Assessment of Change Dynamics of Land Cover and Land Use in Kathmandu Valley of Nepal: A Temporal Analysis Using Arc GIS and Remote Sensing

Abstract

Geographic information system (GIS) and remote sensing has become a useful tool for image analysis to exquisite the information on land surface of the earth. The image obtained from earth explorer are used for land use and land cover change (LULCC) analysis which give temporal and spatial dynamics of ~~the~~ this phenomenon in Kathmandu Valley of Nepal. ~~land use and land cover change of the study area chosen.~~ In this study, ~~the change dynamics of land cover and land use of Kathmandu valley is carried out using the~~ Arc GIS was utilized to assess land use dynamics in the study domain based on Landsat imagery between ~~of the year~~ 2000 ~~to~~ and 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 significantly increased by 16% during the period in Kathmandu Valley .Forest area is found increased , whereas because of concrete structures built in the city caused decrease in water body in the valley. The effects in river system are observed. River bed area is found decreased over this time period. The accuracy of the model used for the study was above 80% with kappa value 0.9 that showed the reliability on the results of the model used.

Keywords: Land use, Land cover, GIS and Remote Sensing

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

Formatted: Numbering: Continuous

Commented [NS1]: Title:
-Authors need to ensure brevity in the study's title, in order to coax readers. Kindly consider revising the current title to read as 'Spatiotemporal assessment of land use systems in Kathmadu Valley of Nepal using geospatial techniques' or something similar within the frame of 14-17 words.

Commented [NS2]: Abstract:
-Repetitive use of phrases like land use and land cover change, Kathmandu Valley and so on makes reading boring. Some aspects were modified to fine-tune the abstract or ensure flow.
*Please refrain from such and ensure brevity, conciseness and precision throughout the manuscript. Corrections here were effected to serve as a guide.
-The abstract needs to be well punctuated (i.e., some grammatical defects/syntax errors were identified here and within the main text).

Commented [NS3]: -Line 13: Kindly state the specific ArcGIS software/version used for the analysis procedures.

Commented [NS4]: -Lines 15-21: Kindly make the main results or findings distinct by using phrases like: Findings indicate…The results demonstrate…and other similar phrases.
-The authors can enrich the results section by integrating some quantitative values to show the decline/increment in each class where necessary.
-The concluding sentence should briefly highlight the main contribution or relevance of this study to the international scientific community and industrial players.

Commented [NS5]: Keywords:
-Please substitute some of the keywords to include other keywords that give this paper more audience. Likewise, some words that do not appear in the title.

Commented [NS6]: Introduction:
-The introductory section requires thorough revision.
-It is quite unclear what the study's rationale or motivation is. Again, research progress; thus, what is known about the topic from a global or regional perspective, and what's unknown yet important to be studied that currently drive this study's objectives remain unclear.
-Tools/approaches used in other jurisdictions must be given to know what is done or opportunities identified in other studies. What drivers or implications were identified in other studies? What gaps or limitations were spotted in other studies that drive this study's literature?
-Authors can enrich the theories and literature which anchor the current study by liaising these to some standardized theories, linked to some specific SDGs like SDG 11, 13, 15 and 17. Kindly refer to the following studies to revise the introduction:
* https://doi.org/10.1016/j.landusepol.2024.107261
* https://link.springer.com/article/10.1007/s10668-021-01848-5
* https://link.springer.com/article/10.1007/s12665-022-10481-y
* https://link.springer.com/article/10.1007/s12665-023-10755-z

-The last paragraph must clearly highlight the research objectives or questions that the current study attempts to address.
-Additionally, the significance of this study's outcome must be integrated in the last or last but one paragraph.

