Centre for Research on Settlements and Urbanism

Journal of Settlements and Spatial Planning

Journal homepage: http://jssp.reviste.ubbcluj.ro/eng/index.html

Investigating Land Use Change in Kabul, Afghanistan

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DOI: 10.24193/JSSP.2022.2.01 https://doi.org/10.24193/JSSP.2022.2.01

K e y w o r d s: *urbanization, land use, environment, informal settlement, LULC, remote sensing, Kabul*

A B S T R A C T

Land use change and land cover are considered as some of the important and effective factors of global environmental change. Therefore, understanding and predicting the causes, processes, and consequences of land use change has become a major global challenge. Kabul is the most populated city in Afghanistan. The face of Kabul has changed after a relatively peaceful period since 2001. The purpose of this study is to analyze land use change in Kabul from 2001 to 2019. We used the quantitative approach to analyse data provided by satellite images of Kabul in 2001 and 2019 from Landsat 8 and 7. Data was processed in ERDAS IMAGINE and Arc Map software to results in the final output. Urban land cover was classified into four classes, namely built-up area, green area, empty space, and mountain, and land cover changes were detected. The results of the image comparison between 2001 and 2019 show that the aggregated built-up area and empty space land cover increased by 69.1749 sq km and, correspondingly, 45.2538 sq km, whereas the green area decreased by 113.4216 sq km. We concluded that land cover has changed improperly. The rate of urban green space per individual is currently very low. These results indicate that the city is in a critical urban situation and the government should provide a comprehensive plan for controlling urban growth and fixing the problems caused by improper land use change in the city.

1. INTRODUCTION

Land use and land cover (LULC) is a key indicator of global environmental change and it is a basic index for the study of the changes that humans make in the physical environment. Interventions are changes in land use and land cover. LULC represents the naturally and artificially distributed features on the Earth's surface, such as forest vegetation, water bodies, and human structures (Mahmon et al., 2015). Researchers have identified the effects of LULC changes on the physical world and human society (Zhang et al., 2022; Lawler et al., 2014; Lambin et al., 2001; McDonald et al., 2019; Gallart and Llorens, 2003; Atasoy, 2020; Arowolo and Deng, 2018). For instance, across the tropics, between 1980 and 2000, more than 55% of new agricultural land came at the expense of intact forests and another 28% came from disturbed forests (Gibbs et al., 2010).

Changes in LULC influence ecosystem services by increasing the availability of certain services, while reducing other services that influence the ability of the biosystem to support human needs, further effecting ecological degradation (Polasky et al., 2011, Hussaini et all et al., 2022). Studies showed that 1% of land conversion led to an average change in ESV of 0.10% during the period of 2000–2008, in China (Song and Deng, 2017). With the acceleration of industrialization, village dwellers have moved to and settled in cities for the improvement of their livelihood. As a result, many small and medium-sized cities (SMCs) have expanded rapidly (UNDESA, 2018; Zanganeh Shahraki et al., 2020). The rapid urbanization, excessive building construction and population density, the loss of public facilities, and the unparalleled demand for infrastructure development have put pressure on the sustainability of cities (Ali et al., 2019). Urban management follows policies, plans, programs, and procedures seeking to ensure coordination between population growth and access to basic infrastructure, and housing (Hosseini et al., 2022, Safdari and Farhadi, 2019). The study of urban growth is a branch of urban geography that focuses on cities and towns in terms of their physical and demographic expansion (Bhatta and Saraswati, 2010). As a complex system, urban growth is affected by human and non-human parameters. Spatio-temporal dynamics and the incorporation of human drivers have the greatest impact on land use change (Veldkamp and Lambin, 2001). The study of urban growth has made significant progress in the last few years and includes various aspects, one of which is the emphasis on urban land use growth. Triggered by increasing population and urban expansion, LULC has experienced development both locally and globally during the last half-century; and LULC growth is expected to continue in the coming decades (Fang et al., 2005). Urban land-cover change threatens biodiversity and affects ecosystem productivity through the loss of habitat, biomass, and carbon storage.

