Spatiotemporal Assessment of Land Use System in Kathmandu Valley of Nepal Using Geospatial Techniques

Abstract

The Kathmandu Valley of Nepal is one the growing urbanization trend spreading city across the Himalayan foothills. This metropolitan valley is experiencing a significant transformation of its landscapes in the last few decades resulting in substantial land use and land cover change. A major systematic study of the urbanization trend and LULC has been felt need on this valley. Considering the importance of LULC change this study is carried out using, Arc GIS to assess land use system and change dynamics in the study area based on Landsat imagery of two decades from 2000 to 2019 at yearly interval. From the study of LULC of Kathmandu valley over the period selected a remarkable change scenario was observed in Agricultural land, Forest area, Vegetation land, Built up and River Bed area. Built up area is found significantly increased by 16% during the period in Kathmandu Valley .Forest area is found increased by 3%, whereas because of concrete structures built in the city caused decrease in water body in the valley by 3% up to the year 2008 and found increased later years with the increase in forest area. The effects in rivers system are observed significantly. River bed area is found decreased over this time period by 9%.This study showed the fast expansion of urbanization area and rapid conversions of agricultural area in Kathmandu Valley (study area).

Keywords: Urbanization, Kathmandu, Land use system, Spatiotemporal, Geospatial Techniques

Introduction

Migration of people to the urban and its surrounding area is increasing every year for the search of better opportunity of employment, healthcare and good education. Improved quality lives are possible in urban area(Sarif, Rimal, and Stork 2020). Especially people prefer to reach developed country like Europe and America in recent years. The population rise due to migration of people in urban area is increasing worldwide. Data shows the population increase in urban city is 55% and will become 60% by 2050. The increased population in city has resulted increased in spread built up area which directly affect to the dynamics of land use and land cover of the city in large scale(Niraj, Thapa, and Shukla 2020). Dense population, traffic flow impacts on the environmental condition of the urban area that causes the city environmentally polluted. Rise in temperature affects to the hydrological cycle of the city consequently a huge impact on the water

sources (both groundwater and surface water) is observed. Uneven rainfall occurs that causes unexpected hydro hazards like landslides and inundation. In urban area the concrete layer has great impact on recharging process of ground water. Agricultural land of the urban are affected(Detection et al. 2012). The fate of agriculture land is serious issue for agriculture based Economy County like Nepal(Shrestha 2023). The city has become impervious layer due to concrete structure built up. To prevent the environmental degradation, hydrological, ecological and geological condition has become a great challenge at present date due to enormous migration of people in urban area.

In this context migration of people from village area is increasing in Nepal however the rate is comparatively is lower than in other countries. The rate of migration in Nepal is about 3%(Pokhrel and Shakya 2021). Migration of people in city area of Terai is increased for the search of opportunity of job, healthcare and better education. Most of the people are migrating to the capital city Kathmandu in large number every year(Paudel et al. 2016). Since 1950 the migration of people to Kathmandu is increasing every year. During civil war (started at1996) migration of people was highest in Nepal. At present most of the people are migrated to Middle East and south east countries like Korea, japan, Malesia, Saudi Arab for job and they prefer to settle down in Kathmandu valley. The remittance has become a good economic support to the nation. But the agricultural lands are used for built up area extensively. It is very clear to forecast in coming years almost all land of Kathmandu valley will be occupied by residential building. The waste product of the city has become a serious issue and challenge for safe management. The world heritage city Kathmandu valley has become the most polluted city in the world. The discharge of sewers from households has become the reason of water pollution of the city. River especially Baghmati which is main drain river of valley is most polluted. The hydrology, ecology and geology are adversely affected due to the rise in populations in valley. City has become expensive to live and affords.

The haphazard urbanization has impact on environment and natural resources(Kshetri 2018). The increasing households are occupying land in uncontrolled way. To manage the agricultural land Nepal government had made five year land use policy in 1952 to address land use problems. But the policy and law did not work by very unstable government so that land management system became very poor and in last decade the uncontrolled land plotting /pooling and slope cutting made the landscape unsafe and unstable. The human intervention decreased the fertile agricultural land of Kathmandu valley(Paudel et al. 2017). Bare land increased and groundwater resources diminished that resulted the water resources problems for drinking water supply system. The river systems of the Kathmandu valley are occupied by unplanned road and building

construction as a result the river bed area are reduced which causes the flood inundation in core market area of the Kathmandu metropolitan city.

These all show the need of study on land use/land cover change in Kathmandu valley to save the landscape and reduce the impact on natural condition of the city that make the city environmentally sustainable. For this purpose the study explores change scenario of agricultural land system, urbanization patterns, water resources condition and rivers systems on temporal and spatial basis from image interpretation/analysis using Geospatial Techniques of two decades at yearly basis. So that the change in land use system and its impacts could be found and forecasted that helps to foster dialogue in the management of urban growth which helps to make effective land use policy to concerned government body.

Material and Method

Study Area

Kathmandu valley is situated in central part of Nepal which comprises three Districts Lalitpur, Bhaktapur and Kathmandu. The coverage area of each District is of 396.74, 123.07 and 413.74 square kilometer respectively .And total area is of 933.32 square kilometer. Geographically it is located between 27^{o} 31' to 27^{o}50' North, and between 85^{o}11' to 85^{0}34' East in the Himalaya Mountains. Elevation ranges from 426 m to 2622 m, with the central part of the valley ranging from 1200 m to 1500 m. It has a dry-winter humid subtropical climate(Asian Development Bank 2015). The region represents wide ranges of topographic features of a bowl-shaped valley (named Kathmandu Valley) surrounded by four mountain ranges Shivapuri, Phulchoki, Nagarjuna, and Chandragiri. Temperate climate having dry winter and hot summer with a mean annual temperature of 16^{oC} to 20^{oC} and mean annual precipitation of 1200 to 1400 mm dominated by Four months of monsoon. The entire area is drained by Bagmati River at the Chovar as outlet. Figures 1 depicts the Digital elevation Model of the study area Kathmandu Valley (Khadka 2021) (Paudel et al. 2016).

Administratively, the Kathmandu Valley is divided into eighteen municipal areas with several small village development committees (VDCs). With the history and culture dating back 2000 years, the cities within the Valley rank among the oldest human settlements in the central Himalayas. The Kathmandu Valley shares the characteristics with many other rapidly urbanizing cities in the region. These include, unregulated urban development, inadequate enforcement of land use policies, poorly maintained infrastructures, the massive influx of people from surrounding rural areas and hinterlands, land speculation, excessive pressure of commercial activities, and gaps in supply and demand for basic services. The population in central part of the

valley is dense and sparsely populated in hilly area of the valley so the study is focused on the central part of the city (Ishtiaque, Shrestha, and Chhetri 2017).

