Land use and Land Cover Change in Kabul, Afghanistan: Using Remote Sensing to Evaluate Urbanization Progress in Kabul

Abdul Hakim Nazari, Gao Fei

Abstract— **This paper presents and evaluates the LULC changes and urbanization in Kabul, Afghanistan. The study used satellite images, socio-economic data, and the information provided by the government of Afghanistan and published in their websites between the years 2000 to 2019.The maximum likelihood classification algorithm is used to classify related remote sensing images.**

Index Terms— **Kabul, Landuse and Landcover (LULC), Change detection, Envi and GIS, Urbanization**

I. INTRODUCTION

For the human society, urbanization is the most widespread anthropogenic cause of LULC (Lopez, Bocco, Mendoza, & Duhau, 2001,Dewan and Yamaguchi, 2009) and the inevitable outcome along with the rapid development(Zhang, Xia, Yu, 2018). Urbanization is playing a sideways influence of economic growth of any country and for the up-to-dated world, urbanization is a vital element(Nitin Mishra, Sanjeev Kummar & Bhaskar R. Nikam; 2019). In the early 1900s, urban populated area was just 15% in the world, while it's increased to over 50% in 2007 (United Nation, 2014) and it's known as an unprecedent rate in human history, but still only 3% of earth's surface is covered by urban area. Even though urban area covers only 3% of earth surface, they had marked global and local effects on environmental conditions (Herold, Goldstein, & Clarke, 2003; Liu & Lathrop, 2002) including hydrologic and hydraulic processes (Zope, Eldho, Jothiprakash, 2016), waterlogging, water shortage, pollution, and urban heat island (Zhang, Xia, Yu, 2018; Xia, 2017), and climate change (Yin, Zhong, Xu; 2010).

Migration of people is a reason for urbanization (P.E. Zope, T.I. Eldho, V. Jothipraksash; 2016).Since 2001, after 9/11 event in which NATO withdrew Taliban regime from Afghanistan and returned a better situation for Afghans to live in peace, a lot people left rural areas toward big cities, at the same time thousands of Afghan immigrants from other countries returned back home, for instance the population in Kabul increased from 1.5million in 2001 to 4.5 million in 2007 (Koser;2007, Majidi;2011) which caused an unprecedent LULC change in Kabul.Therefore it is needed to examine and evaluate the state and trend of urban LULC change, so that the policy makers can avoid the harmness of unplanned urbanization.

Manuscript received April 11, 2020

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At over 40 years, the Landsat Satellites provide the longest temporal record of space-based land surface observations(Roy, Kovalskyy, Zhang; 2016), surface obseravation or LULC change detection is one of the extensively evaluated discussion for detecting and anaylyzing urbanization progress.The powerful, widely applied and cost-effective tools which can accomplish this target is a combined utilization of Geographic Information System (GIS), Global Positioning System (GPS) and Remot Sensing (RS) operations altogether(Hathout 2002, Herold et al.2003, Yin, Zhong, Xu;2010)

Recently a variety of change detection techniques and algorithms have been developed and reviewed for their advantage and disadvatages.Among the numerous change detection technology methods, supervised classification, unsupervised classification, hybrid classification and fuzzy classification are the most commonly applied techniques used in classification (But, Shabbir, Ahmad, Aziz; 2015, Lu et al., 2004, Rundquist et al., 2001; zhang et al., 2000).

In this reseach the main objective was to utilize GIS and Remote Sensing application to evaluate, explore and observe the characteristic of LULC changes in Kabul, Afghanistan over 19 years' time period, and it specifically include:

(1) To provide historical and recent land cover/use maps via integration of supervised maximum likelihood classification and visual interpretation of remote sensing data.
(2)To assess dynamic changes of urbanization phenomena, ecosystem and the factors of LULC from 2000 to 2019.
(3) Provide suggestions to meliorate the LULC changes progresses.