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 challenge to 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 made 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

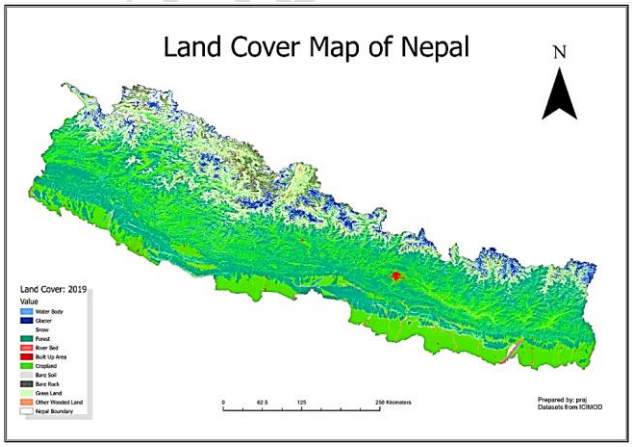
river bed area are reduced which causes the flood inundation in core market area of the Kathmandu metropolitan city.

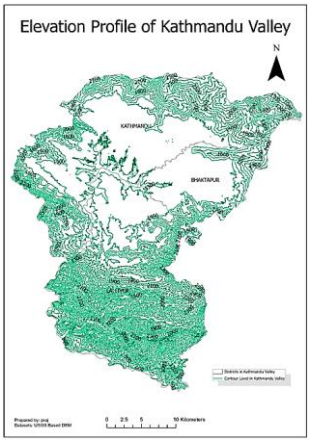
These all show the need of study on land use/land cover change in Kathmandu valley to save the land and reduce the impact on natural condition of the city that make the city environmentally sustainable. For this purpose the study explores change scenario of agricultural land, urbanization, water resources condition and rivers systems dynamics on temporal and spatial basis from image interpretation/analysis using GIS and remote sensing of two decades at yearly basis.

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 27º 31' to 27º50' North, and between 85º11' to 85^{0}34' East in the Himalaya Mountains. Elevation ranges from 837 m to 2723 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 ~~below are~~depicts the land use/land cover map of Nepal (Khadka 2021) and elevation profile ~~map~~ of Kathmandu valley(Paudel et al. 2016).





Commented [NS7]: **Materials and methods:**
-**Study area:** Kindly provide a brief justification for the choice of study area. What is unique about this area, and how important is this area to the research community, policy-makers and the citizens of Nepal?

Figure1. LILC Map of Nepal and Elevation Profile Map of Kathmandu valley

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.

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. 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)

$$Kappa = \frac{Tatal\ Accuracy - Random\ accuracy}{1 - Random\ Accuracy} \quad \ldots(1)$$

Result and Discussion

Accuracy assessment of LULC Classification

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

Commented [NS8]: Figure 1:
-It is quite strange how authors present two different maps and assume readers to spot out the study domain easily. Please link or carve out the study domain from the Land Cover Map of Nepal using a rectangular doodle and arrow to mark the region of interest.
-Some of the text and values in Figure 1 are not readable. Authors could increase the fonts of the scale and text in the legend to enhance readability.

Commented [NS9]: -Lines 107-130: Kindly update the literature here using current literature as given in the earlier comments or references listed.
-Authors should consider integrating or tabulating description of the classes or land features used within the context of this study.

-It will be more appropriate for authors to visualize the reference/input data, image pre-processing and enhancement procedures, type of classification used, change detection analysis and so on. Hence, a flow diagram needs to be designed.
-If the paths and rows used are consistent, kindly indicate them accordingly.
-The methodology section still lacks some key details. Did authors conduct any change detection analysis? If so, what expressions were used in arriving at that?
-All equations in the current manuscript must be numbered in an orderly format.

Commented [NS10]: -Kindly check the spelling of Total in the equation/expression used in determining the Kappa coefficient.

Commented [NS11]: Lines 134-137: How many fell on the right classes or areas and how many didn't? Authors should not just state the number of points sampled without substantiating these with figures.

The main objective of this study is to find the change scenario of land cover and land use in Kathmandu valley on yearly basis from the year 2000 to 2019. The change in agriculture land (crop Land), vegetation cover, water body and river bed area variation due to spread in built up area for households were observed. Over this period the change in Agriculture, water, vegetation, building areas were obtained from the image interpretations. The figure 2 shows the temporal spatial dynamics of LULC image output of the Arc GIS. From the LULC analysis the change in agriculture land was found as shown in figure 4. 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 3 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, built up area and 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 impact 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 shows 8 the river bed variation of the Kathmanduvalley. 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.