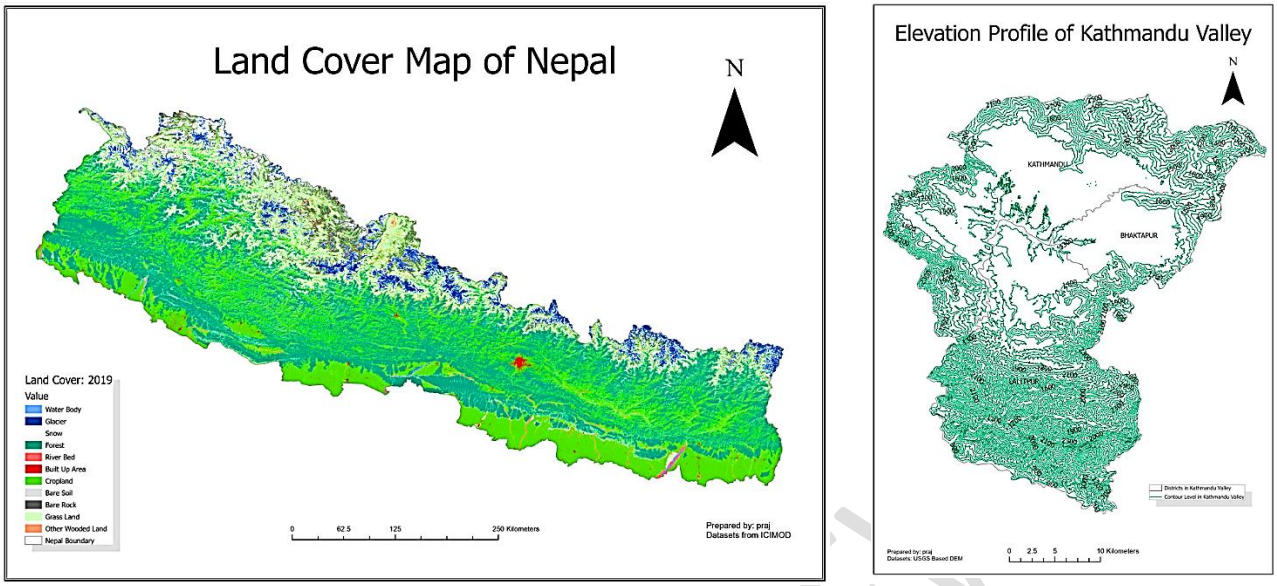


Figure1. Kathmandu valley (study area)

Data Used

The primary data used for LULC mapping and its analysis is satellite imagery. The study used Landsat 7 and Landsat 8 satellite imagery. The satellite imagery Landsat 5TM Landsat 8 OLI and sentinel-2 MSS of the study area were downloaded from the US geological survey image database site (http.//earthexplorer.usgs.gov) and image are projected in spatial reference system WGS 1084UTM Zone 45N. Images downloaded were of the month October as the image of this month were more clear and acquisition qualities were highest with no error detected and no quality issue were observed. There was no visible Cloud cover in this month over the study area.

Image processing

"The downloaded satellite data is pre-processed first before data analysis due to the occurrence of atmospheric effect, topographic effect and geometric effect in the satellite imagery. Atmospheric Correction was carried out for haze removal. The topographic correction chosen is sun angle correction which minimizes the effects that occur due to different positions of the sun (i.e. in the morning, noon, evening). Sun angle correction is termed as absolute radiometric correction obtained by dividing top of atmosphere (TOA) correction by solar elevation angle" (Rimal 2011).

Image classification

"Image Classification is the process of extracting different features class from the satellite imagery-based upon similar DN value" (Abdelkareem et al. 2018). "The supervised automatic

classification method is used for selecting training samples and processing them automatically choosing a maximum likelihood algorithm of supervised classification to prepare the land use and land cover (LULC) map of different years" (Bhatti and Tripathi 2014).

Accuracy measurement

"Accuracy assessment plays an important role in any thematic mapping project. It relates the classified image to referenced data (i.e. Ground truth). Kappa statistics are calculated to understand how closely classified data matched the sample data as ground truth if results close to 1 show truly partial ground condition".(Yankovich, Yankovich, and Baranovskiy 2019)

$$Kappa = \frac{Total\ Accuracy - Random\ accuracy}{1 - Random\ Accuracy}$$

Result and Discussion

Accuracy assessment of LULC Classification

Atmospheric and topographic disturbances are the two of many factors that could affect the accuracy of LULC change detection in mountain regions. The validity of the classification can be determined by accuracy assessment. In this study the accuracy of LULC was determined by 200 samples points taken from historical Google Earth map. These sample ground truths represents ground cover of that time period. These points are compared with classified LULC to prepare transition matrix. Overall accuracy of all of the maps is over 90% and Kappa coefficient is above 0.9.

LULC Analysis

The main objective of this study is to find the change scenario of land cover and land use system in Kathmandu valley on yearly basis from the year 2000 to 2019. From the study, the change in agriculture land (crop Land), vegetation cover, water body and river bed area variation due to expansion in built up area for households were observed. Over this period the change in Agriculture area, water body, vegetation cover, building areas were obtained from the image interpretations. The figure 2 shows the spatiotemporal dynamics of LULC image output of the Arc GIS of the years selected. From the LULC analysis the change in agriculture land was found as shown in figure 3. In the year 2000 the agriculture land was 42.5% where as in the year 2019 it was found 33%. Each year it is reducing. Built up area was found 9% in 2000 where as in 2019 it was found 17%. The dynamics of built up area is increasing each year. The figure 4 shows the change trend of built up area. In the same way the grass land is found decreasing each year. At the year 2000 it was 2.5% whereas at 2019 the area was decreased to 1.5% (figure 5). In 2000 the forest area was 44.5% and found increased up to 50% at the year 2006. After that it was found decreased. In the year 2019 the forest area was found 48%. However during this period from 2000 to 2019 the forest area is found increased. Figure 6 shows the change pattern of the forest

area in Katmandu valley during the selected years. The change dynamics of built up area, grass area, crop land, water body is affected accordingly. With the increase in forest area the water body is also found increased. At the year 2000 water body is found 0.0125% where as in 2019 it is found 0.03 %. The figure 7 shows the variation pattern of water body in Kathmandu valley. With the increase in population and climate change the rainfall pattern is changed and uneven. Land slide and flooding is increasing. Its impact on river bed area is observed. Due to unplanned and non-engineering approach of river control the natural flow of river are affected. Inundation in city has become a problem in rainy season. This was due to change in river bed area. Figure 8 shows the river bed variation of the Kathmandu valley. Figure 9 is the comparative result of LULC change dynamics of Kathmandu valley during the selected periods. Tables 1 and 2 are the area values in square meter and in percentage obtained from image interpretation after validation of the model.