II. STUDY AREA

Our selected region of interest for the current study is Kabul city which is located around 34° 32' 38.0256" N and 69° 9' 38.3472" E GPS point at an altitude of 1800 m (6000 feet) above sea level, which makes it one of the world's highest capital cities. as it's shown in figure1. Kabul is the capital of Afghanistan, a country in middle east which have been politically crowded during last decades. Kabul is a city with 4585 km^2 area and over 6 million population located between Parwan, Kapisa, Laghman, Nangarhar, Logar and Maidan provinces which topographically the flat area contains only 37.7% of it's total area. Afghanistan is located in a semi-dry region where the winter snowfall in high-altitude mountains are the origins of life-supporting river systems (Najmuddin, Deng, Bhattacharya, 2018) and the average annual temperature is 11.4 °C. About 362 mm of precipitation falls annually.

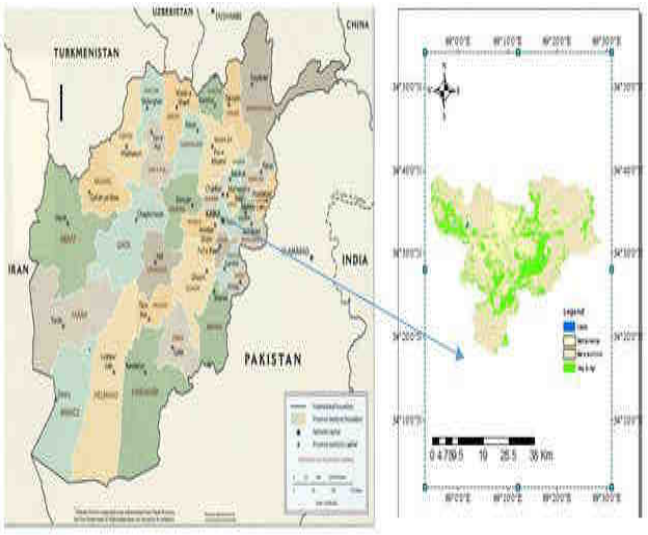

Figure1. Study Area

III. METHODOLOGY

3.1 Data collection

In this study we used satellite data and secondary data, the satellite data which we used include are two multispectral satellite images from Landsat5 (TM) and Landsat8 (OLI) to evaluate LULC changes between the year's 2000 to 2019, the satellite data used in this study was provided by united states geological survey (USGS) (https://earthexplorer.usgs.gov), and the secondary data which included ground truth data, aerial photographs, and topographic maps, among these the ground truth data which is collected using GPS in the form of points is used for overall accuracy assessment, georeferencing and classification.

Table.1 Satellite data specifications

Data	year of acquisition	Bands/Colors	Resolution (m)	Source
Landsat 5 TM	2000	Multi-spectral	30	USGS
Landsat8 (OLI)	2019	Multi-spectral	30	USGS

3.2 Atmospheric correction and Data Resizing

Atmospheric correction can significantly improve the interpretability and use of an image. All atmospheric corrections procedures were performed while using the module implemented in ENVI software, and the steps repeated to cover scenes for both years analyzed. The images were then resized to selected regions of interest across the study area.

From two methods of atmospheric correction which are physical atmospheric correction and image-based atmospheric correction we used image-based atmospheric correction; image-based atmospheric correction subsequently contains two other sub methods which are dark object substratin (DOS) and empirical line (ELM) methods of atmospheric corrections.

In this peace of work we used DOS method for a better result as it's explained in (Majeed Nazeer, Janet E. Nichol and Ying-Kit Yung).

3.3 Noise Reduction

Noise can be effectively removed from multispectral data by transforming to the MNF space, smoothing or rejecting the most noisy components, and transforming to the original space(Green, Berman, Switzer, Craig; 1988).