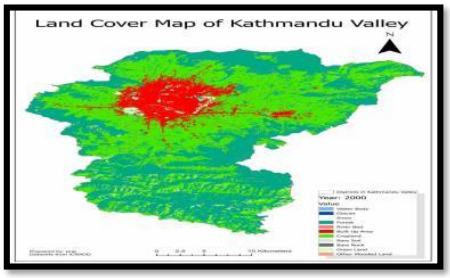
Year	Water Body	Forest	built up area	Crop Land	Grass Land	River Bed
2000	125	524557	105873	505693	27562	474
2001	145	523061	96557	507091	27584	519
2002	152	543620	92814	498980	28040	652
2003	128	561270	95693	479699	26536	748
2004	108	578019	101084	457867	26536	779
2005	142	589276	105309	443620	24808	770

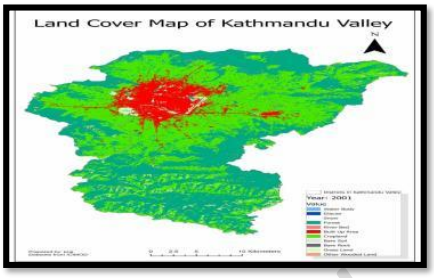
Commented [NS12]: **Results and Discussions**
-Please separate the discussions from the results section.
-For coherence and consistency purposes, the study's results must be presented based on the order of how the objectives are presented.
-Please ensure results in the tables are not repeated but briefly summarized.
-Figures and Tables must be placed close to where they are first mentioned. Hence, I suggest authors re-organize the results section by developing it into sub-sections with corresponding brief description to the results.

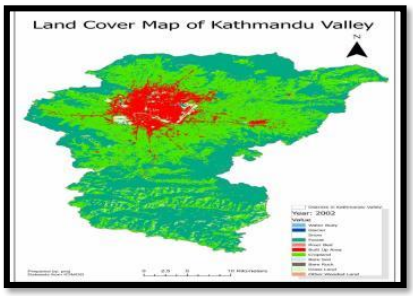
2006	156	592323	108000	438208	24420	705
2007	134	587101	110784	441338	23910	617
2008	135	582946	114646	443073	23209	504
2009	111	575346	119570	447632	22026	402
2010	125	573473	124231	446675	20944	309
2011	119	570290	127725	447460	20063	212
2013	65	560502	130614	454063	19836	180
2014	74	559532	133527	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

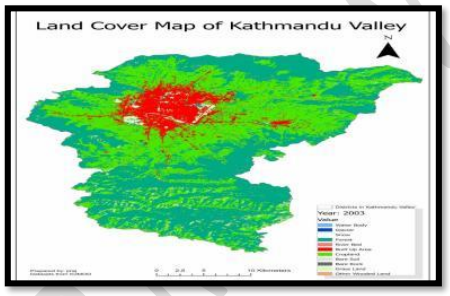
Table 2.LULC Area in percentage of Kathmandu Valley over the time period Selected

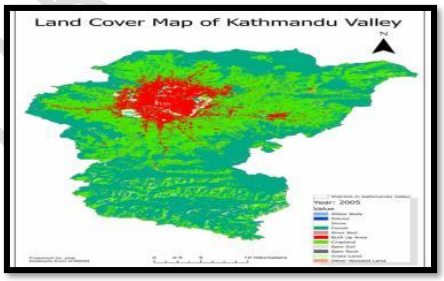
Years	Waterbody (%)	Forest (%)	Built-up area (%)	Cropland (%)	Grassland (%)
2000	0.0001327	0.4461	0.09	0.43006	0.02343969
2001	0.0001277	0.4483	0.0827	0.43457	0.02363933
2002	0.0001293	0.4623	0.0789	0.42435	0.02442449
2003	0.0001089	0.4773	0.0814	0.40795	\0.02384619
2004	9.185E-05	0.4916	0.086	0.38939	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