However, despite projections that world urban population will increase to nearly 5 billion by 2030, little is known about the future locations, magnitudes, and rates of urban expansion (Seto et al., 2012). Urban growth and land-use changes have occurred in most cities all around the world. The global urban population is expected to grow by approximately 1.84% per year between 2015 and 2020, by 1.63% per year between 2020 and 2025, and by 1.44% per year between 2025 and 2030 (Knorr et al., 2019). Although cities grow over time and have a tendency to grow, it cannot be said that cities grow in the same way and at the same speed (Duranton and Puga, 2013).

The development of any city should be based on the principles of sustainability. Sustainable development implies a strategy that manages all natural and human assets and resources, such as financial and physical resources, to increase wealth in the long term. Sustainable development is opposed to any policy or practice that somehow endangers the interests of future generations (Tosun, 2001; Quinn, 2006, Safdari Molan et al., 2021, Farhadi et al., 2022).

Although many studies have been conducted to explore rapid urbanization, most studies on remotely sensing urban expansion have focused on high- or middle-income countries such as the U.S. or China (Reba and Seto, 2020). For instance, a study in the state of Montana (USA) shows that land use changes in this area were modeled linearly between 1860 and 2000. The database created for this modelling included environmental, socio-economic and spatial change information parameters; the data in this large set was comparatively analyzed to show the continuous changes from agricultural and forest lands to urban uses or other types of agricultural uses (Aspinall, 2003). Remote sensing provides reliable, consistent, and long-term data sources to monitor the LULC change. Scholars have employed remote sensing imagery to study the changing urban environment and model urban growth (Dewan and Yamaguchi, 2009; Yuan, 2008; Wulder et al., 2008; Zhu and Woodcock, 2014).

Land use/cover change in Dhaka Metropolitan of Bangladesh showed that between 1960 and 2005 built-up areas increased by approximately 15,924 ha, while agricultural land decreased by 7,614 ha, vegetation decreased by 2,336 ha, wetland/lowland decreased by 6,385 ha, and water bodies decreased by about 864 ha. The amount of urban land increased from 11% (in 1960) to 344% in 2005 (Dewan and Yamaguchi, 2009). The results of research in Mankato, USA shows that from 1971 to 2003, urban impervious surfaces increased from 18.3% to 32.6%, while cropland and grassland decreased from 54.2% to 39.1%. The dramatic urbanization caused evident environmental impacts in terms of runoff and water quality, whereas the annual air pollution removal rate and carbon storage /sequestration remained consistent since urban forests were steady over the 32-year span (Yuan, 2008).

In the beginning, Afghanistan was largely rural. Afghanistan's cities have had a growing trend during history. Kabul has been the capital of Afghanistan since 1776 and has faced various events during its history. The most important event that affected Kabul in recent decades is the war in the country. Afghanistan was involved in the 1979-1988 war, and then again in the civil war from 1996 to 2001. During war situations, many people immigrated to other countries because of the insecurity and economic and political uncertainty. The large cities, especially Kabul, were involved in the war. Many people left their homes, whilst many houses and infrastructure elements were destroyed. Since 2001, the relative peace in Afghanistan has encouraged many of the emigrated people to come back to the country. Also, Kabul has the highest potential for attracting immigrants from other cities and other countries. Kabul's population was of approximately 1.5 million in 2001. With an increase of up to 4,114,000 people in 2020, Kabul has become one of the world's fastest-growing cities (Zanganeh Shahraki et al., 2020).

Unfortunately, there are many gaps in the master plan of Kabul, which do not offer applicable solutions to the current issues. Also, the city's growth has not followed the provisions of the master plan of Kabul. The lack of attention to the high population density in region 13, the lack of attention to the flooding of roads, the lack of a plan for streets with narrow and inappropriate width, the lack of attention to the insufficient parks in different areas, the lack of plans to build houses on the mountain are some of the most significant deficiencies of the master plan of Kabul city.