The minimum noise fraction (MNF) transform is a linear transformation that transform as modified from Green et al. (1988) and implemented in ENVI,this application consists of the following separate principal components analysis rotations:

- First rotation (noise whitening process),uses the principal components of the noise covariance matrix to decorrelate and rescale the noise in the data.
- Second rotation uses the principal components derived from the original image data after they have been noise-whitened by the first rotation and rescaled by the noise standard deviation, Since further spectral processing will occur, the inherent dimensionality of the data is determined by examining the final eigenvalues and the associated images.Then we can divide the data space into two parts: one part associated with large eigenvalues and coherent eigenimages, and a complementary part with near-unity eigenvalues and noise-dominated images. Using only the coherent portions separates the noise from the data, thus improving spectral processing results.

ENVI has the option of applying an MNF transform to individual spectra.

3.4 Image pre-processing

The landsat images acquired for the years 2000 and 2019 were covered by less than 10% cloud and the acquisition dates for the landsat images is chosen to be September. The whole region of interest was classified by assigning each image cell to the training sample category of the highest probability of match. On average, 60 training samples were created for each land use category.

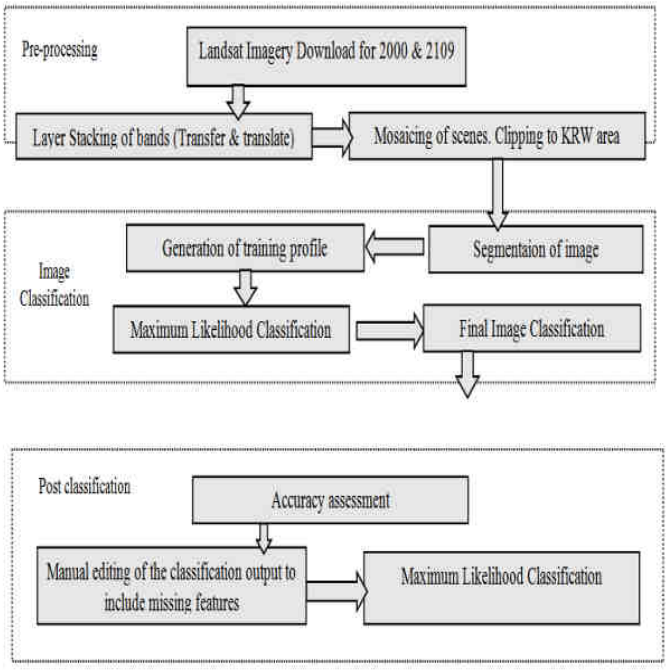

Fig.2 the flowchart indicating image processing steps.

3.5 Supervised Classification

Among supervised classification methods the maximum likelihood method is a well known and widely used one. This classification uses the training data by estimating and variances of the classes, which are used to estimate probabilities and also consider the variability of brightness values in each class.

Supervised classification uses the spectral signatures obtained from training samples to classify an image. With the assistance of the Image Classification toolbar, ArcGIS can easily create training samples to represent the classes we want to extract. We can also easily create a signature file from the training samples, which is then used by the multivariate classification tools to classify the image

supervised classification method can be accomplished based on Bayesian probability theory and when the training data is provided accurately this classification method can bethe most powerful classification method. (K Peumal & R Bhaskaran 2010).

Baysian classification is a probabilistic technique which is capable of classifying every pattern until there is no more unclassified patterns remain, Baysian methods take the parameters as random variables with known prior distribution. this method is compared with It's based on Bay's classifiers, moreover, Bayes' classifier assumes that presence of a particular feauture of a class unrelated to the presence of any other feauture. It estimates the occurance of different attribute values for the different classes in training set. It then uses these probabilities to classify recall paterns. (Ratika Pradhan, M.K. Ghose, A. Jeyaram. 2010)

Table.2 Description for the classified catagories

Sr. No.	Class name	Description
1	Built up Area	Land modified by humans such as habitation, industrial and mining area, transportation etc
2	Vegetation	Agricultural area, forest, Shrubs and grassland.
3	Barren Land	Areas with less than 10% vegetation contains rocks, sands, stone and hard soil.
4	Water	Visible Water surface, lake and dam.