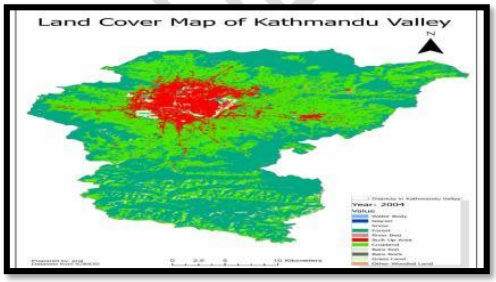

Land Cover Map of Kathmandu Valley

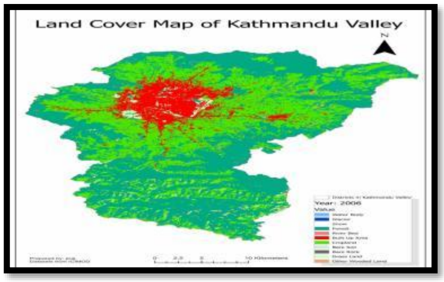

Land Cover Map of Kathmandu Valley

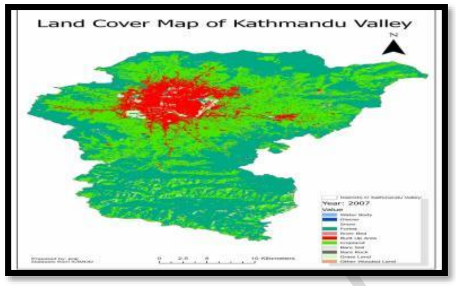

Land Cover Map of Kathmandu Valley

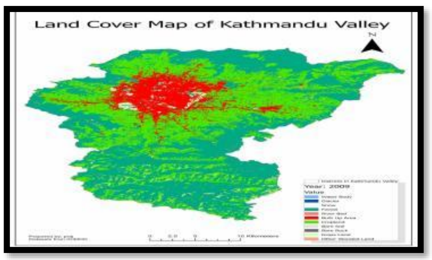

Land Cover Map of Kathmandu Valley

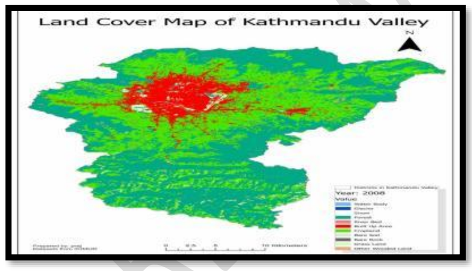

Land Cover Map of Kathmandu Valley

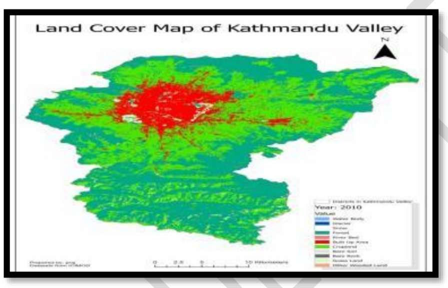

Land Cover Map of Kathmandu Valley

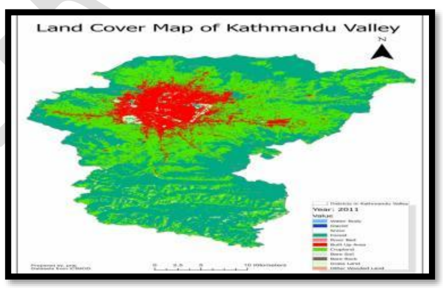

Land Cover Map of Kathmandu Valley

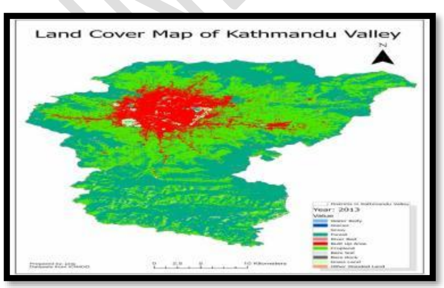

Land Cover Map of Kathmandu Valley

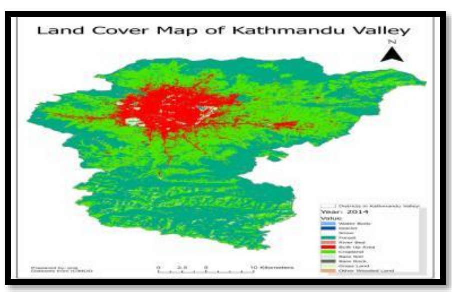

Land Cover Map of Kathmandu Valley


Land Cover Map of Kathmandu Valley


Land Cover Map of Kathmandu Valley


Land Cover Map of Kathmandu Valley


Land Cover Map of Kathmandu Valley


Land Cover Map of Kathmandu Valley