As a result, the city has undergone unplanned growth. Many incompatible land uses are located in the immediate proximity. We can note the mixture of industrial and residential land uses in some central parts of the city. Many agricultural lands were converted to residential. Kabul is a non-resilience city, which is a major part of this issue because of improper land use changes in the city. For example, mountains that become urban environments with inappropriate slopes are vulnerable to various types of damage such as floods, earthquakes, and landslides. Therefore, observing land cover change patterns will help us make better decisions and plan for urban resilience[1].

The purpose of this research paper is to investigate land use change in Kabul, Afghanistan, from 2001 to 2019, up by showing the amount of land use changes in these years. Results can be useful for managers and planners of Kabul city to pay attention to the environmental planning of this city, to reduce the risk of destruction of green spaces and pristine urban spaces in the coming years and reveal the effects of urban growth on land uses during this period. As a general truth, land use change implies converting a type of land cover into another type, for example, converting the forest land use to residential land use or agricultural land cover to industrial land use.

The land covers considered in this study are built-up areas, green areas, empty spaces, and mountains. Green areas refer to green land use specific to cities, such as parks, gardens, forests, grass-covered lots, etc. Empty spaces refer to lands that are not built up. There are many empty spaces spread throughout the residential land cover. Overall, empty spaces apply to the bare and non-built-up lands among the other land covers.

In this research, mountains were not considered as empty space land cover, but as a distinctive category, mountain land cover. The mountain land cover was considered in this study because mountains represent a large part of the city land cover in Kabul. A range of mountains crosses the city administrative area, which physically divide the city in two parts; the built-up areas (residential houses), green areas, and the empty space land cover in the mountains. In recent years, many houses were built in the mountains in Kabul (Fig. 1). Then, it is likely that parts of the mountain area will be integrated into other land covers due to land cover overlapping. The satellite imagery for the 2001 to 2019 period will be used to illustrate these dynamics.

Fig 1. Residential land use on the mountains, Kabul, Afghanistan.

2. THEORY AND METHODOLOGY

Land use changes are an important research topic in the scientific literature and a great number of studies are published annually on this subject. Aqbelaghi et al. (2018) explored the factors that influenced physical growth in Tehran, Iran, based on sustainable urban development in terms of environmental dimension and the preservation of environmental conditions in the next two decades. Predicting future urban growth is difficult. This paper has predicted urban growth in the absence of a fundamental change in the nature and extent of factors affecting urban growth, although these factors constantly change during time, particularly in Tehran, seen as an under-developing city.

Soffianian et al. (2010) explored the changes in residential areas in Isfahan, Iran. The results showed that Isfahan has experienced urban sprawl and horizontal growth. Authors concluded that physical expansion does not follow the rules of land use planning and sustainable development, and this pattern will likely repeat in the future. They suggested some guidelines for protecting these lands such as using non-agricultural lands for building, as well as ensuring that urban growth is densely concentrated.

Dadras et al. (2014) referred to the situation of Bandar Abbas and the way it has grown over 6 decades. The results show that Bandar Abbas has a chaotic and fast increase in urban sprawl. The authors found that this city grew from medium-sized to large.

Moghadam and Mofrad (2017) studied the urban sprawl in Mashhad, Iran, between 1996 and 2016. The land cover change results in Mashhad city showed that the built up area has shown a constant increase (from 1996 to 2016) and the empty space and agriculture/green spaces have decreased over the last two decades. These observations act as warning that urban planners should pay more attention to the environment. If this decrease continues in the future, city dwellers will be faced with shortage of green space and agricultural lands.

1 Urban resilience has conventionally been defined as the measurable ability of any urban system, with its inhabitants, to maintain continuity through all shocks and stresses, while positively adapting and transforming toward sustainability.

Willie et al. (2019) illustrated the spatial pattern of land surface thermal characteristics and urban growth in King Williams Town. The results showed that urban growth changed the land cover in this city between the years 1995 and 2018. Authors found that in 1995 the vegetation recorded the highest share of land cover and, correspondingly, grasslands, water bodies and built-up areas had lower land shares. In 2018, built-up surfaces increased by 50.1%, vegetation cover had low values and declining by 9.5%, water bodies decreased by about 0.6%, and grasslands decreased by 39.6%. This study shows that the land use change was not environmentally friendly in this city.