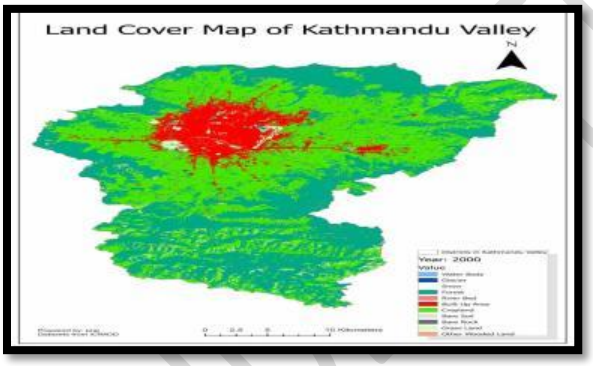
Table.1. LULC Area in square meter of Kathmandu Valley over the time period Selected.

Year	Water Body	Forest	built up area	Crop Land	Grass Land	River Bed
2000	125	524557	105873	505693	27562	474
2001	145	523061	96557	507091	27584	519
2002	152	543620	92814	498980	28040	652
2003	128	561270	95693	479699	26536	748
2004	108	578019	101084	457867	26536	779
2005	142	589276	105309	443620	24808	770
2006	156	592323	108000	438208	24420	705
2007	134	587101	110784	441338	23910	617
2008	135	582946	114646	443073	23209	504
2009	111	575346	119570	447632	22026	402
2010	125	573473	124231	446675	20944	309
2011	119	570290	127725	447460	20063	212
2013	65	560502	130614	454063	19836	180
2014	74	559532	133527	452833	19109	156
2015	72	560408	137813	448338	18687	168
2016	58	559850	145614	441925	18493	160
2017	76	560381	159489	428028	17952	150
2018	70	561182	189101	397724	19391	241
2019	319	562624	197039	389377	17186	336

Table 2.LULC Area in percentage of Kathmandu Valley over the time period Selected

Years	Waterbody (%)	Forest (%)	Built-up area (%)	Cropland (%)	Grassland (%)

2000	0.0001327	0.4461	0.09	0.43006	0.02343969
2001	0.0001277	0.4483	0.0827	0.43457	0.02363933
2002	0.0001293	0.4623	0.0789	0.42435	0.02442449
2003	0.0001089	0.4773	0.0814	0.40795	\0.02384619
2004	9.185E-05	0.4916	0.086	0.38939	0.02256714
2005	0.0001208	0.5011	0.0896	0.37727	0.02109759
2006	0.0001327	0.5037	0.0918	0.37267	0.02076762
s2007	0.000114	0.4993	0.0942	0.37533	0.0203339
2008	0.0001063	0.4958	0.0975	0.3768	0.01973774
2009	9.44E-05	0.4893	0.1017	0.38068	0.01873168
2010	0.0001063	0.4877	0.1057	0.37987	0.01781151
2011	0.0001012	0.485	0.1086	0.38054	0.0170667
2013	5.528E-05	0.4767	0.1111	0.38615	0.01686923
2014	6.293E-05	0.4758	0.1136	0.3851	0.01625096
2015	6.123E-05	0.4766	0.1172	0.38128	0.01589208
2016	4.933E-05	0.4761	0.1238	0.37583	0.01572709
2017	6.463E-05	0.4766	0.1356	0.36401	0.01526701
2018	5.953E-05	0.4772	0.1608	0.33824	0.01649078
2019	0.0002713	0.4785	0.1676	0.33114	0.01461557



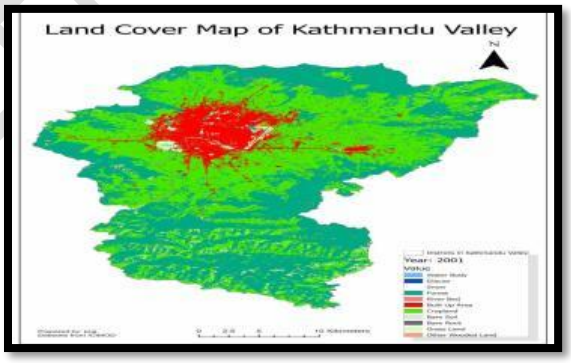
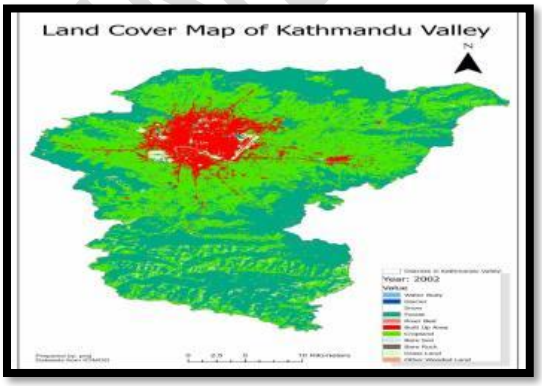


Image 2000 Image 2001



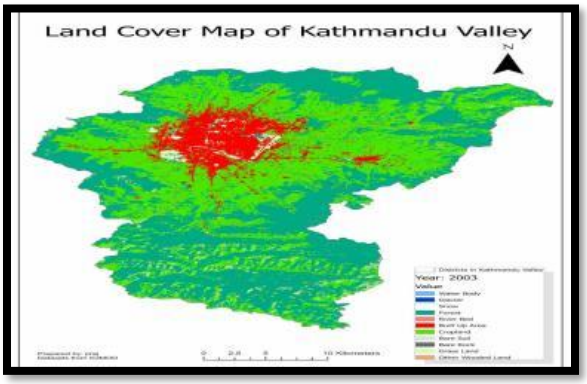
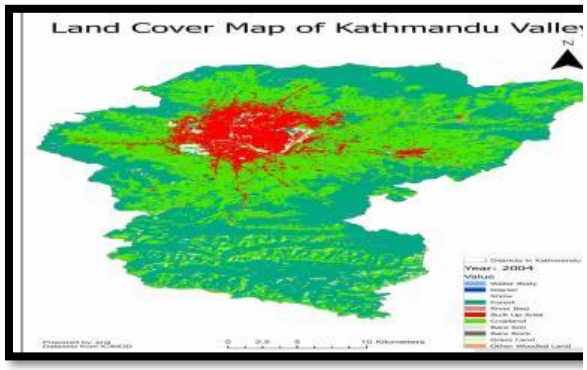