3.6 Post processing tasks

Smooth out boundries between classified categories, removing noise which misclassified isolated pixels produced are what is required in Post processing (Stanely, Omar, Josiah, William and Carlos 2018).

Post-classification processing refers to the process of removing the noise and improving the quality of the classified output and the processing classified outputs are as follows in general:

- Filitering the classified outputs. (Majority filter tools in ArcGIS)
- Smoothing class boundries and clamps the classes. (Boundary clean tools)
- Generalizing classified output by removing small isolated regions. (Region group tools).

3.7 Land cover/ Land use change detection

Post classification change detection method is used to observe the LULC changes in the current work. And overlay procedure using the ArcGIS was adopted in order to obtain the spatial changes in LULC during 2000-2019. Application of this technique resulted in a two-way cross-matrix obtained by the application of this technicque was used to describe the main types of change in the study area. A cross tabulation analysiss on a pixel-by-pixel basis was conducted todetermine the quantity of conversions from a particular land cover to the others counted in catagories over the evaluated period.

IV. Results and Discussion

4.1. Accuracy assessment:

Assessment of classification accuracy for 2000 and 2019 images was carried out to determine the quality of information derived from the data. The results showed that the achieved overall classification accuracies were 85% which matches the least required accuracy in (Stanely Mobako, Omar, Josiah, William and Carlos; 2018).

Table3. A crosstabulation matrix table for classified LULC.

		Land Use 2019				
	C.C	Barren Land	Built Up Area	Vegetation	Water	Grand Total
Land Use 2000	Barren Land	54449.99	10549.83	446.9324	16.13851	65462.8942
	Built Up Area	147.3085	21152.22	140.7015	0.088146	21440.3202
	Vegetation	298.8824	4430.55	10914.03	0.319878	15643.78139
	Water	45.34465	290.3936	33.96141	102.3219	472.021585
	Grand Total	54941.53	36423	11535.62	118.8685	103019.0174

4.2 Land use/ Land cover change

the classified LULC map of Kabul city for the years 2000 and 2019 is given in Fig3. and related to that Table4. shows the classification results summary. Afghanistan is a landlocked country with less annually precipitation, therefore the predominant class in the catagories is barren land, However, the observation shows that barren land reduced from 63% in 2000 to 53% in 2019. Conversely, Built_up area has a 15% increment, from 20% in 2000 to 35% in 2019.

Table 4. LULC change details for the years 2000 and 2019.

Land cover/ use classes	2000		2019	
	Area (in hectares)	Percent (%)	Area (in hectares)	Percent (%)
Built Up Area	21332.79	20.70221	36405.63	35.32951
Vegetaion	15831	15.36305	11643.93	11.29975
Barren Land	65345.67	63.41411	54874.8	53.25275
Water	536.49	0.520632	121.59	0.117996

