for identification of LULC change and urban in Dhanusha District of Nepal.

Material and Methods: In order to gather data and conduct research, the thesis used remote sensing (RS) and geographic information system (IS) methodologies. Using categorization and change analysis of satellite imagery, the LULC alterations were examined. The change in urban sprawl was analyzed using statistical analysis and the future simulation was done using machine learning of trend and simulation using Cellular Automata (CA) Markov model.

Observation and Result: Satellite image analysis for trend analysis of urban sprawl in Dhanusha district was achieved for different six classes; Water, Developed, Sand/Barren, Forest, Shrubland and Cultivated/Planted areas. During the period of 1993 and 2021 the developed areas increased by more than three-fold by 4.9% from 18.33 Sq km. to 76.56 Sq km. The decrease in agricultural land in the same period was 11.4% of the total area from 743.46 Sq km. in 1993 to 608.64 Sq km. in 2021. The developed areas had sprawled around the roadway intersections of the district and mainly concentrated in Janakpur sub metropolitan area. During the period of 1993 to 2013 there was gradual increase in urban areas which peaked after 2013 to 2021. In the simulated image the developed area was 63.77 Sq. Km. and 5.4%. The result of 2003 and 2013 simulation had more accuracy which was used for the simulation of 2033 and 2043. The result showed increase in developed area to 99.52 Sq. Km in 2033 and again increase in developed area in 2043 to 130.58 Sq. Km. Small settlements along the roadway intersections turned into dense settlements during the period.

Conclusion: This study has importance in understanding the future urbanization sprawling patterns following current trend which can be used for proper management and planning of the area to ensure proper infrastructure development and management for sustainable development.

Keywords: sprawl modelling, LULC, land change, land cover

Introduction

The global population has shifted from an agricultural rural area to urban cities and metropolis, largely after the industrial revolution in 18th century has created a major wave of urbanization. Globally, the urban population has increased by approximately six times since 1950, from 751 million to 4.2 billion as of 2018, and over the following decades, it is anticipated that the rural population would finally diminish and the urban population will increase to six billion and more (Ghosh, 2019). As per Mundhe & Jaybhaye publication they define urbanization as the urban development strategy that results in population

growth, built-up area expansion, population densification, and urban lifestyle (Mundhe & Jaybhaye, 2014). Human population densification, economic progress and the expansion of construction land represents the leading driving forces in land use changes (Qiu et al., 2019).

Land Use land Cover (LULC) is defined as two terms where land use is referred as human activities on/in relation to the land (Lo, 1986) while the term "land cover" refers to the plant and man-made structures that cover the land (Alam et al., 2020; Burley, 1961). Since the 20th century, land use change has had a significant impact on ecology and has been one of the determining forces for altering the surface of

the Earth. (Bielecka, 2020; Chapin et al., 2002). LULC changes under rapid urbanization has been a most important driving force that has influenced and altered the global and regional eco-environmental conditions (Qiu et al., 2019). Uncontrolled and unmanaged urbanization and LULC changes raises many issues like unapproved urban sprawl, loss in agricultural land, unregulated rise in land value and other many problems (Mundhe & Jaybhaye, 2014).

Nepal is one of the least urbanized country but at the same time is also one of the fastest urbanizing country (Bakrania, 2015). Urban development in Nepal has been a 13 spontaneous process such that the positive aspects of urban areas as engines of economic development and therefore national development have not been appreciated by policymakers and development experts (Tiwari, 2008). Urbanization in Nepal has mainly been observed in the capital city, along highways and towns on the southern border with India. After 1950, there was a significant influx of people from mountainous and hilly regions into Nepal due to the building of east-west routes and the elimination of malaria in the Terai region (Devkota, 2012). Due to changes mostly resulting from anthropogenic and natural factors effecting the national and regional environment, LULC in Nepal has altered continuously over the recent past (Paudel et al., 2016).

Population in the Terai areas increased from 37% to 47% from 1971 to 1991 with 31% increased population density and similarly urban areas increased from 10 to 33 to 36 in 1951 to 1987 and 1991 in Terai increases were from 5 to 21 urban centers (Satterthwaite et al., 2010). The Terai region of Nepal is regarded as the nation's food basket, but since 1988/1989, metropolitan areas have grown at an average annual pace of 12%, endangering the area's valuable agricultural land (Rijal et al., 2020). In the mountain and hilly areas of the country, the tough physical conditions and lack of arable lands have become major push factors while pull factors in the Terai region which area plains are the job opportunities and the availability of farming lands (Satterthwaite et al., 2010).

The rapid urbanization in country has intensified the deficit of urban infrastructures, access to piped

water supply had declined from 68% in 2003 to 58% in 2010, solid waste collection is low and inadequate resulting in open piles (Elisa & Gabriela, 2013). Similarly, the haphazard urban expansion has contributed to the other problems like inadequate housing infrastructures, pollution, urban slums, traffic congestion and decline of agricultural lands. The country's constitution prohibits the government from enforcing any restrictions on the use of private property, which creates additional challenges for urban governance in Nepal while increasing the vulnerability of the urban population to multiple 14 hazards, especially the urban poor (Timsina et al., 2020).