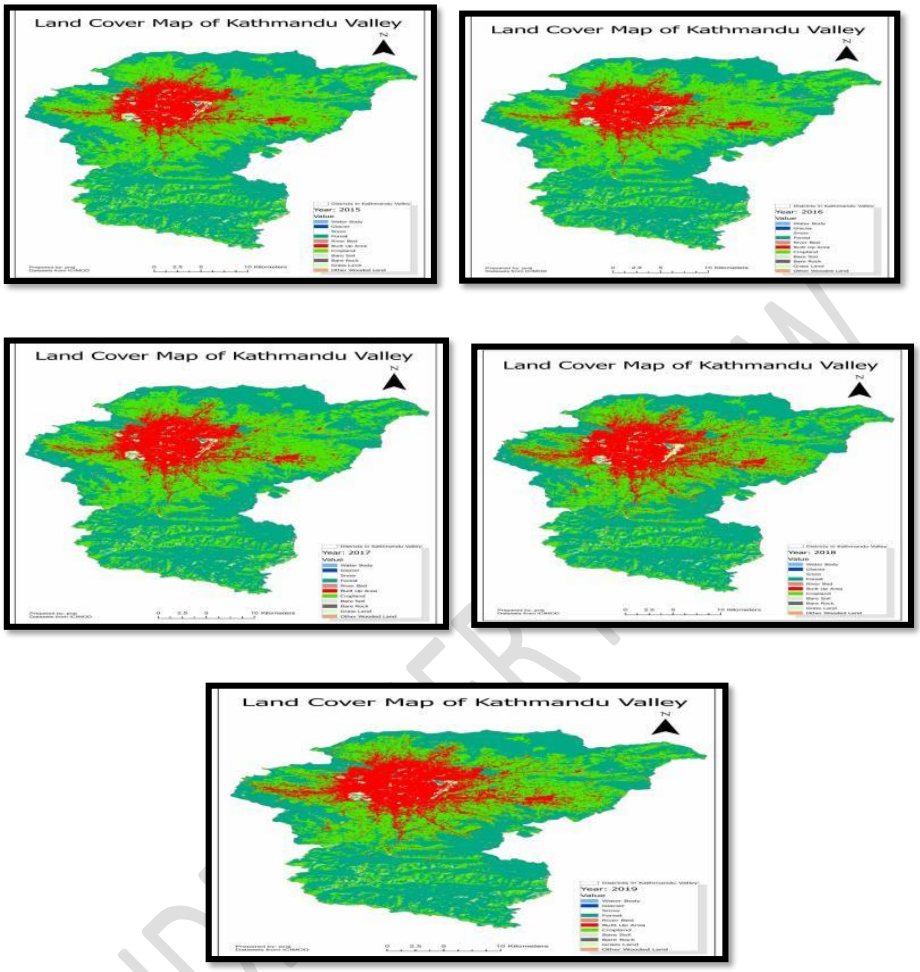


Figure.2 Spatial Dynamics of LULC of Kathmandu valley from image Analysis in ARC GIS of the years 2000 to 2019

Commented [NS13]: Mode of presentation for Figure 2 is not acceptable. Since it is year-on-year basis, authors can add the respective year to each figure in figure 2, and increase the font size of the text in each figure.
-Kindly remove the axis title header from each image 'Land cover Map of Kathmandu Valley' since there is a caption for the said figure.
-All the figures in Fig. 2 can be captured as one figure by reducing the sizes of each figure. Changes in each year could be traced since they have the same legend or description.
***Please place them on one layout tap and use just one legend, scale and direction for Figure 2. Increase the fonts of the text in Fig. 2 for readability. Ensure uniformity in other figures as well throughout the manuscript.

