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 analysis which give temporal and spatial dynamics of the 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 on Landsat imagery of the year 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 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 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 the land use/land cover map of Nepal (Khadka 2021) and elevation profile map of Kathmandu valley(Paudel et al. 2016).

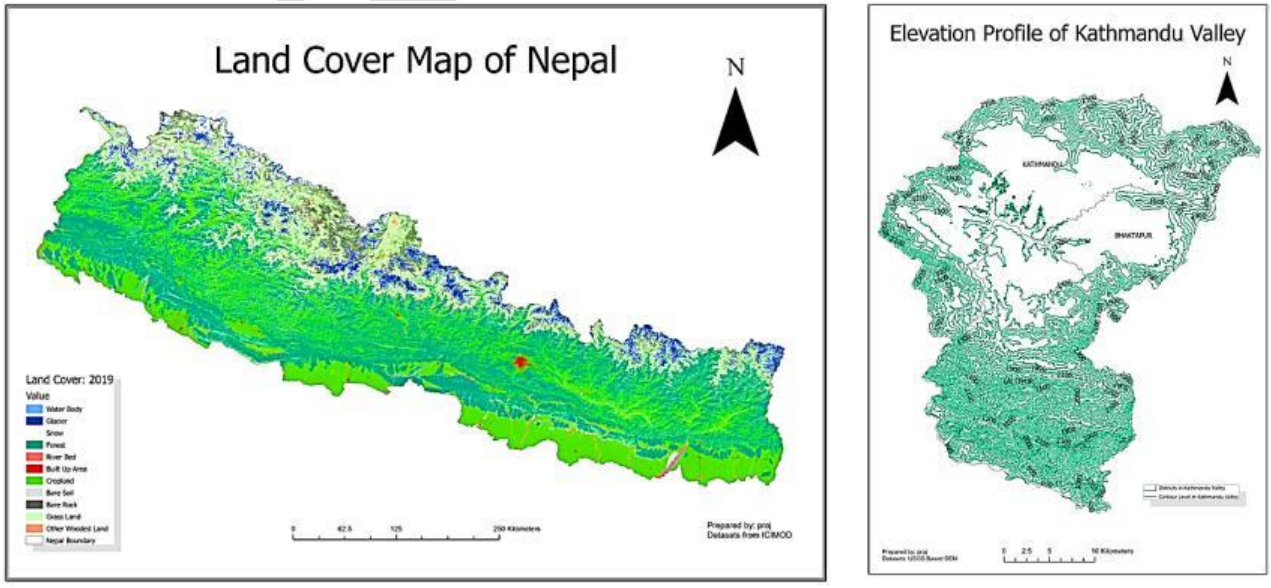


Figure1. LILC Map of Nepal and Elevation Profile Map of Kathmandu valley

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)

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

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

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.

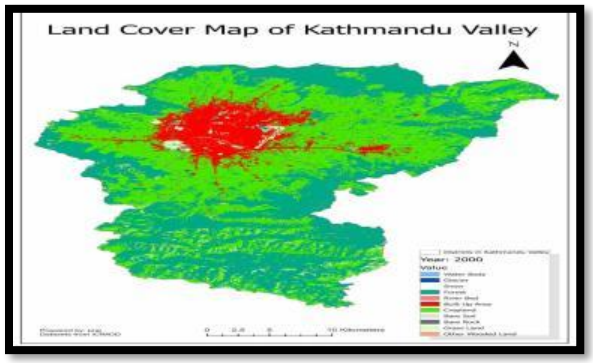
Table.1. LULC Area in square meter of Kathmandu Valley over the time period Selected.

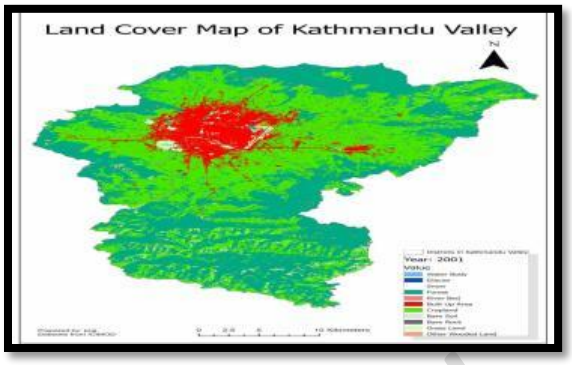
Year	Water Body	Forest	built up area	Crop Land	Grass Land	River Bed
2000	125	524557	105873	505693	27562	474
2001	145	523061	96557	507091	27584	519
2002	152	543620	92814	498980	28040	652
2003	128	561270	95693	479699	26536	748
2004	108	578019	101084	457867	26536	779
2005	142	589276	105309	443620	24808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