Rural villages and markets are urbanizing quickly yet lack the most basic infrastructure (Satterthwaite et al., 2010). The problem of urban pollution has been a major concern for officials and planners. The problem of grey and black water stagnation has been more significant in the cities of terai plains because of low gradient for water flow. The haphazard urbanization has caused more pressure on these already existing problems. Historic cities like Janakpur are more vulnerable as their cultural and historical artifacts are in more need for preservation. Urban land use and cover in Nepal has changed significantly over the past 30 years due to the unprecedented rate of expansion, necessitating intensive historical LULC study for future change analysis (Paudel et al., 2016).

GIS has been extensively used for LULC change analysis. Development of computational power and One could think of a GIS-based spatial information management system as an integrated software and hardware set. The capabilities of trend analysis, modeling, mapping, and spatial tabular display as well as a framework for decision-makers and specialists are improved by the integration of GIS with satellite imagery. Landsat has been one of the widely used satellite imagery for various geographical analyses ranging from land changes to environmental and climate studies. The free and easy availability of the imagery contributes to the wide use of the imagery. The medium resolution imagery with wide range of spectral band makes it perfect for land change analysis.

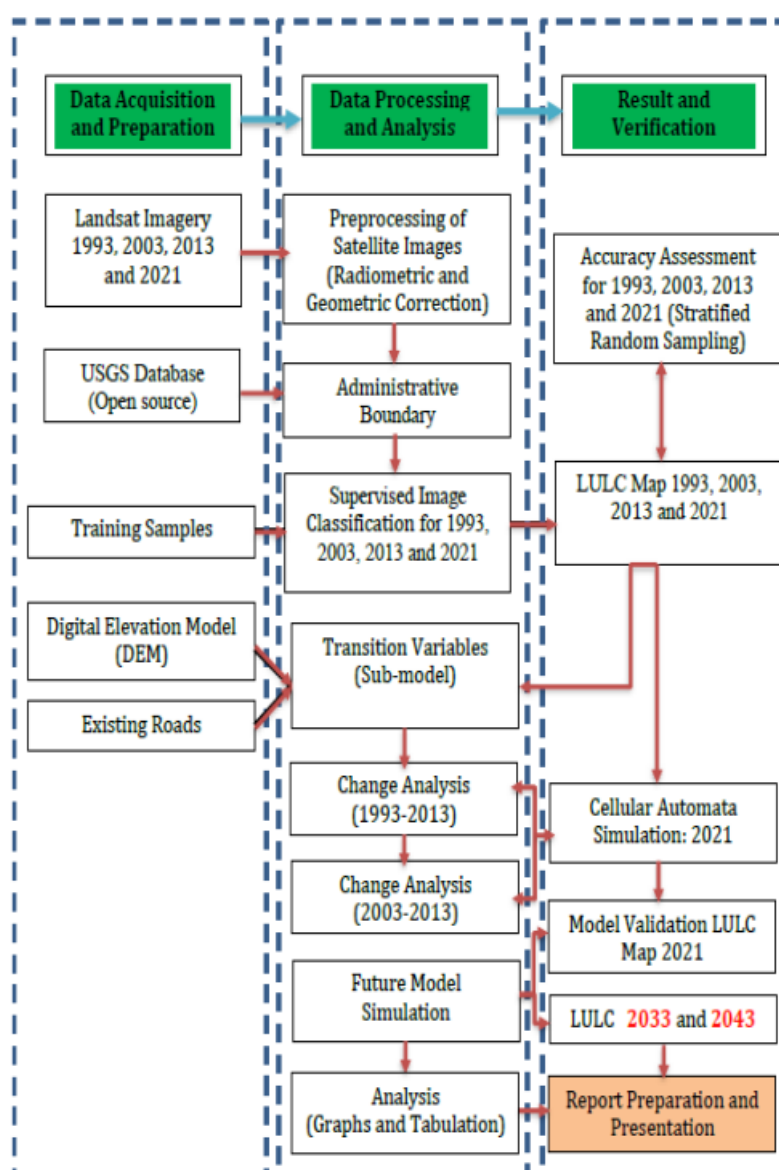
LULC analysis provides a spatial outlook for the current situation and changes in the environment. This analysis is used to understand and manage the

land uses. LULC analysis has widely been used in urban planning and management. Urban sprawl modelling is used in LULC analysis and planning to identify the probable high urbanization potential areas by looking into the trend of past urban pattern. The model can be helpful in directing future LULC. One of the most crucial considerations is the utilization of the land15 in sustainable development so the look into land use of past and future can be important for the urban planning and rural planning with most benefit and little financial and technical resources for plan implementation.

LULC and Urban Sprawl modeling in the Dhanusha district was based on temporal remote sensing data of the study area. The study mainly investigated the trend of land use and cover changes in the Dhanusha district, with the application of temporal Landsat images. Temporal images from 1993, 2003, 2013, and 2021 were used for analyzing the changes focused on built-up. ArcGIS Pro was used for processing images and LULC mapping and the urban sprawl model was created using the QGIS MOLUSCE plugin The following sections provide the process's specifics.