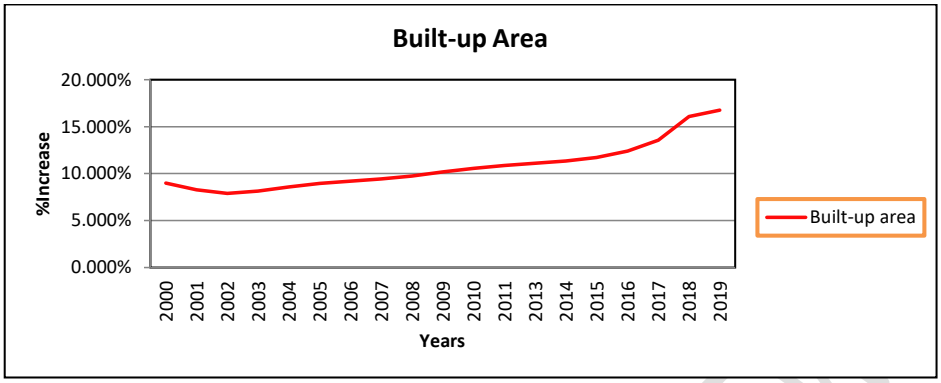


Figure3. Change Dynamics of Built up Area of Katmandu valley over 2000 to 2019

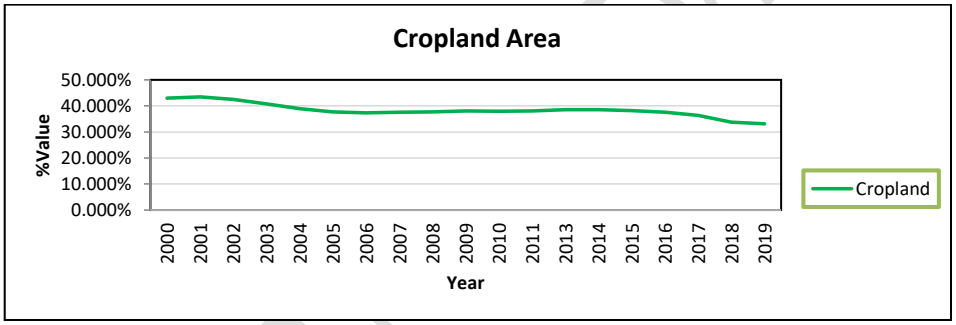


Figure4. Change Dynamics of Cropland in Kathmandu valley over the time period of 2000 to 2019

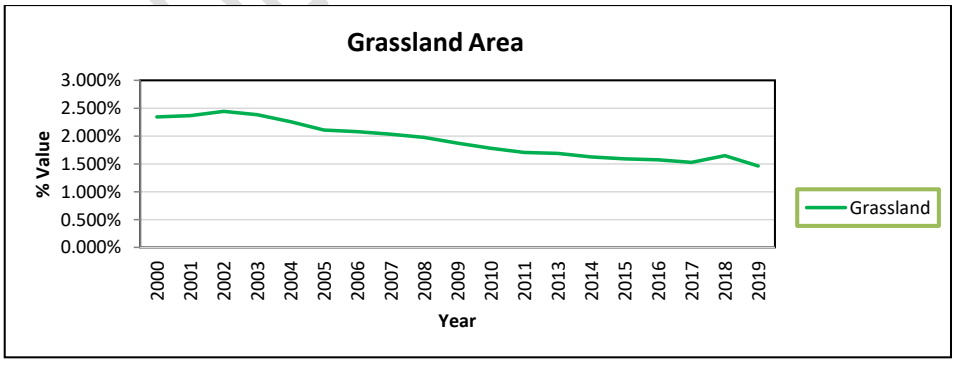


Figure5. Change Dynamics of Grass Land Area of Kathmandu Valley over the time period of 2000 to 2019