The specifics of urban growth and urbanization trends are extremely important in urban literature. Urban growth is recognized as a spatial-temporal and demographic process. It refers to the importance of cities as the main venue of economic and social activities (Bhatta and Saraswati, 2010).

Urban sprawl is another specific issue related to urban growth. Urban sprawl is partially caused by the need to accommodate an increasing urban population. Bhatta and Saraswati (2010) present a schematic diagram of urban growth patterns (Fig. 2).

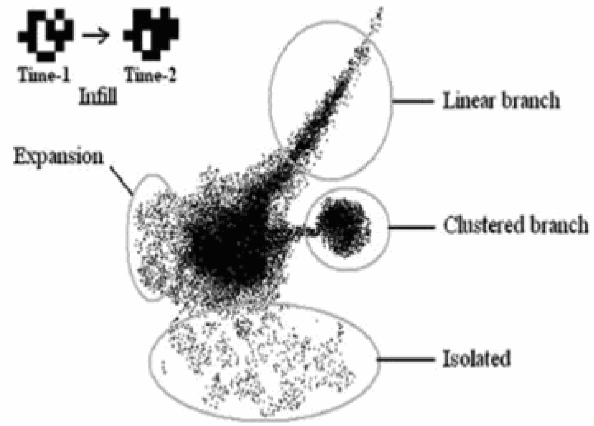

Fig 2. Schematic diagram of urban growth pattern *(source: Bhatta and Saraswati, 2010, p. 11).*

There are different methods for observing urban growth, based on the area of study. Willie et al. (2019) used NDVI and NDBI indexes for mapping the urban growth in King Williams Town. The variation in SUHI over the city indicates their results of land use change. The spatio-temporal pattern of LST was used in this study for better underlining the specific results. Dadras et al. (2014) analysed the urban growth of Bandar Abbas city by using Geographical Information System (GIS), Remote Sensing (RS) data, and aerial photos. By using mixed methods to analyse urban growth provides reliable results because the limitations related to each method are minimized and covered by other methods. Moghadam and Mofrad (2017) studied the process of urban sprawl in Mashhad, Iran. Remote sensing and geographic information system (GIS) techniques, statistical approaches, and Shannon's Entropy were used to generate this model, which is considered suitable because Shannon's Entropy is a good approach for analyzing the horizontal growth of a city. Soffianian et al. (2010) explored the changes in residential areas in Isfahan, Iran, by using remotely sensed imagery. Aqbelaghi et al. (2018) used multi-time Landsat satellite images and considered various environmental and ecological indicators in their research.

In this study, the supervised classification method was used for image classification. The ERDAS IMAGINE Signature Editor allowed us to create, manage, evaluate and edit signatures for the area of study. After collecting signatures, both images were classified into four classes, namely built-up areas, green areas, empty spaces, and mountains. Then, the maps of land cover types for the two reference years (2001 and 2019) were generated using Arc Map and ArcGIS software (Fig. 7 and Fig. 8).

The amount of changes in the area of each land cover between 2001 and 2019 were extracted after making and running a model in the ERDAS IMAGINE environment. As a result of the model, the final map was produced.

The final map contains the information on the amount of land cover change for the years 2001 to 2019. The area of every land use change is presented in Table 2. The changes in the four types of land covers during the eighteen years (2001-2019) were investigated by analysing the produced maps. Based on population data for 2001 and 2019, the land cover changes and the city growth in Kabul, during the years 2001-2019, were analysed.

Landsat imagery data for the 2001 and 2019 were collected from the USGS website (Fig. 3 and Fig. 4). Data was processed in ERDAS IMAGINE software to illustrate Kabul land cover, as the area of study.