Work flow of LULC analysis

Material and methods



Data Used

Landsat Imagery

The United States Geological Survey (USGS) Earth Explorer website offers free access to photographs of Landsat satellites. The area of interest can be defined using a polygon, circle, or predefined area in an interactive world map. The date range can be specified for obtaining images of the required date-time. Similarly, the cloud cover percentage can be defined as limiting the cloud cover of the imageries. Landsat Collection 2 level 2 data, Landsat Collection 2 level 1 data, Landsat C2 atmospheric auxiliary data, Landsat Collection 1 datasets, and Landsat Legacy datasets are among the datasets included under Landsat. Landsat 8-9 Operational Land Imager (OLI) / Thermal Infrared Sensor (TIRS) C2 L2, Landsat 7 Enhanced Thematic Mapper (ETM+), and Landsat 4-5 Thematic Mapper (TM) C2 L2 are among the level-2 data from Landsat Collection 2 that can be downloaded.

Software Used

The software used for the main analysis and mapping was ArcGIS Pro. Similarly, the QGIS MOLUSCE plugin was used for the change analysis and change prediction for future LULC. The report preparation was conducted in Microsoft Word and the charts and tables were analyzed in Microsoft Excel.

Results and Discussion

Land Use Land Cover Classification

The land use land cover of Dhanusha district in the year 1993 was mainly agricultural and forest area dominant. The area of 743.46 Sq km. was covered by planted/ cultivated lands which is the highest land use in the area with a percentage of 63.0%. The second major land use was forest areas which was calculated as 322.47 Sq km. and was covering 27.3% of Dhanusha. The third main land cover was Shrub areas which covered an area of 51.57 Sq Km. and was covering 4.4% of the area. The shrublands were formed along the riverbanks. The data of the LULC in the district is presented in Figure 19.

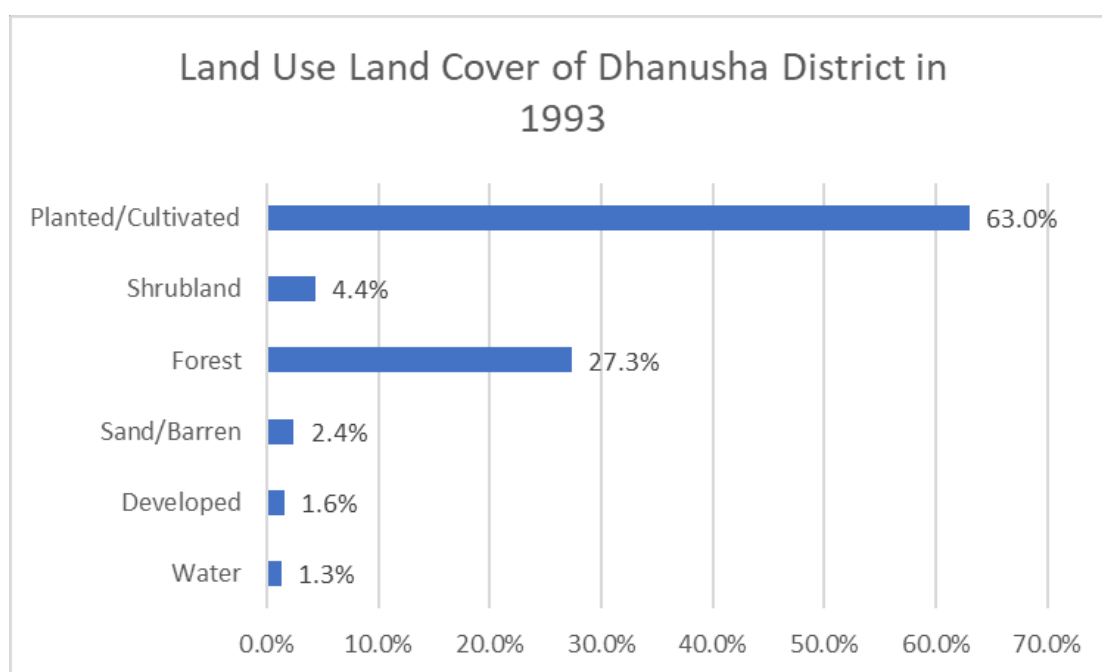
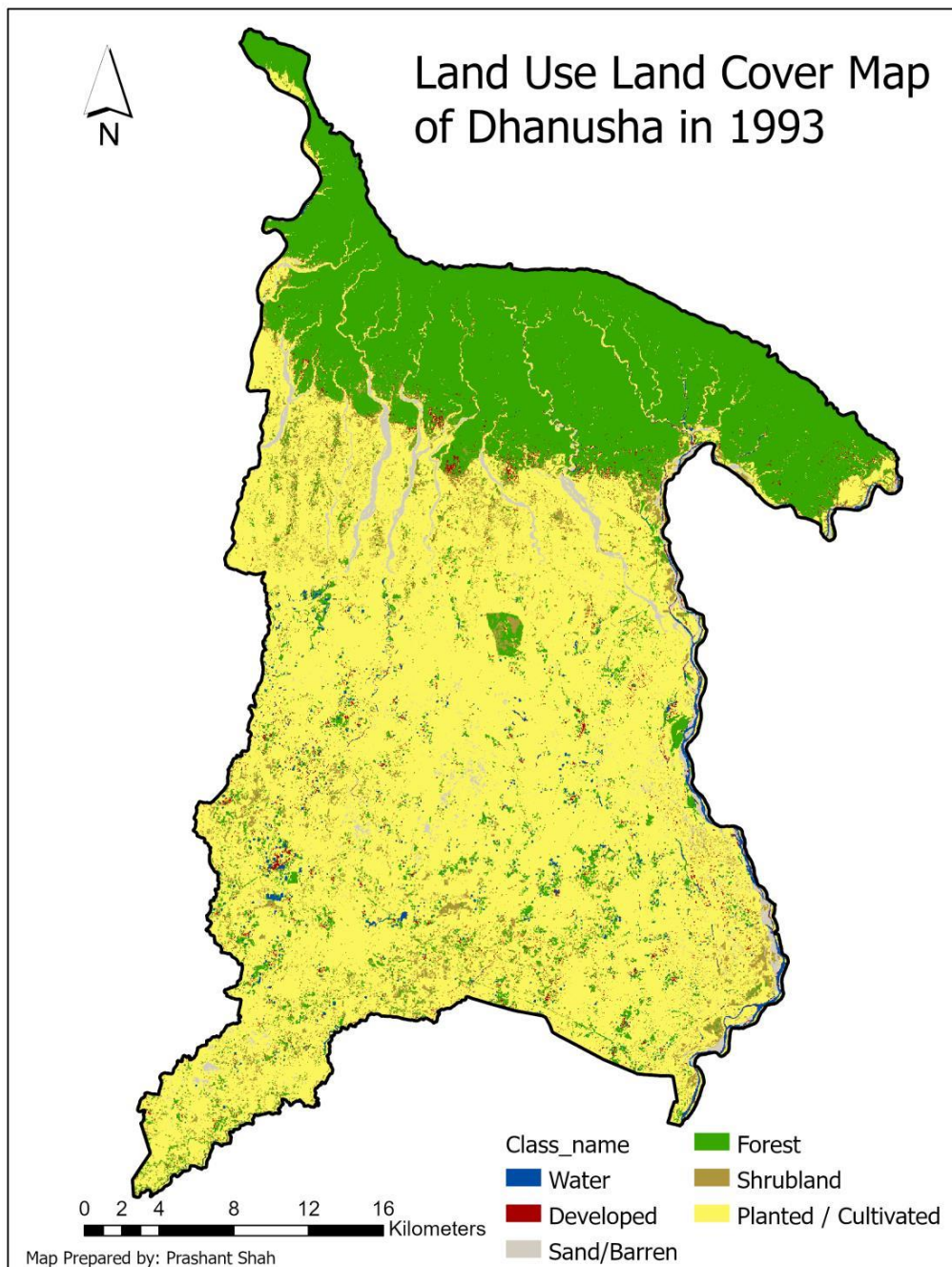