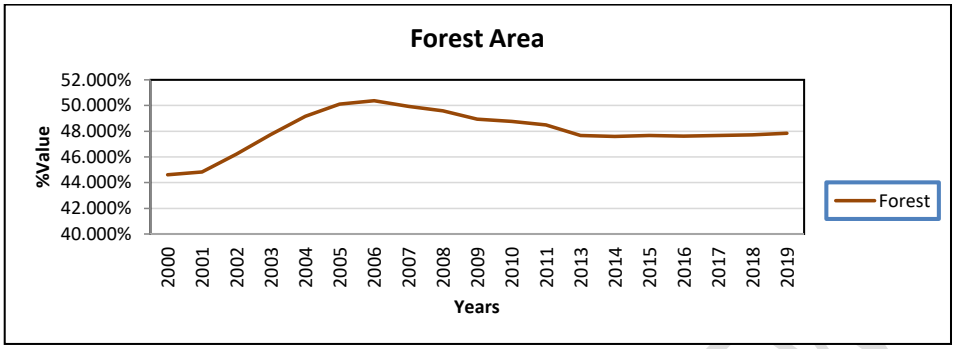


Figure 6. Change Dynamics of Forest area of Kathmandu valley over the time period of 2000 to 2019

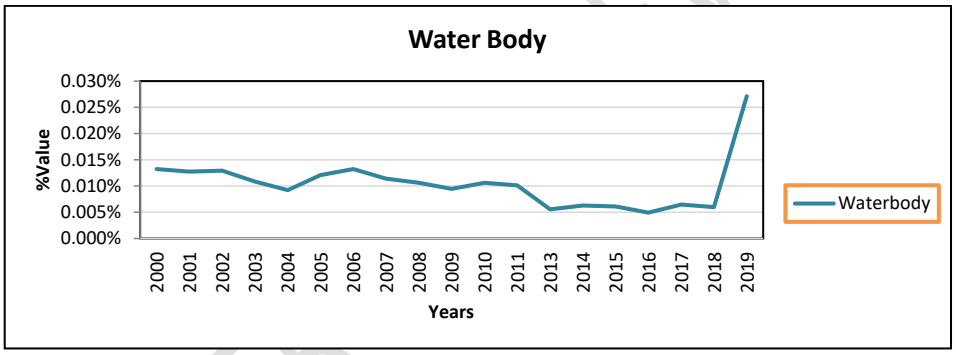


Figure7. Change Dynamics of Water Body in Kathmandu valley during the period of 2000 to 2019

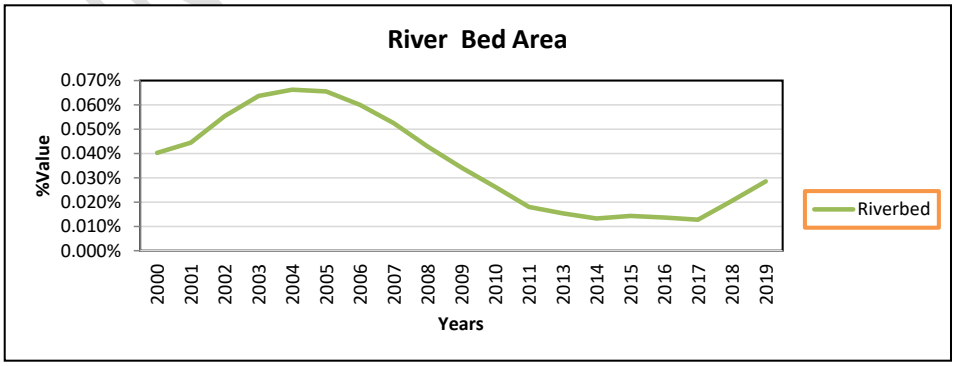


Figure 8. Change in river bed area in Kathmandu valley during the years 2000 to 2019