Image 2002 Image 2003



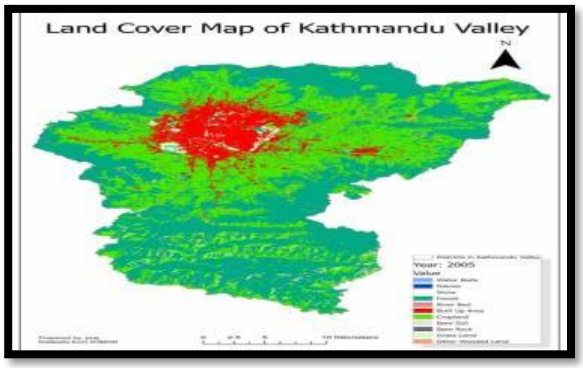
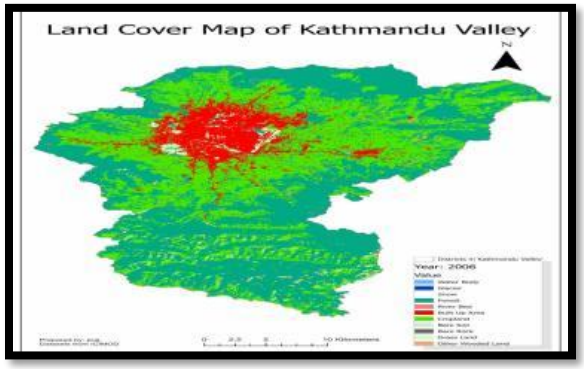


Image 2004 Image 2005



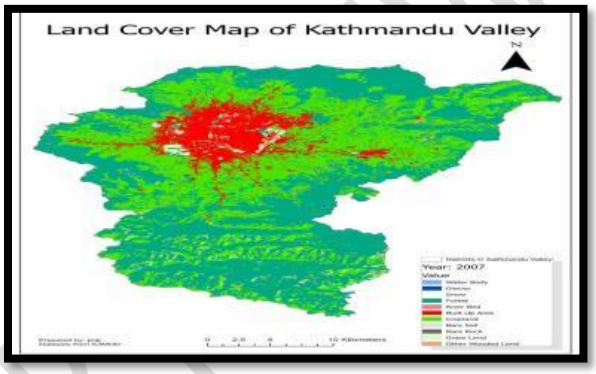
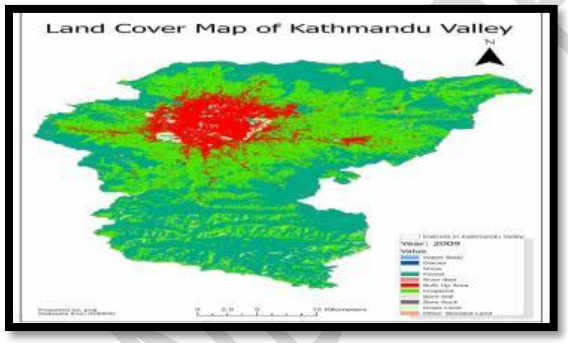


Image 2006 Image 2007



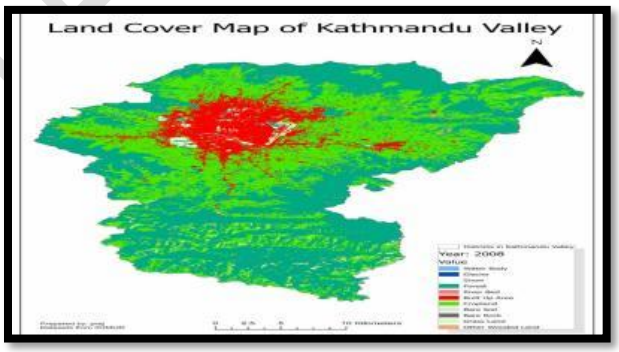
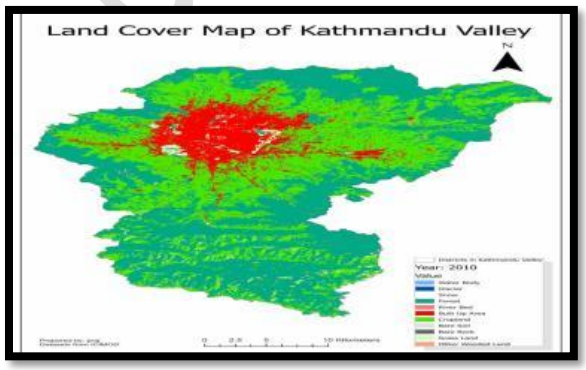


Image 2008 Image 2009



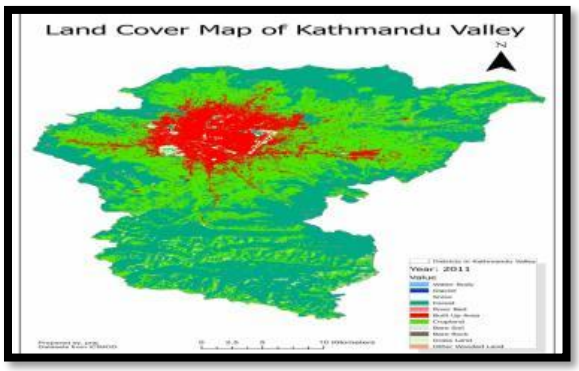
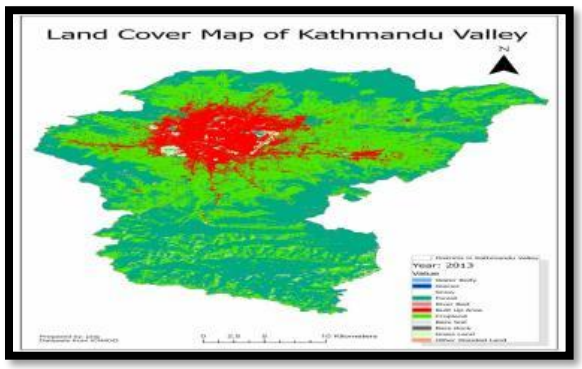


Image 2010 Image 2011



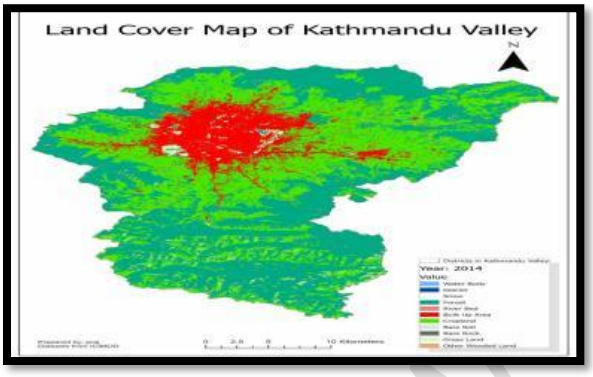
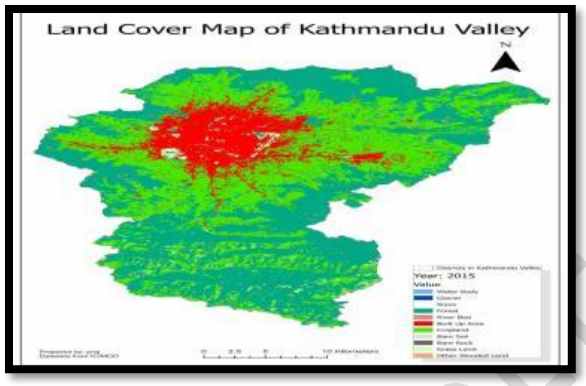