Figure no. 1. Land Use Land Cover Data in 1993

The least amount of study area was covered by water body which is 15.46 Sq km. which covered an area of 1.3%. The second lowest land use was developed which covered an area of 18.33 Sq km.

in the district and had a 1.6% coverage in the area. The Sand / Barren areas had a total area of 27.70 Sq km. and covered an area of 2.4% of the Dhanusha district.

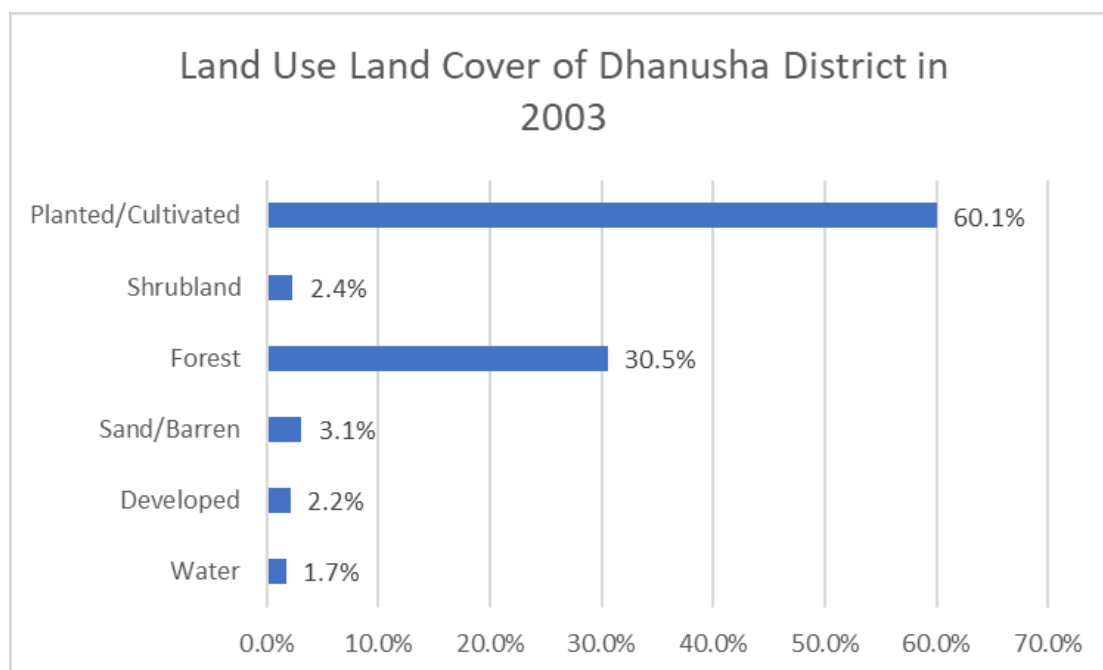
The LULC map of the Dhanush District in 1993 is presented in the Map 3