Afghanistan is located in the central part of Asia. The surface area of Afghanistan is 647,500 sq km (Country profile; Afghanistan, 2008). Afghanistan is a land-locked and mountainous country. Geographically, Afghanistan is divided into three major regions: the Central Highlands, the South-western Plateau, and the Northern Plains (State of Afghan Cities, 2015). There are six climatic zones in Afghanistan: hot and dry desert (desert), mountainous climate, Mediterranean climate, steppe climate, monsoon climate, and Alpine tundra climate. Kabul is the capital and also the largest city of Afghanistan, located in the eastern part of the country. It is situated at 1,800 meters above sea level. Kabul sprawls across a long, narrow valley between the Hindu Kush Mountains and stretches along the Kabul Sea.

The climate of Kabul is affected by the general climate in Afghanistan. The country is located almost in the middle of Asia, therefore latitude, longitude, mountain range, and distance from the sea, are all factors that influence the climate of Afghanistan. Kabul has a semi-arid continental climate. Kabul was the first metropolis of Afghanistan, is the economic and cultural centre of Afghanistan, and it is considered the most populated city in the country, with more than 4.5 million people residing on approximately 1030.511 sq km (Fig. 5).

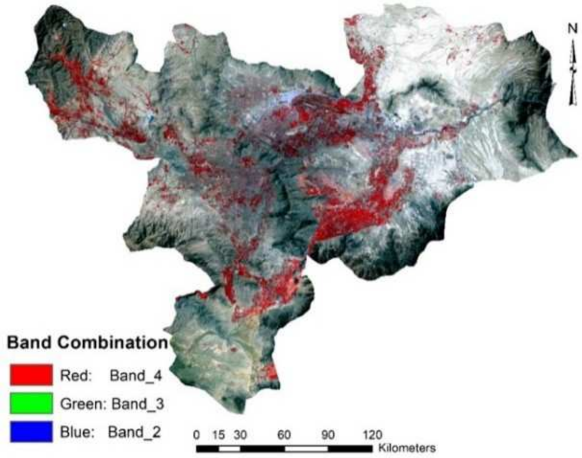

Fig 3. Satellite image, Kabul, 2001.

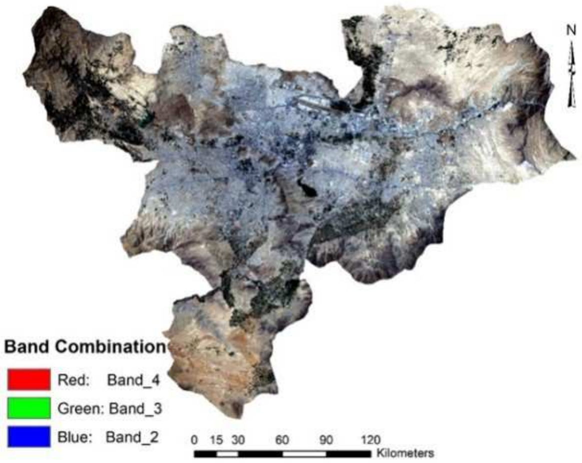

Fig. 4. Satellite image, Kabul, 2019.

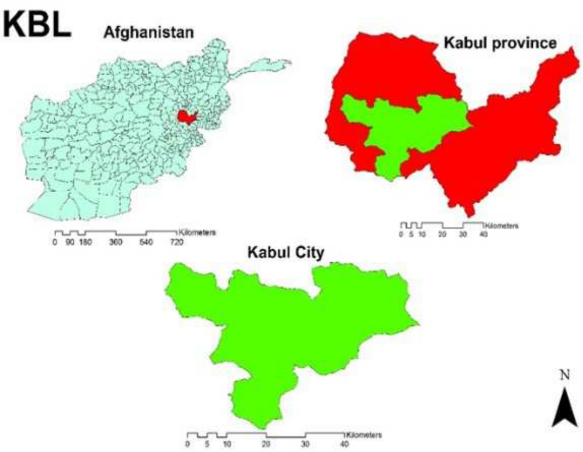

Fig. 5. Kabul location in Afghanistan.