Image 2013 Image 2014



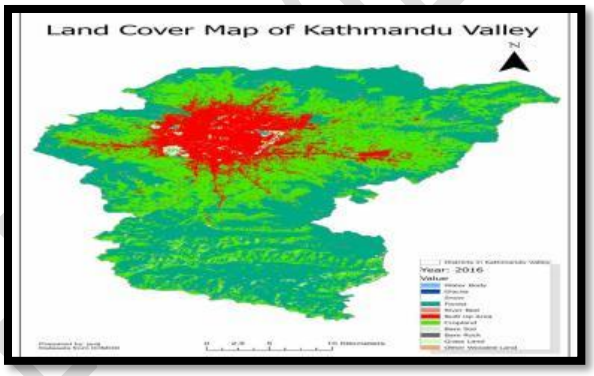
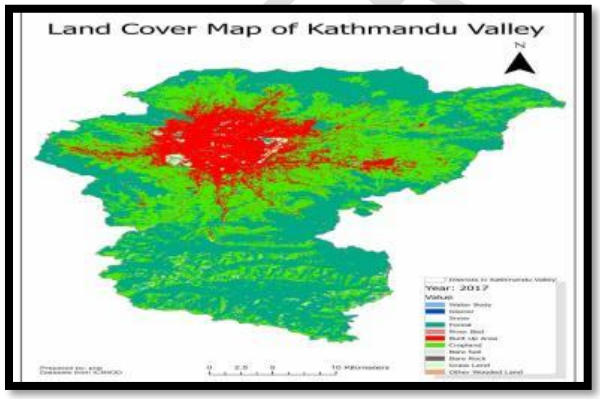


Image 2015 Image 2016



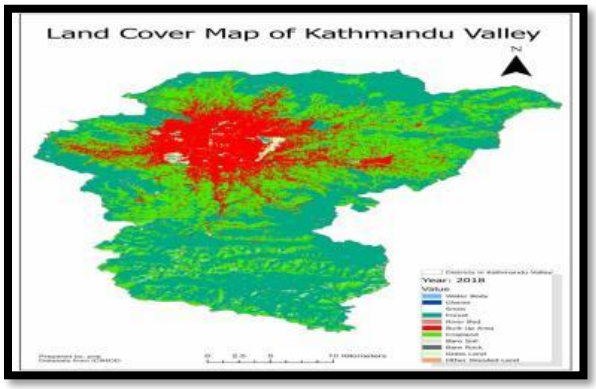


Image 2017 Image 2018

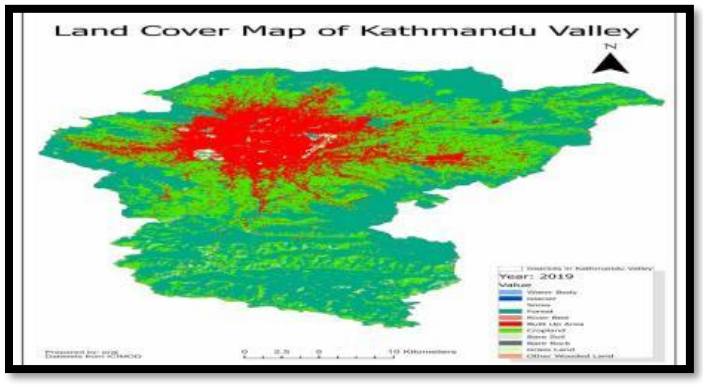


Image 2019

Figure.2 Spatial Dynamics of LULC of Kathmandu valley from image Analysis in ARC GIS of the years 2000 to 2019

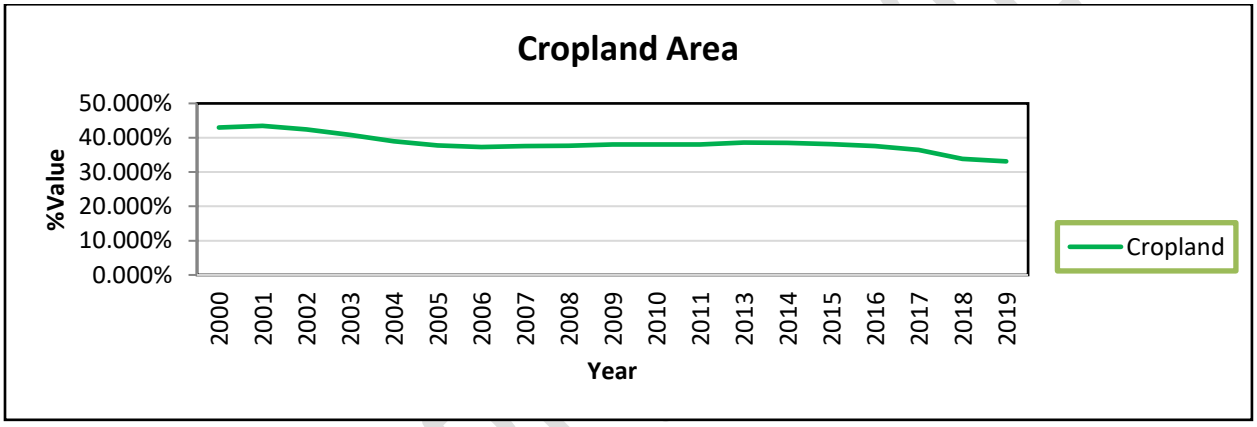


Figure 3. Change Dynamics of Cropland in Kathmandu valley over the time period of 2000 to 2019