Land Use Land Cover Map of Dhanusha District in 1993

The land uses land cover of the Dhanusha district in the year 2003 was like the year 1993 with mainly agricultural and forest areas dominant. The agricultural areas decrease by 2.9% in 2003. The area of 708.83 Sq km. was covered by planted/cultivated lands which is still the highest land use in the area with a percentage of 60.1%. The second

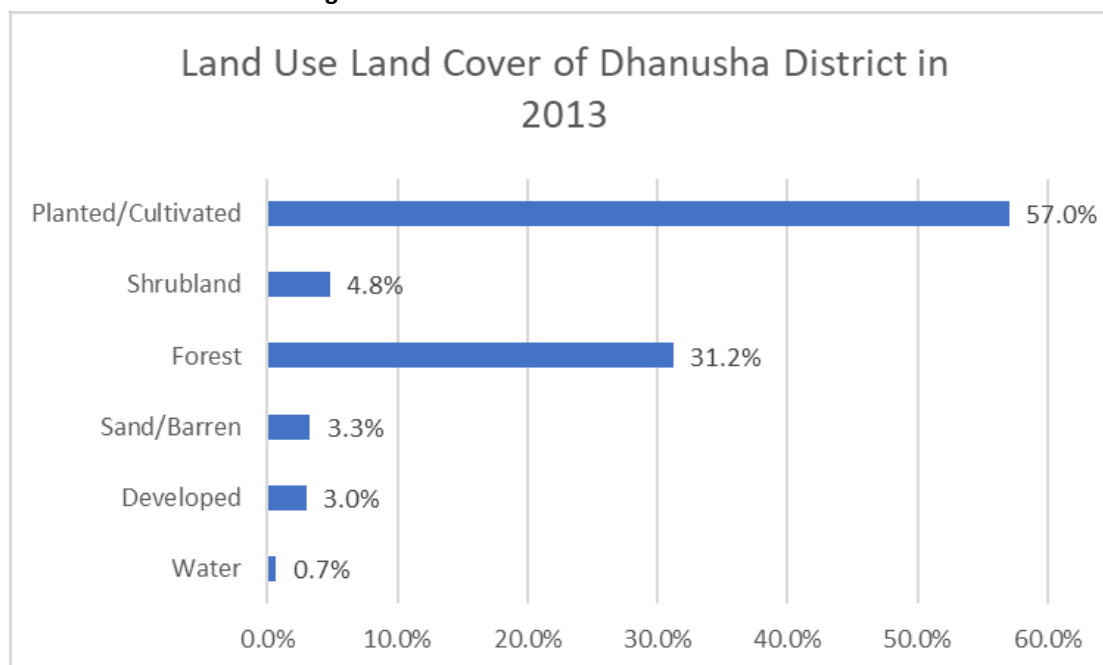
major land use was forest areas which was calculated as 360.07 Sq km. and was covering 30.5% of Dhanusha. The third main land cover was Sand/Barren areas which covered an area of 37.05 Sq Km. and was covering 3.1% of the area. The shrubland and barren areas changed significantly from 1993 to 2003. The barren/ sandy areas were formed along the riverbanks. The data of the LULC in the district is presented in Figure no. 1.



The least amount of study area was covered by water body which is 20.60 Sq km. which covered an area of 1.7%. The second lowest land use was developed which covered an area of 25.57 Sq km.

in the district and had a 2.2% coverage in the area. The Shrubland areas had a total area of 27.87 Sq km. and covered an area of 2.4% of the Dhanusha district. The developed areas increased by 0.6% and in 2003 had an increase in coverage of 7.24 Sq km.