Kabul lies at an elevation of about 5,900 feet (1,800 meters) in the east-central part of the country, in a triangular valley between the Asama and Sherdawaza mountain ranges (UN-Habitat, 2015). Kabul has 22 districts and its population is of 4.273 million people in 2020, representing more than 41% of the population living in the urban area in Afghanistan. More than 71 of the residential areas are informal settlements (State of Afghan Cities, 2015). The population density of Kabul is 4,500 residents per sq km. The population of Kabul increased by more than 2.5 million people from 2001 to 2019. Most districts of the city are characterized by high population density (Fig. 6).

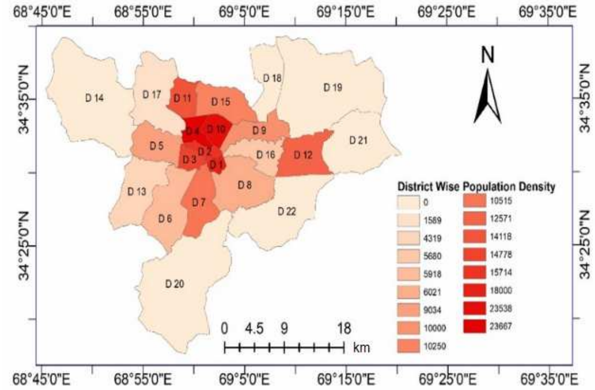

Fig. 6. Spatial distribution of population in Kabul *(source: Central Statistics Office, Kabul, Afghanistan. Estimated Population, 2017).*

Table 1. Kabul population by districts.

No.	Name city district	Area (km^2)	Population projection (21.09.2020)
1	City district 1	4.673329	117,810
2	City district 2	6.761004	143,303
3	City district 3	9.219954	173,165
4	City district 4	11.626117	369,455
5	City district 5	29.238911	341,413
6	City district 6	49.10282	377,649
7	City district 7	32.532463	451,758
8	City district 8	48.430241	375,646
9	City district 9	24.45329	325,026
10	City district 10	12.988659	398,589
11	City district 11	17.369218	312,097
12	City district 12	34.795302	57,357
13	City district 13	46.642585	263,662
14	City district 14	82,331417	451,588
15	City district 15	32.117685	426,448
16	City district 16	25.163346	185,183
17	City district 17	55.988736	115,989

Source: Central Statistics Office of Afghanistan. Estimated Population, 2017.

3. RESULTS AND DISCUSSION

Land cover has suffered modifications from 2001 to 2019. The results show that built up area, green area, and empty space land uses have significantly changed (Fig. 7 and Fig. 8). The results show an increase in the built up area, while the green area decreased.

The results show that, between 2001 and 2019, the aggregated built-up area and empty space land covers increased by 69.1749 sq km (29% increase compared to 2001) and, by 45.2538 sq km (187% increase compared to 2001); the green area has decreased by 113.4216 sq km (41% decrease compared to 2001). Some 72.9774 sq km (26% of green space in 2001) of the green area have been converted into built-up area. Preserving the green area (forests and parks) has been one of the less important issues in the process of urban growth in Kabul.

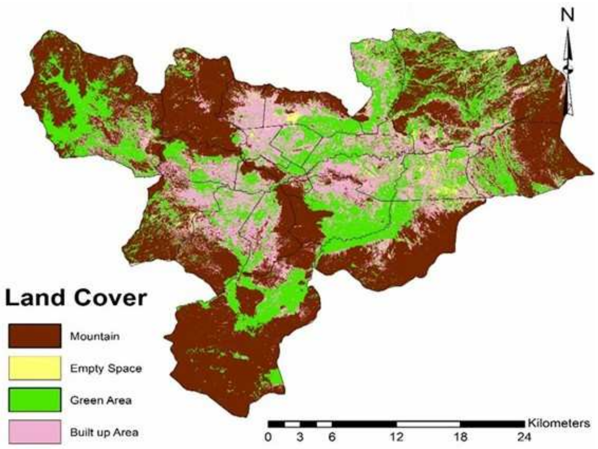

Fig. 7. Land cover in Kabul, 2001.