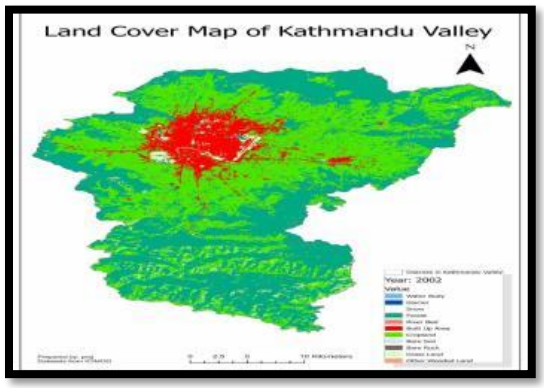
2006	156	592323	108000	438208	24420	705
2007	134	587101	110784	441338	23910	617
2008	135	582946	114646	443073	23209	504
2009	111	575346	119570	447632	22026	402
2010	125	573473	124231	446675	20944	309
2011	119	570290	127725	447460	20063	212
2013	65	560502	130614	454063	19836	180
2014	74	559532	133527	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
N
Year: 2000
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
Bare Rock
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers


Land Cover Map of Kathmandu Valley
N
Year: 2001
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
Bare Rock
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers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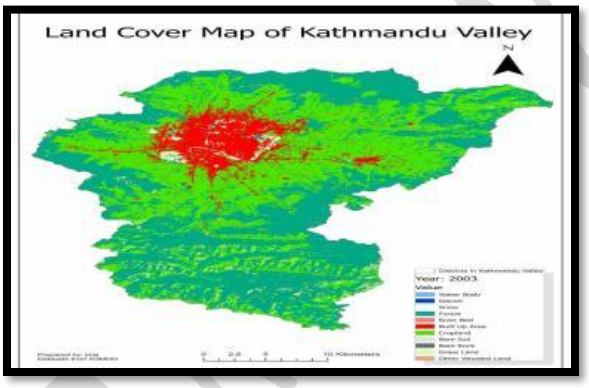
N
Year: 2002
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
Bare Rock
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers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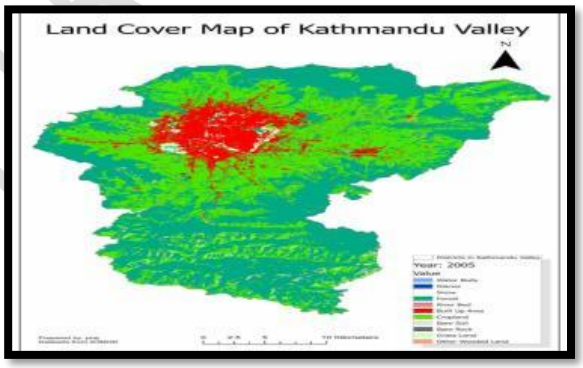
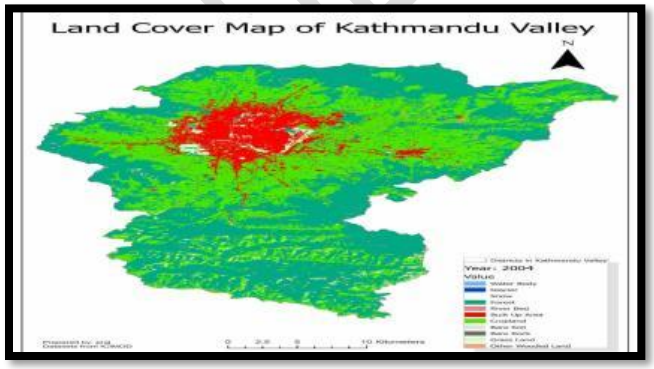
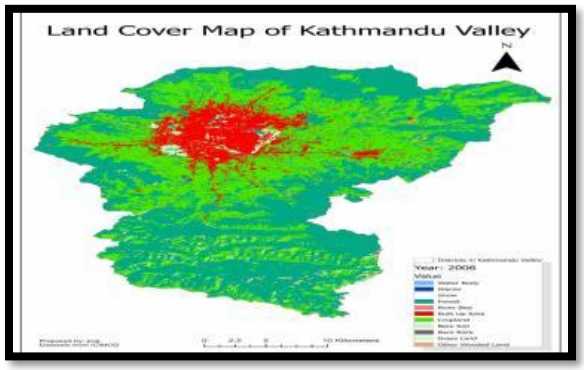
Year: 2003
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
Bare Rock
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers


Land Cover Map of Kathmandu Valley
N
Year: 2005
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
Bare Rock
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers


Land Cover Map of Kathmandu Valley
N
Year: 2006
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
Bare Rock
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers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N
Year: 2006
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
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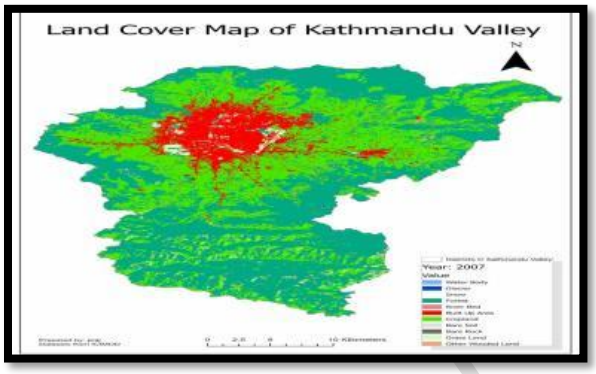
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers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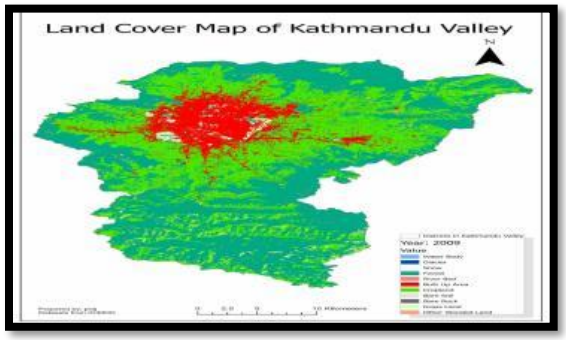
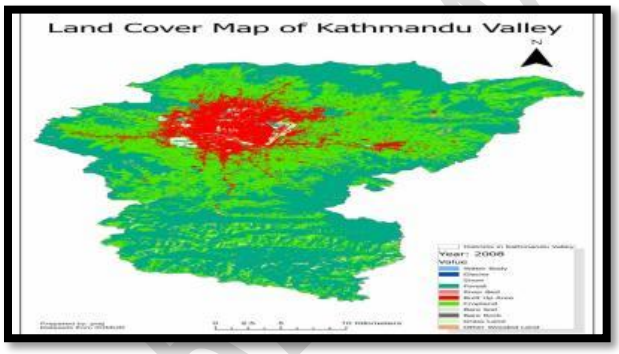
N
Year: 2007
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
Bare Rock
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers


Land Cover Map of Kathmandu Valley
N
Year: 2009
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
Bare Rock
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers


Land Cover Map of Kathmandu Valley
N
Year: 2008
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
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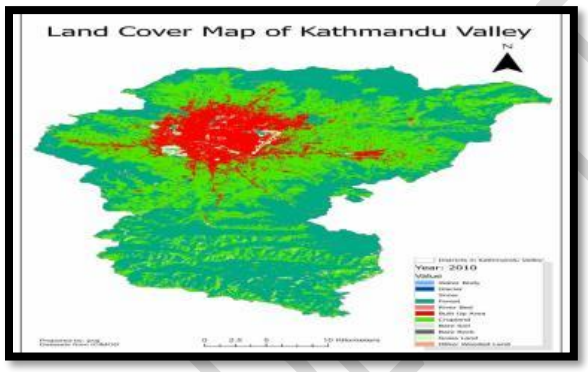
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers


Land Cover Map of Kathmandu Valley
N
Year: 2010
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
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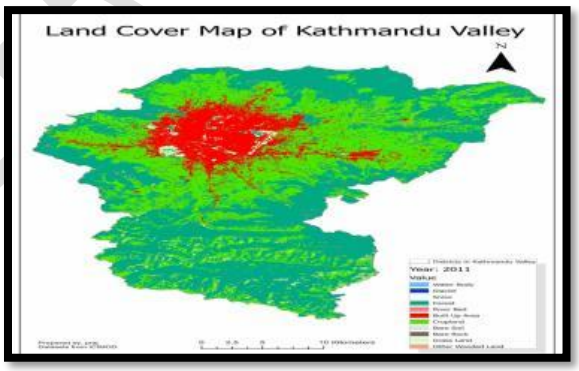
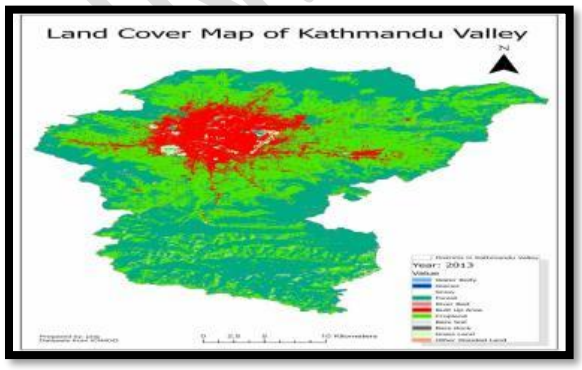
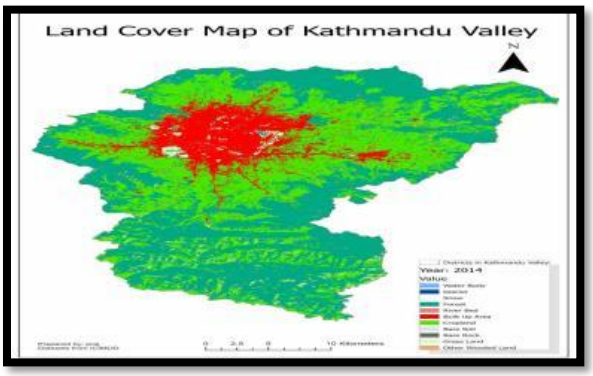
0 2.5 5 10 Kilometers


Land Cover Map of Kathmandu Valley
N
Year: 2011
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
Bare Rock
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers


Land Cover Map of Kathmandu Valley
N
Year: 2013
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
Bare Rock
Grass Land
Other Wooded Land
0 2.5 5 10 Kilometers