Figure no.2. Land Use Land Cover Data in 2013

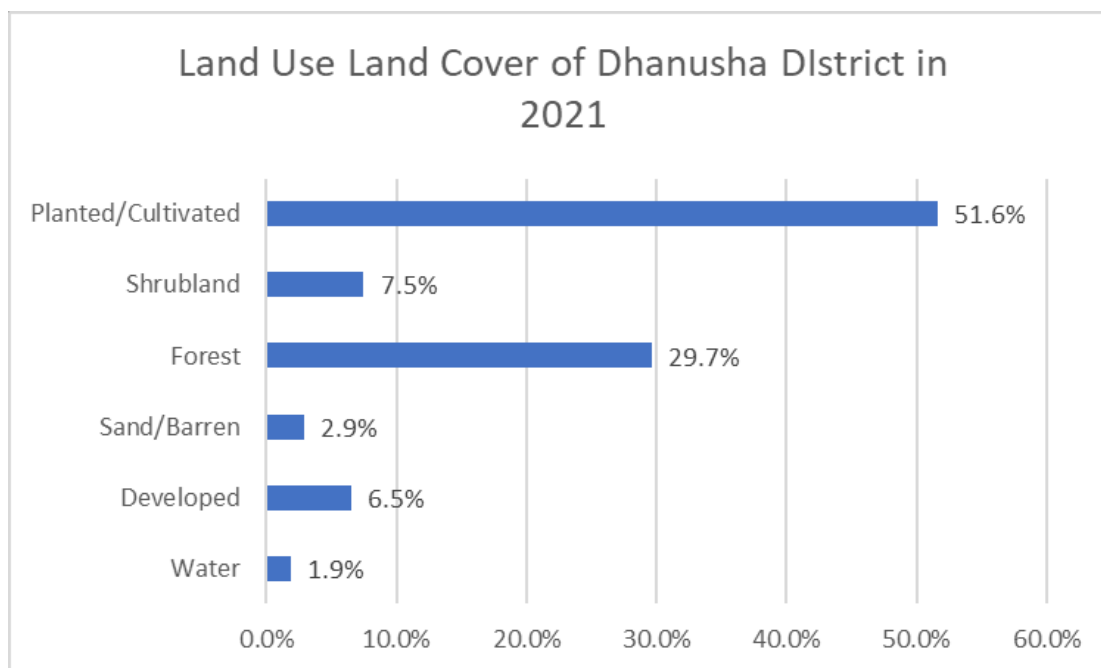


The least amount of study area was covered by water body which is 8.17 Sq km. which covered an area of 0.7%. The second lowest land use was developed which covered an area of 35.30 Sq km.

in the district and had a 3% coverage in the area. The Barren/ Sandy areas had a total area of 38.57 Sq km. and covered an area of 3.3% of the Dhanusha district. The developed areas increased

by 0.8% and in 2013 had an increase in coverage of 9.73 Sq km

. Land Use Land Cover Data in 2021



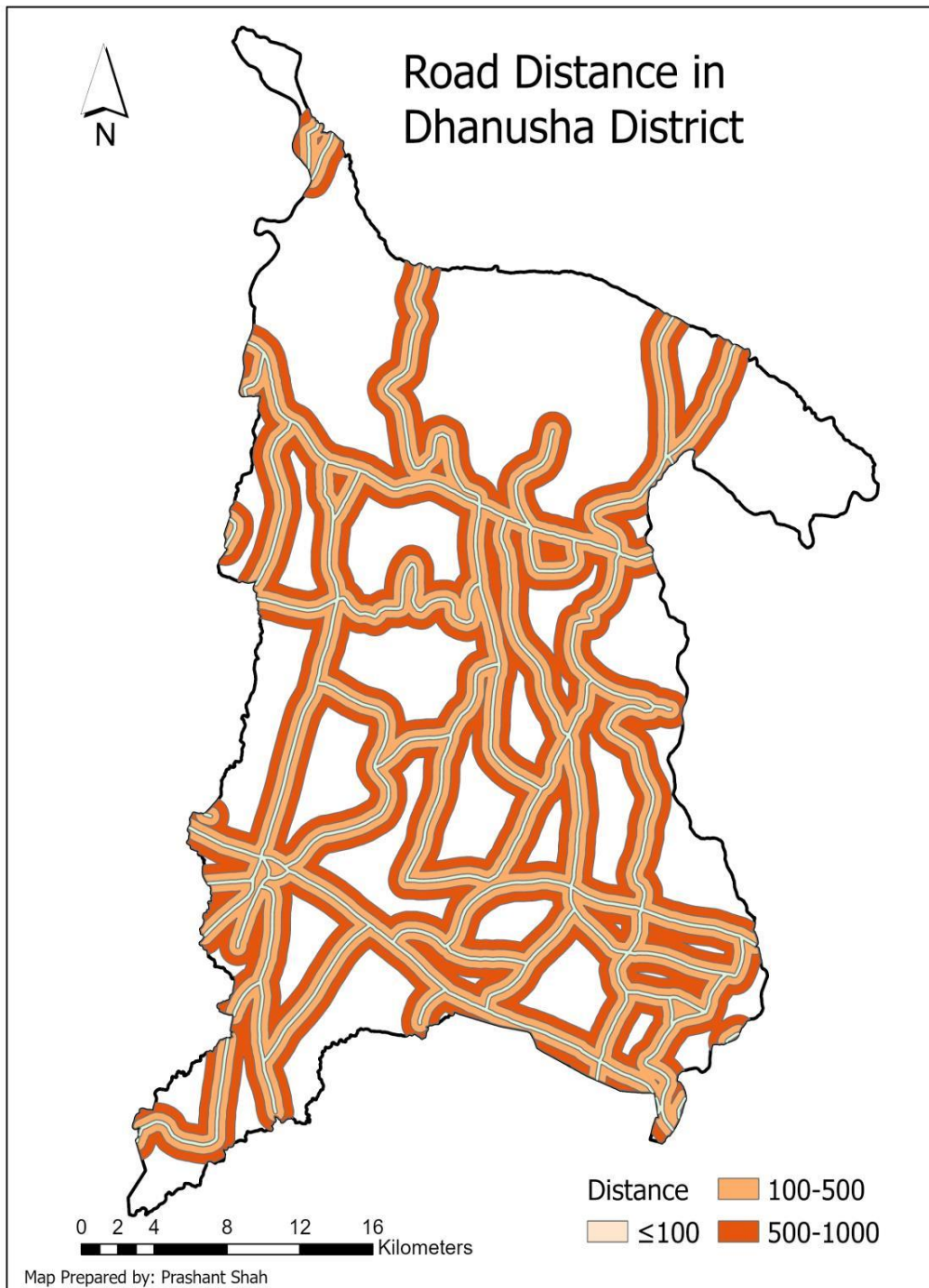
The least amount of study area was covered by water body which is 22.07 Sq km. which covered an area of 1.9%. The second lowest land use was Sand/Barren which covered an area of 34.43 Sq km. in the district and had a 2.9% coverage in the area. The Developed areas had increased significantly, and areas had a total area of 76.56 Sq km. and covered an area of 6.5% of the Dhanusha district. The developed areas increased by 3.5% and in 2021 had an increase in coverage of 41.26 Sq km.