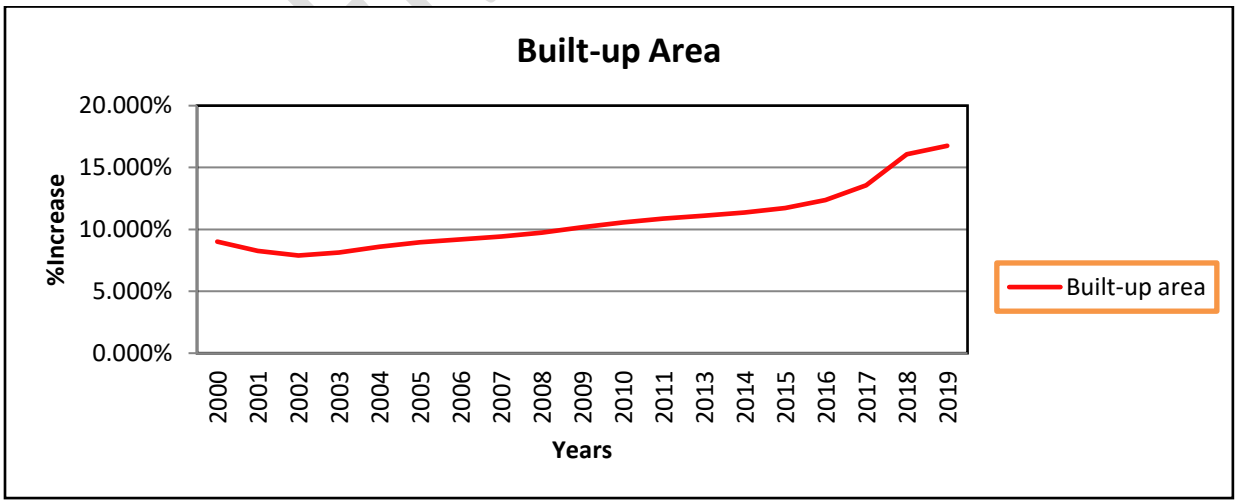


Figure4. Change Dynamics of Built up Area of Kathmandu valley during 2000 to 2019

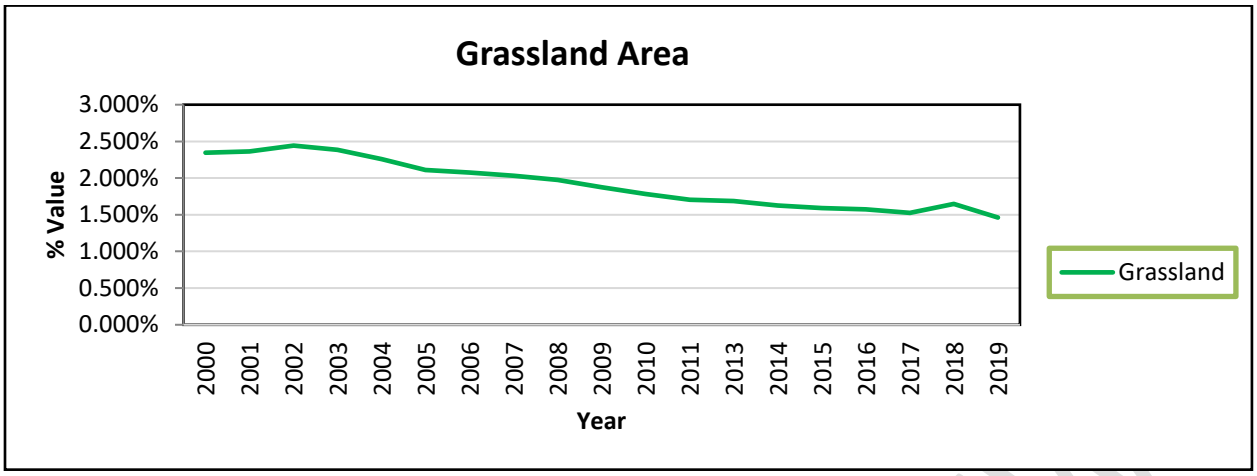


Figure 5. Change Dynamics of Grass Land Area of Kathmandu Valley over the time period of 2000 to 2019

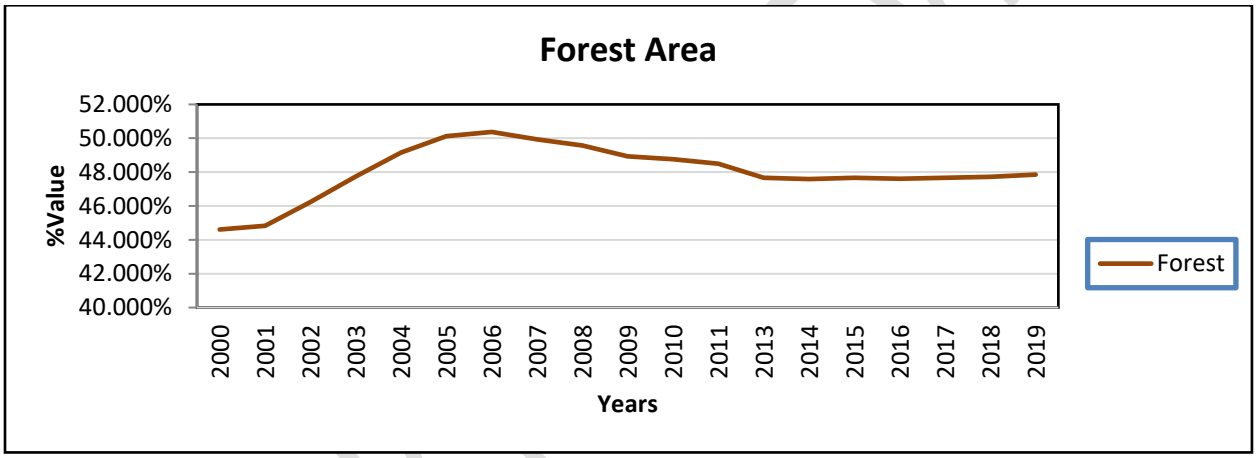


Figure 6. Change Dynamics of Forest area of Kathmandu valley over the time period of 2000 to 2019

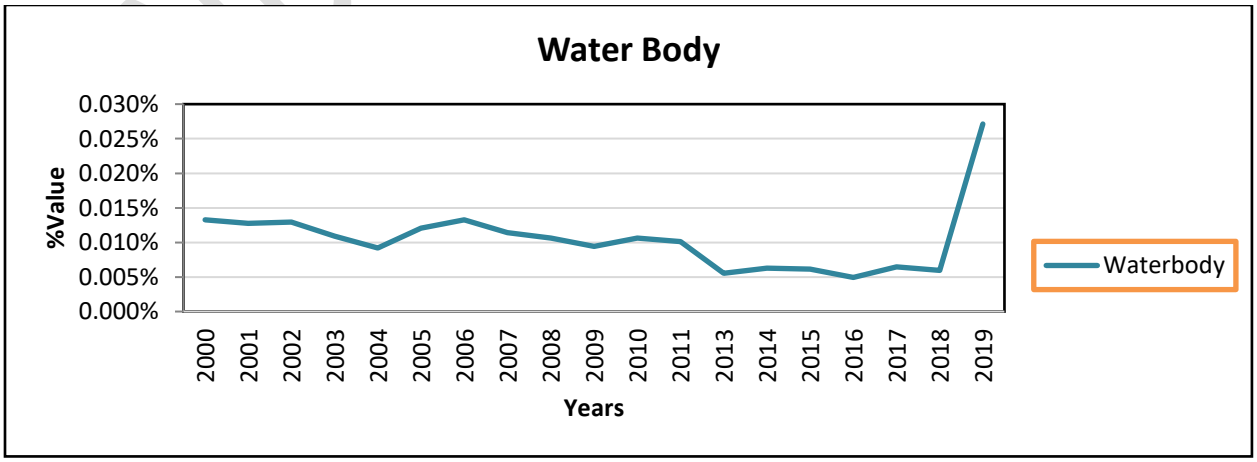


Figure7. Change Dynamics of Water Body in Kathmandu valley during the period of 2000 to 2019