Land Cover Map of Kathmandu Valley
N
Year: 2014
Value
Water Body
Glacier
Snow
Forest
River Bed
Built Up Area
Cropland
Bare Soil
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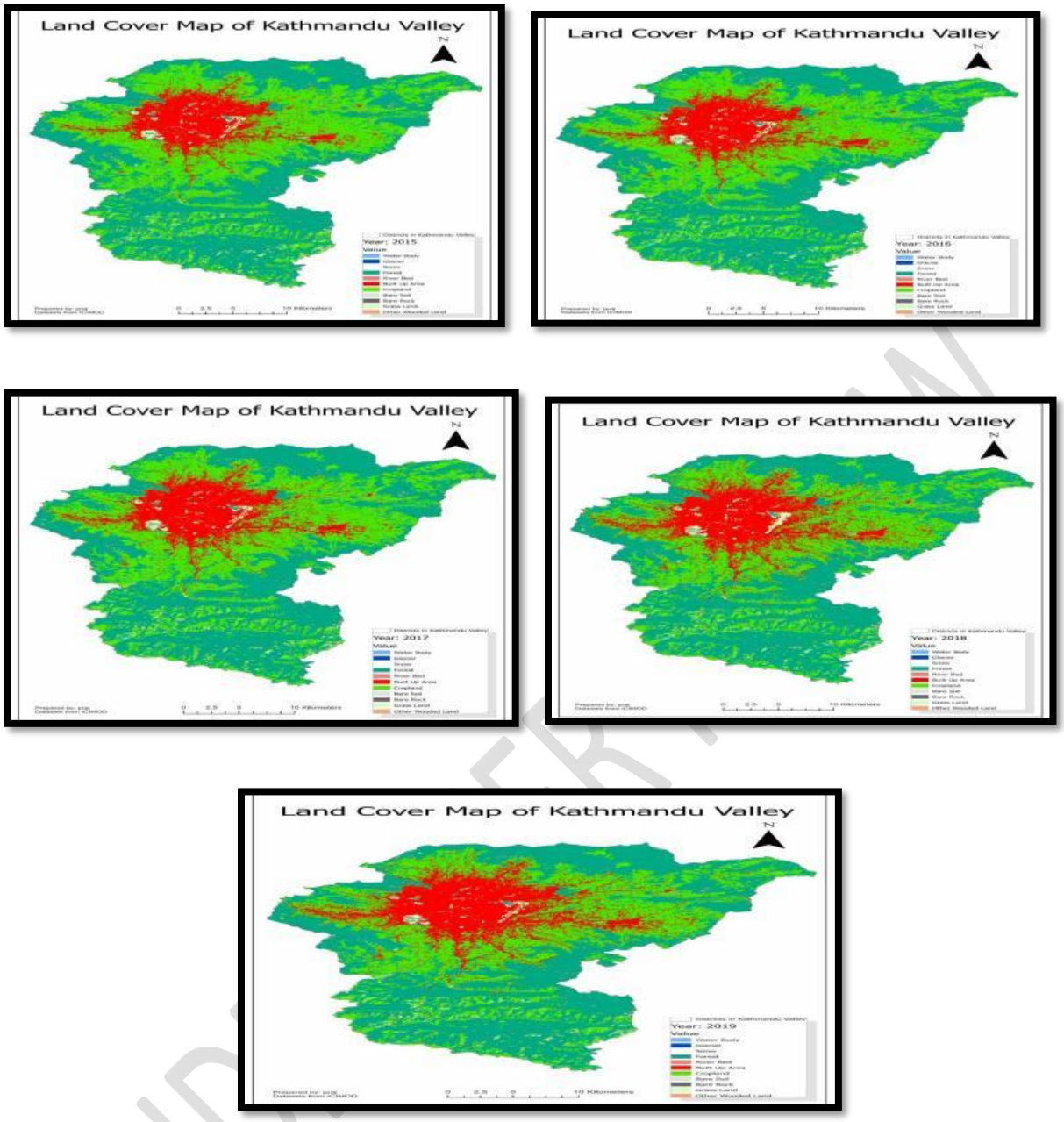

Figure.2 Spatial Dynamics of LULC of Kathmandu valley from image Analysis in ARC GIS of the years 2000 to 2019