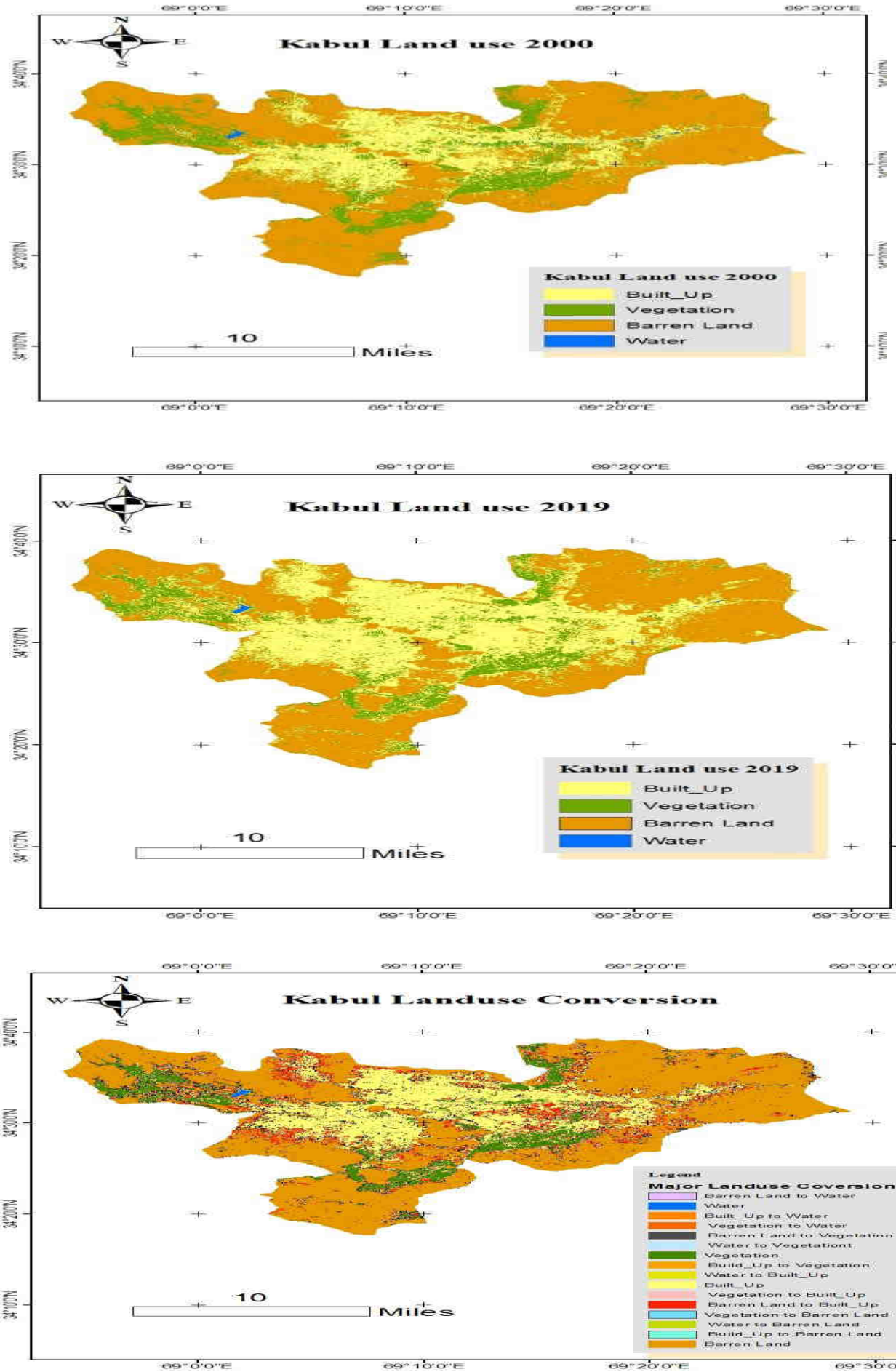

Fig.3. classified landuse/Cover and conversion maps of Kabul city in 2000 and 2019

Two other important life factors, the Water and Vegetation has decrement, in 2000, Kabul land was covered 15% by natural and semi natural vegetated area, meanwile 0.5% of the land was covered by water body, but in 2019, vegetated area decreased to 11% of the land cover and water decreased to 0.1% (120 Ha) respectively.

4.3 Urbanization

Different factors are mentioned to be the reason of LULC changes, LULC is constantly changing because of different reasons, the factors influencing LULC can happen physically, socially and economically, taken from mentioned factors the most effective factor causes land use change in Kabul is the gowth of the residential area or urbanization.