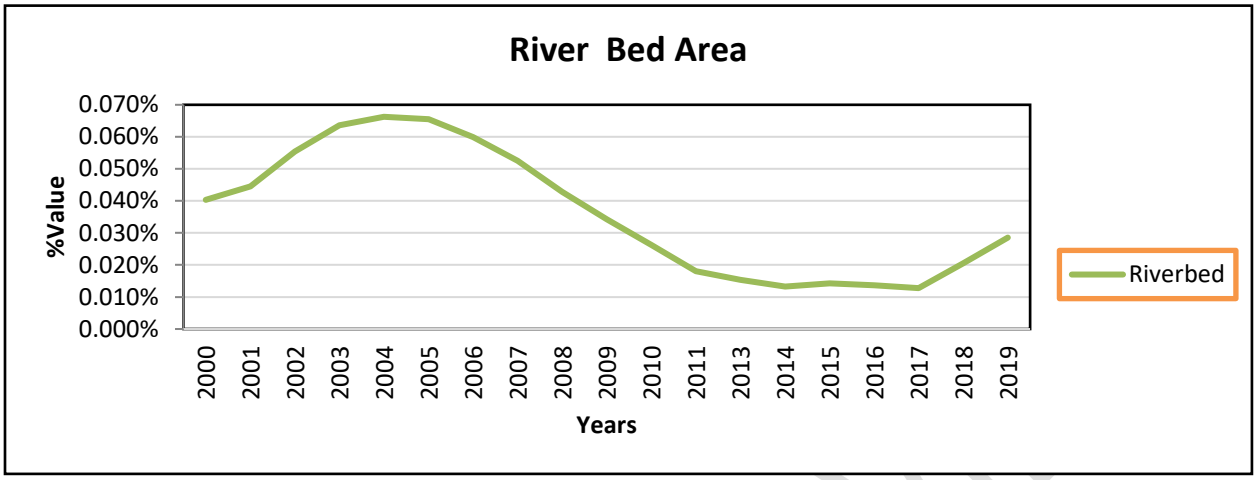


Figure8. Change in river bed area in Kathmandu valley during the years 2000 to 2019

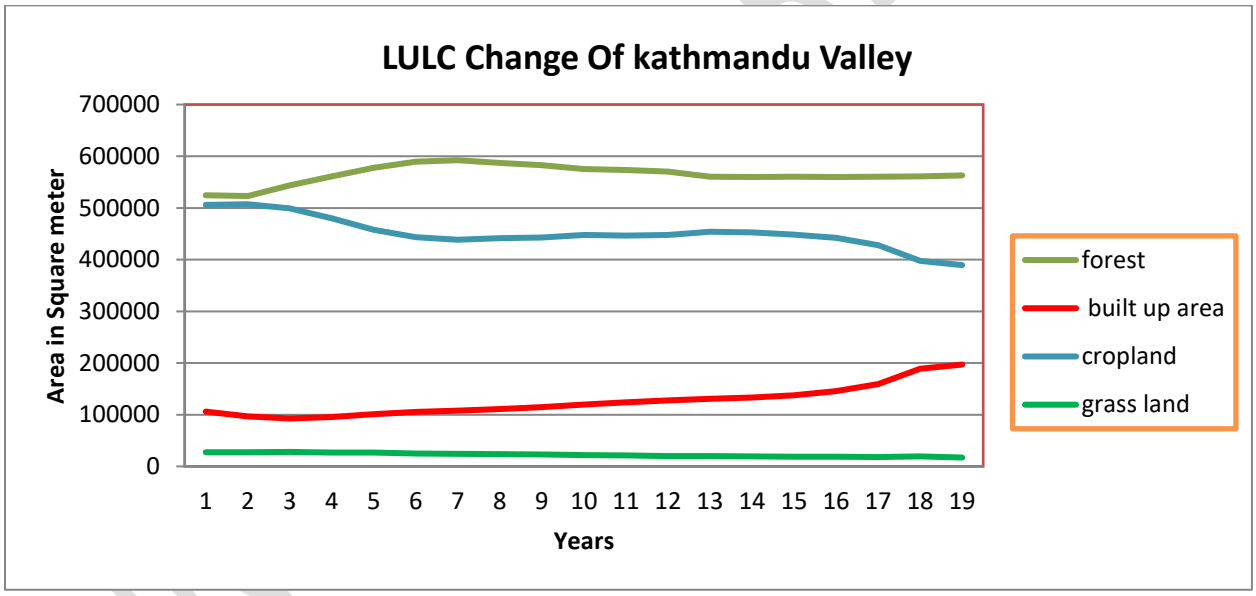


Figure 9. Spatial LULC change in Kathmandu valley, a comparative result over the time period 2000 to 2019.

Key Drivers for the LULC Change in Kathmandu Valley

The results of the LULC change detection depicts that this valley has experienced an unprecedented and unbelievable level of urban growth in the last two decades. The population growth in the final quarter of the 20th century witnessed a rapid expansion of the Kathmandu valley, reflecting the trend of urban growth dominant in the Himalayan region. This trend transformed the Kathmandu valley composed of the network of small towns each with their own

place-based identities and sophisticated architectural heritage into a metropolis of 'concrete layer', struggling to preserve its historical identity and ecosystem services. Based on a review of the existing literature , it is identified that several immediate causes that have directly contributed to this transformation, includes (a) rural-urban migration, (b) economic centrality, (c) socio-political factors, and (d) booming real estate market. All of these are arguably related to government policies. Increasing the risk of food security has become a big challenge due to rapid urbanization and an increment in food import has direct impact on national economy due to reduction in agricultural area and productivity. Rural people are becoming poorer due to centralization of all facilities, opportunities and people are motivated to migrate to the city for the search of employments. The number of homeless people is increasing in uncontrolled way in Kathmandu valley in recent years because of this there are conflicts and agitation between the public and administration to be faced time to time. Living environment is worsening; Humanity and moral values are losing. People are becoming self-centric in cities of Valley. People are motivated to engage in counterproductive work like agitations and strikes in the name of political agendas. Kathmandu is naturally the political and administrative center of the country, and it also became a safe refuge for those internally displaced people during the political turmoil period of 1996 to 2008. Overall, the Valley is the hub for all important socio-economic sectors in the country: tourism, finance, industry, education, transportation, and healthcare.