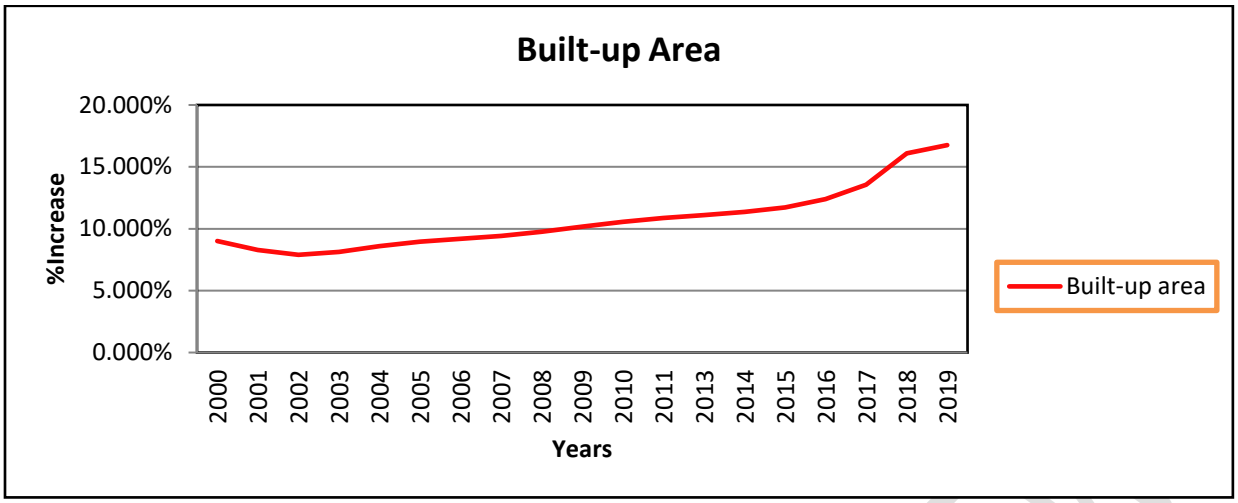

Figure3. Change Dynamics of Built up Area of Katmandu valley over 2000 to 2019

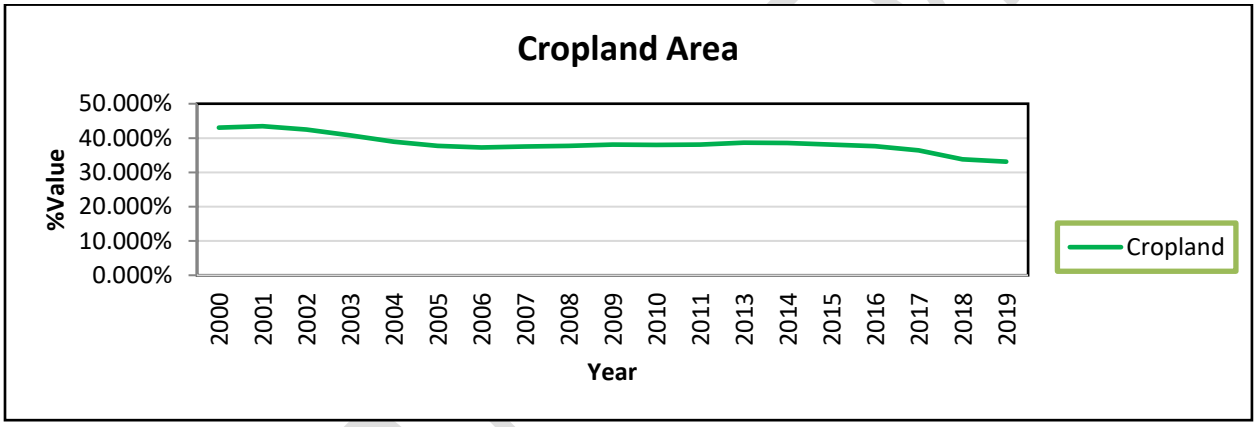

Figure4. Change Dynamics of Cropland in Kathmandu valley over the time period of 2000 to 2019

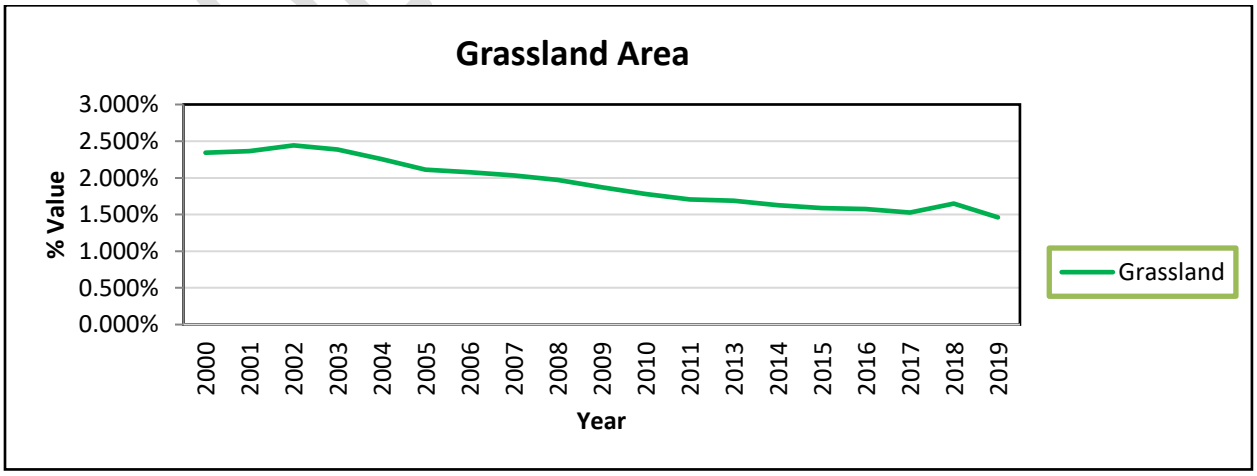

Figure5. Change Dynamics of Grass Land Area of Kathmandu Valley over the time period of 2000 to 2019