Every year a great volume of agricultural land is being coverted to urban land (Osama Hidayat, Yoshitaka Kajita,2019). LULC analyzer's researches show that most of LULC changes occurred in developing countries, among them Kabul city is one of the fastest growing city in the world (Guardian, 2014) and this include increment of population also, for instance, Kabul population increased from 1.78 million in 1999 (Noori, 2010) to 6 million in 2014 (the guardian, 2014; Haroon Nazire, Michihiro, Seth, Shigeki, 2016). This sudden change happened after the fall of Taliban regime in 2001, besides, there was one more reason that at the same time a lot of Afghan immigrants and people seeking for job entered to big cities, specially in Kabul, it was not only because a new peaceful Afghanistan, but also to search for employment and other economic opportunities.

Thus, an unprecident increase in population and urban expansion government faced with a huge challeng of management.

4.4 Development of Informal Settlements in Kabul City

Kabul, a city of approximately 6 million people, has been undergoing rapid urbanisation for the last three decades, Kabul population was increased with mostly by those who immigraged to other countries during Afghanistan civil war, only 20% of the city master plan is applied to the city and the rest 70% of Kabul residents live in informal settlements(Paul collier, IGC, 2018)

As a resident of Kabul city, I strongly believe Kabul informal settlements can make a very big issue for the Afghan future governers, for instance, around 1 million of Kabul residents are living in 13th district of Kabul 15 districts (Fig.4) which have only one low capacity road to service entry into the entire district and it causes a big traffic jam during morning and evening traffic times.

Evidence from Latin America suggests that retrofitting infrastructure after settlement has occurred can be up to three times more expensive than installation alongside housing construction.

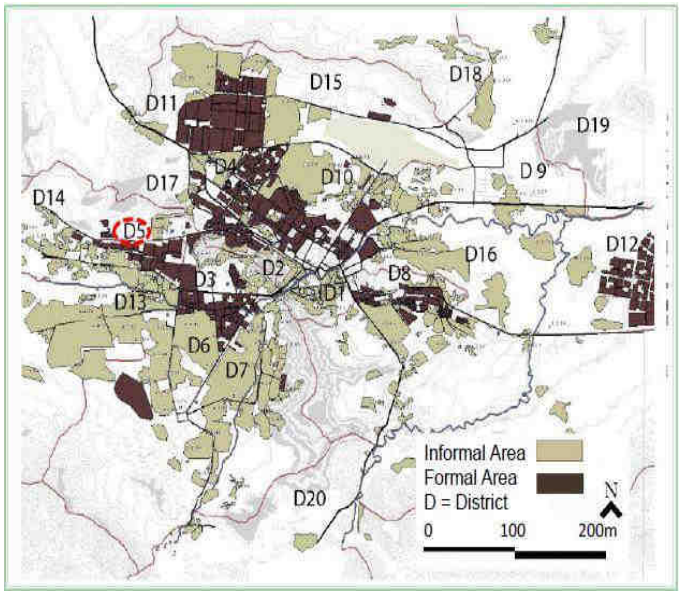

Fig.4: Kabul City Different district's Formal and Informal development.

CONCLUSION

In this study GIS and Remote sensing technology is used to assess and observe land use and land changes in rapidly growing and arid environment of Afghanistan, Kabul city. Results in this study show that a lot LULC changes happened in Kabul city, specially the urban area increased from 20% in 2000 to 35% in 2019 of it's total area. Unplanned increment urban area in Kabul city caused a lot troubles to the environmental factors like water, vegetation, and air pollution.

We end this study with highlighting some points which need Immediate attention, one big challenge for Kabul environment protectors is vegetation areas increament,and water resources management. Urban vegetation can keep cities cool, acts as a natural filter and noise absorber (Chandra Kant pawe & Anup Saikia;2017, Patarkalashvili; 2017).

To decrease the negative impacts of urbanization it's needed to ask policy makers, staffs of urban planning and international stakeholders to take it in consideration that Kabul unplanned urban area is unprecedently growing up while there is no strong urban infrastructure is existed.

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