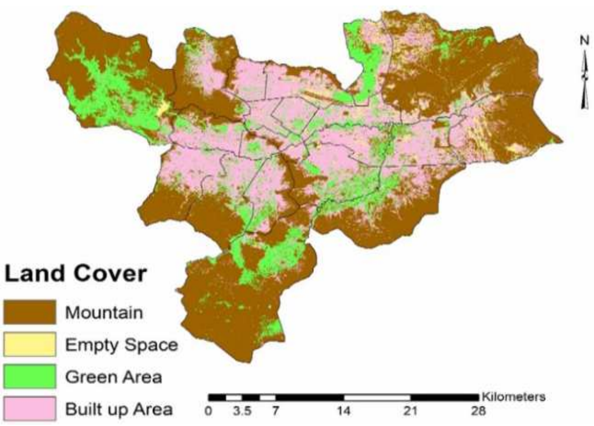

Fig. 8. Land cover in Kabul, 2019.

Table 2. Land cover change in the period 2001-2019.

Land cover / Year	Built up area (km^2)	Green area (km^2)	Empty space (km^2)
2001	237.2796	273.1203	24.3378
2019	306.4545	159.6987	69.5916
Change 2001- 2019	69.1749	-113.4216	45.2538

As determined by the United Nations Environment Organization, the availability of urban green space per individual is 5-20 square meters and in the United States of America, 75 square meters per individual (Bauer, 2014). The amount of green space in Kabul is insufficient and limited, although there is green space potential in Kabul, for example, hills, the fringe of Logar sees, Paghman, Gole Bagh area, etc. In comparison to neighbouring countries, the standard urban green space for Kabul's citizens should be of 8 square meters per individual. However, it is only of 5 square meters per individual. From 2001 to 2019, 108.2493 sq km (40% of green space in 2001) of green space were maintained as green land use.

Different combinations of land use have been observed in the city. Some parts of land covers have a bit of an overlap. Some parts of informal settlements are located on hill-sides and the slopes of the mountains. The mountains that are located in the inner parts of the city are mostly occupied by informal settlements. From 2001 to 2019, 82.7388 sq km (27% of built space in 2019) of the mountain area have been replaced by built-up land use. There are many agricultural lands created on the elevations, too. The slopes of mountains and hill-sides that are located in the outer parts of or around Kabul are used for agriculture purposes. The mountains and hills in the districts 6,7,8,13,16 have been assigned residential and other built-up land uses (Fig. 9).

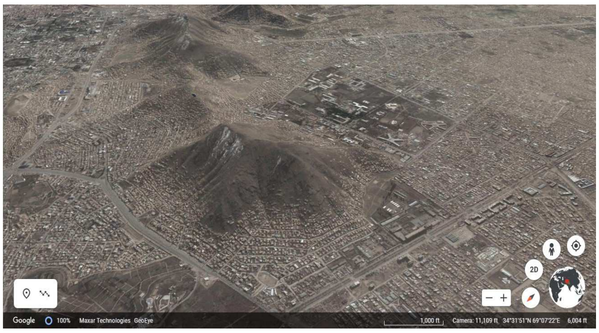

Fig. 9. Residential land use on the mountains, Kabul, Afghanistan *(source: Google Earth).*

Analyses show that 31.8384 sq km (equivalent to 133% of Empty space in 2001) of the mountains are converted to empty space. Large parts of the mountains have initially been converted to bare land, then to residential, road, industrial, and military land use. Also 11.1142 sq km of the green area have been converted to empty land. The non-standard use, the overuse of agricultural land, and the consecutive devastating floods in some agricultural lands caused some agricultural land use to lose its potential and subsequently be converted to empty land. In addition, parts of the green areas between the industrial and the residential areas have been changed into empty lands, because of the lack of attention of officials and incorrect planning. Most of the green spaces located inside the city have been given residential, commercial, and industrial use due to space scarcity in the city. Based on the population growth in the city, the results mentioned above were predictable. Urban growth has generated a significant increase in population density in districts 13, 1, 2, and 3. Most types of land cover in these areas are built-up areas. Figure 9 shows that in these districts people transformed even the mountains and hills into living areas. The highest elevations in these districts are occupied by informal settlements.