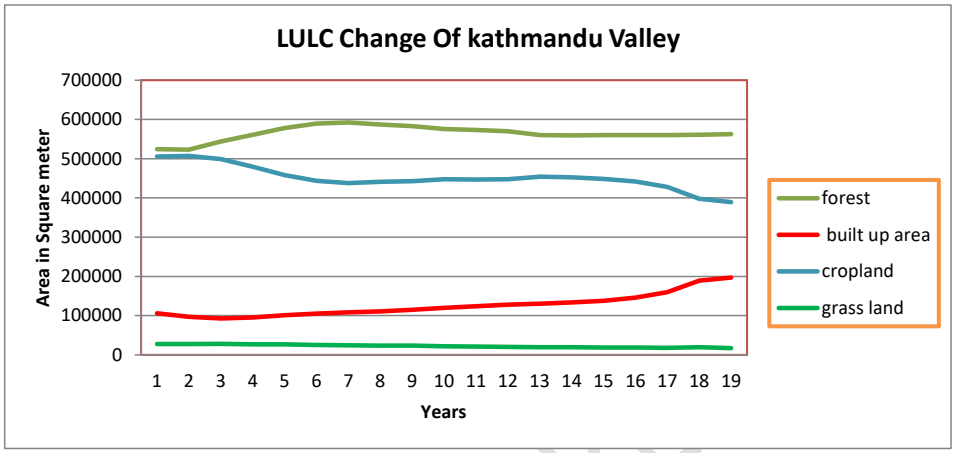


Figure 9. Spatial dynamics of LULC change in Kathmandu valley, a comparative result over the time period 2000 to 2019.

Commented [NS14]: -Fig.9 is more temporal than spatial. What's spatial about Fig.9. Please be mindful of your choice of terms. Again, how come there is no waterbody feature in Fig.9? Why does authors omit riverbed and water body features? Justification/correction/clarification is needed.

Discussion

Land use and land cover information contributes significantly on the study of agriculture and urban planning .The acquisition of the information can be effectively done using remote sensing technique. In this study Landsat 8 multispectral image with spatial resolution of 30 meter were used for temporal and spatial change dynamics analysis of Kathmandu valley, Nepal. The supervised classifications of the image on Arc GIS were carried out. The accuracy assessment for overall efficiency and kappa values for the selected time period were found within the acceptable range of required rating value for the model. From the analysis the change in agricultural land and built up area 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 2019 it is reduced significantly. With the increase in built up area the river bed areas are reduced due to which the natural river courses are affected. The reduction in grass land, water body, crop area and increased population that led to increase in spread 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 shows rise in maximum temperature

Commented [NS15]: **Discussions**:
-Kindly restructure or re-develop this into sub-sections to discuss findings based on the **changes; the driving forces by discussing the direct/indirect, spatial and aspatial factors linked to socio-cultural, political, economic and biophysical factors, as well as the consequences/implications**.
-The discussion section lacks more representative or relevant works. Refer to the studies I listed in the introduction and other ones in Asia or Nepal to improve the discussion section. Authors need to compare findings to existing literature within the study area and across the globe. Does the current study agree or refute existing findings? If not, what makes the current results different?
-Authors need to highlight the main events in some specific years under the driving forces sub-section like prolonged dryness, drought, floods, policy directives and so on which probably drove significant changes within the given study period.
-Again, hotspot analysis and locational changes must be indicated. Which specific areas within the Valley or in Nepal experienced significant changes and so on.

above 35 degree in summer which is unexpected and notable for Kathmandu valley. To prevent the city the LULC study has become an effective way to gather the information(Islam et al. 2018).

~~c~~Conclusions

In conclusion concerning the site and its study the satellite images of Landsat 8 and its analysis found easy and applicable tool for the interpretation , analysis of features and their real ground situations of any time period through supervised classification and unsupervised classification of area. And from the study there are some important recommendations based upon the results obtained from the analysis 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.

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

Commented [NS16]: Conclusions:
-Requires a thorough revision. Kindly begin by a brief introduction or rationale and summarize the main findings in 3-4 bulletins without quoting verbatim what has already been presented in the results/discussion sections.
-What are some of the study limitations or challenges and research opportunities that could drive future studies? I suggest you add a section captioned 'Limitations and future outlook/studies' and a 'Policy implications' sub-section to highlight the practical value of this study's outcomes.

Other comments:
-Major grammatical defects and syntax errors were identified throughout the manuscript. I suggest authors seek for the assistance of someone with command over English to improve the proficiency level of the paper.
-Clearly, there is still a lot of work to be done. Re-organization or restructuring is required to improve the scientific outlook of this paper.

Commented [NS17]: References:
-Authors need to adhere to the referencing style of the journal. There are several inconsistencies and inaccuracies in the given reference list.

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."

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.