Urban Sprawl Modelling

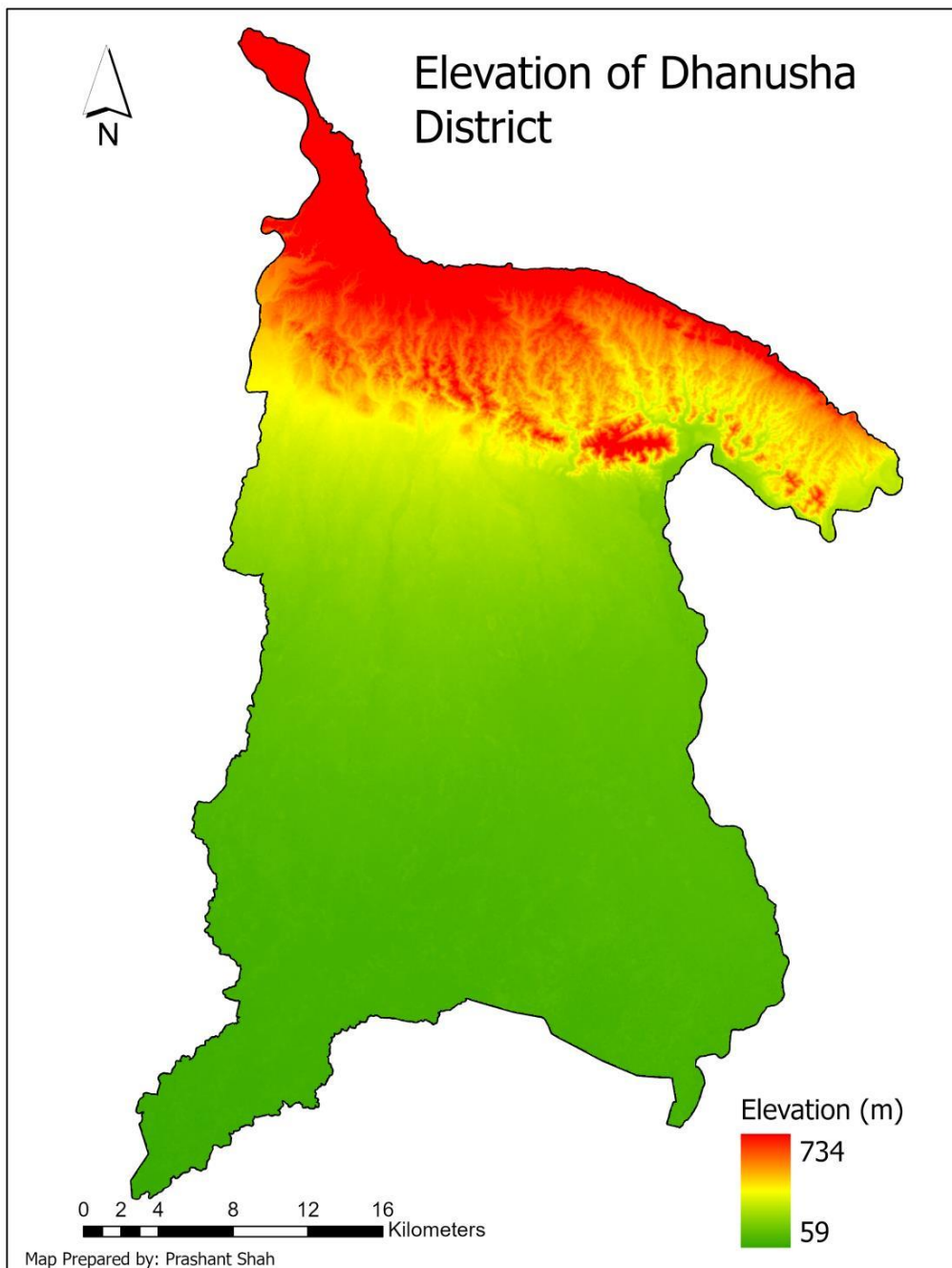
Modeling urban sprawl is the process of creating a trend analysis of historical images and using the trend process for the preparation of future scenarios of urbanization in the area. Modeling of the future urban sprawl was done in QGIS using the MOLUSCE plugin. QGIS is an open-source software used for geographic information analysis. The future prospect of urban sprawl in 2033 and 2043 were analyzed using LULC maps of 1993, 2003, 2013, and 2021. In the first step, the LULC map of 1993 and 2013 was used to analyze the accuracy of modeling the LULC of 2021. In a second step, the LULC map of 2003 and 2013 was used to analyze the accuracy of modeling the LULC