Discussions

"Land change trajectories/paths of the Kathmandu Valley detected in this study represent a silent urbanization trend that is sweeping across the Himalaya region and beyond that controls the flow of all economic and financial transactions, industrial production, and most importantly the governance of a country" (Ishtiaque et al. 2017). From the analysis, the most striking change is in the agricultural land and built up area that are significantly increased. During the period 2000 to 2019 the built up area is increased by 16% whereas agricultural land is reduced by 15%. The forest area is increased by 10 % from 2000 to 2006 but by the year 2019 it is reduced at unprecedented level. With the increase in built up area the river bed areas are reduced due to which the natural river courses are affected enormously. The reduction in grass land, water body, crop area and increased population that led to increase in expansion of built up area has impacts on environment of the city. Air pollution, water pollution and noise pollution are increased in valley staggeringly. Solid waste product is increased and its proper management has become big problem, challenges and issues for the local government. The hydrology, ecology is affected due to extreme temperature variation. The studies showed rise in maximum temperature above 35 degree in summer which is unexpected and notable for Kathmandu Valley. "This trend clearly

shows the essential and importance to study the sustainability implications of urban spread in this fragile, mountainous landscape. A mountainous valley like Kathmandu cannot sustain the urban growth rate that much level it is experiencing. It is urgent to examine the impacts of the conversion of agricultural land to the built environment, socio-ecological significance of disappearing open space, fragmentation of habitats and important biological corridors, changes in urban food and diet system, rising urban divide, increasing pollution levels, and most importantly, the governance of urban growth (or the lack thereof).To prevent the city the LULC study has become an effective way to gather the information" (Islam et al. 2018).

Conclusions

In conclusion concerning the site Kathmandu Valley and its study using Geospatial Techniques found easy and applicable tool for the interpretation, analysis of features and their real ground situations of any time period . And from the study there are some important recommendations made based upon the results obtained from the study for the better management, conservation and monitoring of land resources as follows

- Government organization should work through the collaboration and cooperation with non-government organization and stake holders of the valley.
- The agricultural land management policy of the government should be effective for the protection of land and enhance the productivity making self-dependent on food product. The policy should minimize human induced hazard to the agricultural resources, water resources, environment and ecology of the valley.
- The local people should be motivated for the protection of the resources by creating incentive based programs and opportunities so they look after the resources themselves .Public Participation approach is essential to preserve the city and its ambiance.

Data availability statement: Most datasets generated and analyzed in this study are in this submitted manuscript. The other datasets are available on a reasonable request from the corresponding author with the attached information.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

References

Abdelkareem, Osman Esaid Adlan, Hatim Mohamed Ahmed Elamin, Muneer Elyas Siddig Eltahir, Hassan Elnour Adam, Mohamed Eltom Elhaja, Abualgasim Majdeldin Rahamtalla, Osunmadewa Babatunde, and Csaplovics Elmar. 2018. "Accuracy Assessment of Land Use Land Cover in Umabdalla Natural Reserved Forest , South Kordofan, Sudan." *International Journal of Agricultural and Environmental Sciences* 3(1):5–9.

Asian Development Bank. 2015. "Solid Waste Management of Kathmandu Metropolitan City." 321–42.

Bhatti, Saad Saleem and Nitin Kumar Tripathi. 2014. "Built-up Area Extraction Using Landsat 8 OLI Imagery." *GIScience and Remote Sensing* 51(4):445–67.

Detection, Change, I. N. Land, U. S. E. Land, Using Landsat, and Satellite Imagery. 2012. "CHANGE DETECTION IN LAND USE LAND."

Ishtiaque, Asif, Milan Shrestha, and Netra Chhetri. 2017. "Rapid Urban Growth in the Kathmandu Valley, Nepal: Monitoring Land Use Land Cover Dynamics of a Himalayan City with Landsat Imageries." *Environments - MDPI* 4(4):1–16.

Islam, Kamrul, Mohammed Jashimuddin, Biswajit Nath, and Tapan Kumar. 2018. "The Egyptian Journal of Remote Sensing and Space Sciences Land Use Classification and Change Detection by Using Multi-Temporal Remotely Sensed Imagery : The Case of

Chunati Wildlife Sanctuary ,." *The Egyptian Journal of Remote Sensing and Space Sciences* 21(1):37–47.

Khadka, Dak Bahadur. 2021. "Opportunities and Challenges in Irrigation Practices and Agricultural Productivity Scenario in Nepal : A Review." *Journal of Current Trends in Agriculture , Environment and Sustainability* 2(1):1–7.

Kshetri, Tek. 2018. "NDVI, NDBI & NDWI Calculation Using Landsat 7,8." *Https://Www.Linkedin.Com/* (September 2018):8.

Niraj, K. C., L. Thapa, and D. P. Shukla. 2020. "Fate of Agricultural Areas of Kailali District of Nepal: A Temporal Land Use Land Cover Change (LUCC) Analysis." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives* 43(B3):1601–6.

Paudel, Basanta, Yi li Zhang, Shi cheng Li, Lin shan Liu, Xue Wu, and Narendra Raj Khanal. 2016. "Review of Studies on Land Use and Land Cover Change in Nepal." *Journal of Mountain Science* 13(4):643–60.

Paudel, Basanta, Yili Zhang, Shicheng Li, and Xue Wu. 2017. "Spatiotemporal Reconstruction of Agricultural Land Cover in Nepal from 1970 to 2010." *Regional Environmental Change* 17(8):2349–57.

Pokhrel, Madan and Narendra Man Shakya. 2021. "Assessment of Future Land Use / Cover Change of Kathmandu Valley Using Two Models of Land Change." 8914:463–71.

Rimal, Bhagawat. 2011. "APPLICATION OF REMOTE SENSING AND GIS , LAND USE / LAND COVER CHANGE IN KATHMANDU METROPOLITAN CITY , NEPAL ."

Sarif, Md Omar, Bhagawat Rimal, and Nigel E. Stork. 2020. "Assessment of Changes in Land Use/Land Cover and Land Surface Temperatures and Their Impact on Surface Urban Heat Island Phenomena in the Kathmandu Valley (1988–2018)." *ISPRS International Journal of Geo-Information* 9(12).

Shrestha, Him Lal. 2023. "Mapping and Modelling of Land Use Change in Nepal." *Journal of Forest and Livelihood* 18(1):39–53.

Yankovich, Ksenia S., Elena P. Yankovich, and Nikolay V Baranovskiy. 2019. "Classification of Vegetation to Estimate Forest Fire Danger Using Landsat 8 Images : Case Study." 2019.