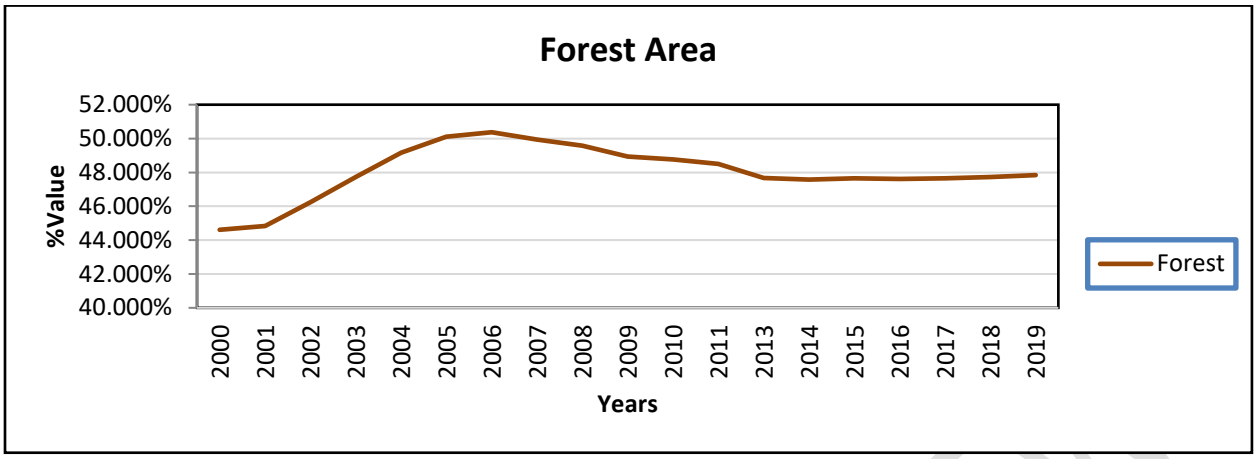

Figure 6. Change Dynamics of Forest area of Kathmandu valley over the time period of 2000 to 2019

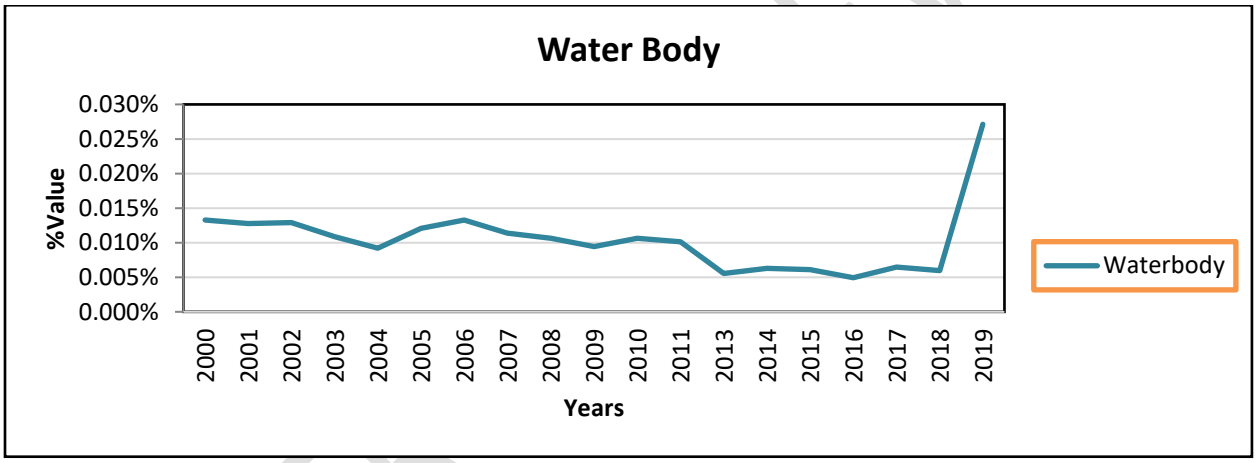

Figure7. Change Dynamics of Water Body in Kathmandu valley during the period of 2000 to 2019