of 2021. The first input was used as the initial map of 1993 and the final map of 2013 was used. The spatial variables of distance to existing roads and DEM. The correlation was evaluated for the first raster distance to roads and the second raster DEM. The correlation of the raster was done using Pearson's Correlation. The DEM was used to consider that the plain areas in the study area will be more developed in the future than the areas which are hilly. In the high elevated regions, hills are less used for housing development when plain lands are available, plain areas are also easy for agricultural use which makes them more available for urban sprawl. The distance to roads was classified from up to 100 meters, 100 to 500 meters, and 1000 meters. The distance to the road as the spatial variable means that the places that are near the existing roads will have more population growth and sprawl than those places far from the roads. The distance to the road considers development will take place in areas where roads are existing as infrastructure development will be available in areas that already have roads. The road network is on the southern side of the study area, elevation was also higher in the northern side of the area. Road distance is shown by using multiple buffers for different distances from existing

Road Distance in Dhanusha









Elevation Map of Dhanusha



The LULC simulation was verified for accuracy assessment with LULC classified-image of 2021. First the image of 1993 and 2013 was used for the simulation of LULC 2021. The spatial variables of DEM and road buffers, the geometry was checked for the input and variable images. In the second step the correlation was evaluated for the spatial

variables, first raster, DEM, and second raster roads. The Pearson's Correlation was used for the result. The third step was Area changes. The area changes were measured for all the classes of LULC. 1 being water, 2 as developed, 3 as barren, 4 as forest, 5 as shrubland and 6 as agricultural lands. The area changes, class statistics are presented in Figure 3.

Class statistics		raster units					
	Class color	1993	2013	Δ	1993 %	2013 %	Δ %
1		15500700.00 sq. metre	8149500.00 sq. metre	-7351200.00 sq. metre	1.30694304481	0.687125893909	-0.619817150905
2		18415800.00 sq. metre	35417700.00 sq. metre	17001900.00 sq. metre	1.55272998798	2.98624685842	1.43351687044
3		28840500.00 sq. metre	38684700.00 sq. metre	9844200.00 sq. metre	2.43168959363	3.26170428469	0.830014691063
4		324411300.00 sq. metre	370266300.00 sq. metre	45855000.00 sq. metre	27.3527706616	31.2190394959	3.86626883431
5		51824700.00 sq. metre	57375000.00 sq. metre	5550300.00 sq. metre	4.36960467686	4.83757876716	0.467974090308
6		747034200.00 sq. metre	676134000.00 sq. metre	-70900200.00 sq. metre	62.9862620351	57.0083046999	-5.97795733521

Conclusion and Recommendation

This chapter discusses and concludes the results of this study. The result showed an increase in the developed areas of the district from 1993 to 2021 and is predicted to increase in 2033 and 2043. In 1993 the developed area was 18.33 sq. Km. which increased to 25.57 Sq. Km. in 2003 and same as that increased to 35.30 Sq. Km. in 2013 and also increased in 2021 to 76.56 Sq. Km. The maps of 2003 and 2013 were more accurate for the simulation of 2021 LULC than the maps of 1993 and 2013. The projected LULC of 2021 showed similar results as the classified LULC of 2021. The projected LULC increased to 99.52 Sq. Km. in 2033 and again increased in 2043 with an increase of 130.58 sq. Km. The conclusion from this study is that the simulation of LULC give a fairly accurate representation of future urban sprawl trend. The trend study can help in various sectors of urban planning. The study showed results of years near to the forecast years gives better result than past years. The difference can be because of factors that create population increase in recent years. The same was observed as the developed areas had increased in recent years than in past years which can be because of the popularity of the migration in the area from other areas in recent years. This study will be useful in land use planning in Dhanusha district.

The use of classification methods, simulation methods, RS and GIS was useful through the study. The use of open-source software made the work comparatively easy for analysis of various parts of the study. The open-source software provided an easy operation of the simulation process. MOLUSCE plugin in QGIS was easily available from

the plugin section of the application and download was very easy in little time. The direction for using the application and plugin was easily available in google and YouTube which eased the task.⁸⁷

In future the study should be done using high resolution images with better computers and available images. The analysis can also be checked with this result. The use of satellite images for the study is recommended as its ease of use in land use planning. The data should be used by the district and its municipalities as a reference for land use planning in their areas but because of the limitations of the study more accurate study should be performed for practical use in the area. The study can be used along with another suitability study with many spatial factors influencing the urban sprawl in the area.

Limitation and Future prospective

The limitation of the study includes the checking of accuracy with other relevant studies in the area. The study was done in 30m resolution satellite imagery which could have affected the accuracy of the classified images of all the years used in the study. The use of high-resolution images would have given a better accurate result. The processing power of personal computers also was low for high-resolution images and the availability of free satellite imagery for this resolution meant the use of such images for analysis. The accuracy of the images was analyzed using google earth historical images and the satellite images and the ground data could not be used for the study due to its limitations in part of the study. The factors that influenced the urban sprawl were examined using DEM and roads only as other factors were not available for the study area.

The study of land use land cover is important and examination of past and future trends can be important in land use planning. There may be high-

functioning computerized systems which can handle huge amounts of data. The large high-resolution real-time data will be more accurate in analyzing the process of land use changes and simulation in the future.

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