A significant part of district 17 was occupied by residential land use. After 2001, most of the people that migrated to Kabul from the provinces, which are located in the north of Kabul, have settled in district 17 as most of those have the same religion and ethnicity.

There is lower population density and less built-up area coverage in districts 14, 18, 19, 20, 21, and 22 in comparison with other districts. The topography of these lands prevented them from being subjected to an increased rate of population growth as in the case of other districts. In city, district 14 has the largest empty space and less built-up areas, and more agricultural and mountainous lands are seen here.

Landsat images of Kabul for the years 2001 and 2019 were collected and processed by using ERDAS IMAGINE and ArcGIS software. Images were classified into four classes: built-up area, green area, empty space, and mountain areas. Using the demography data of Kabul, the results of the study were analyzed. It seems that Kabul had uncontrolled urban growth after 2001. The relative peace in 2001 attracted many people to Kabul. These people increased the demand for housing. This increased demand, as well as space and land limitations have affected the land use pattern in Kabul. A large part of the mountainous area, hills, green spaces, and empty spaces have been converted into residential areas.

Due to its attractiveness and social and economic development in comparison with the other cities in Afghanistan, Kabul has grown rapidly.

In Kabul, most urban plans have been elaborated locally and without fundamental planning. Over 80% of people live in informal settlements. Districts 8 and 13 are two of the most populated areas - almost all parts of their residential areas are informal. These districts are unable to supply basic urban services like electricity, proper road infrastructure, and accessibility to hospitals and schools. Many informal settlements have been built on the mountains and hills in Kabul, especially in districts 1, 2, and 3.

The green area has decreased from 2001 to 2019. Many agricultural lands and gardens have been destroyed or converted for other land uses. The urban green space rate is too low in Kabul and could soon become a critical problem.

4. CONCLUSION

Our objective was to investigate the land use change in Kabul, the capital of Afghanistan, in the period 2001 - 2019. Land use planning in Kabul is a matter of concern. Unplanned development, ignoring urbanism and environmental rules, destroying urban areas, and insufficient urban infrastructure services are the most important urban issues that need to be addressed.

The rapid increase in the urban population in Kabul caused horizontal growth in the city. The urban sprawl is in the process of becoming a serious challenge in Kabul.

Also, the results of other researches (researches that have been conducted on the cities of developing countries and have urbanization conditions like Afghanistan) are in line with the results of this research.

The research of Sattari et al. (2020) shows that the built-up area in the city of Tehran (the capital of Iran) has increased from 9% in 1974 to 54% in 2018, the green area has decreased from 18% in 1974 to 4% in 2018, whilst the empty space has decreased from 73% to 43% in these years.

Ghorbani et al. (2016) in the research they conducted on Tabriz in Iran showed that during the period 1984-2011, empty space with an area of 151,962 hectares in 1984 has decreased to 147,052 hectares in 2011. The built-up land, which was about 7,220 hectares in 1984, has increased to 22,346 hectares at the end of the period, the agricultural land with an area of 25,369 hectares in 1984 has decreased to 22,489 hectares in 2011.

Creating a green belt around the city could be effective for controlling horizontal urban growth. Preventing people from building more houses on the mountain slopes and hill-sides could be a way of controlling informal settlements. Protecting the existing green areas and extending the surface of green areas should be considered by the government.

Some of the most important solutions that can be suggested to prevent early changes in land use in Kabul include the supplying the lack of land uses and creating suitable capacities in the regions should be the attention of the government. Also, distributing capital and job opportunities could distract focus from Kabul.

Finally, the green area has been decreasing. It should be protected. The authorities should strive to manage the environmental impact across the entire value chain from research to development, and production. Planners and local authorities should pay more attention to natural resources and the environment. The informal settlements, especially those located on the mountains and hillsides, face many natural hazards. Those settlements do not even meet the lowest housing physical standards. The government should provide comprehensive plans for solving the urban growth issues. The integrated study of land cover change provides a resource for planning and managing urban development policies or strategies.

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