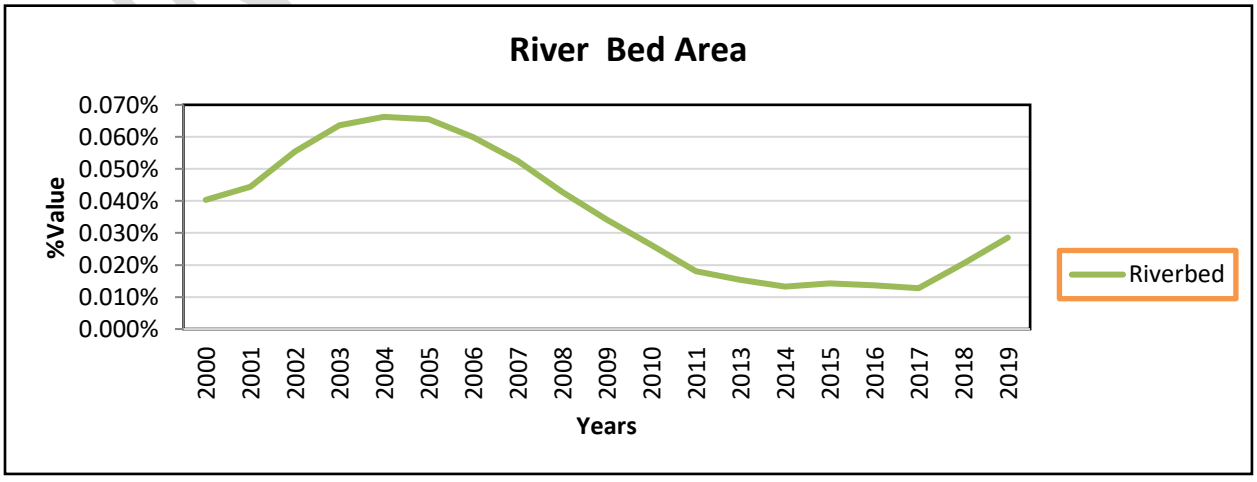

Figure 8. Change in river bed area in Kathmandu valley during the years 2000 to 2019

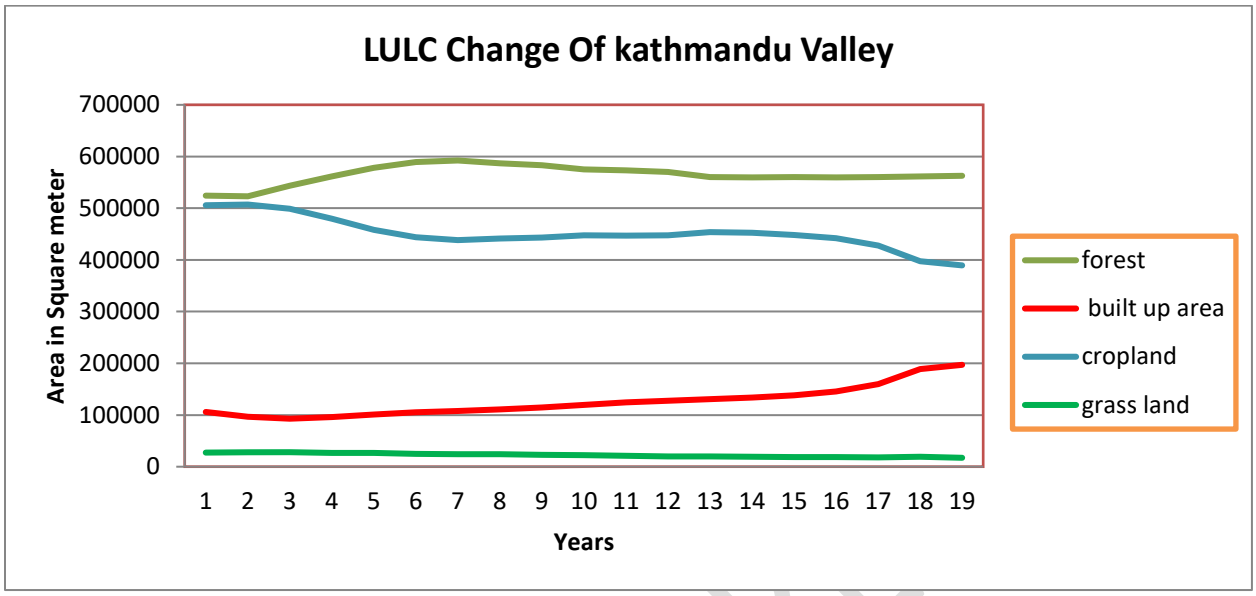

Figure 9. Spatial dynamics of LULC change in Kathmandu valley, a comparative result over the time period 2000 to 2019.

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

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).

conclusion

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.

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