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Assessment of Land used/land cover change in Helmand, Afghanistan: A case study

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Abstract

Economic development and the pressure of population growth at the global level have provided the context for continuous land use/land cover change, which directly influences the changes in the climate, the ecosystem, and the hydrologic cycle. This study addresses the land use land cover (LULC) and related changes and their implications in Helmand, Afghanistan, in the past 20 years. Landsat satellite images processed through ERDAS IMAGINE and ArcGIS were employed. The entire area of Helmand is divided into four main covers, and the changes in these covers were identified during the last twenty years (2000-2020). The results indicate that land use/land cover has changed significantly in the past 20 years. During this period, urban cover increased from 42 km^2 to 292 km^2, agricultural command area increased by more than 2781 km^2, equal to three times the amount of agricultural land in 2000, and desert cover decreased by about 3015 km^2. Overall, the transition speed was high from 2015 to 2020, and most of these changes happened in the central parts of the province. However, from an economic point of view, the increase in urban and agricultural cover is a positive development. Still, these changes also created various problems for residents, such as the depletion of groundwater resources affected by the excessive use of groundwater for flood-irrigations of agricultural command areas, etc... If continuous, this territory will face a severe scarcity of drinking water.

Keywords: Land used/land cover, cultivated land, urban area, desert land, groundwater drop

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1. Introduction

Land is a natural source; due to human and environmental factors, the cover of land is continually changing universally, and it is never possible to stop, but it needs to be regulated [1]. The physical features on the Earth, such as forests, water, vegetation, urban areas, and so on, are called land cover, while the cover used based on human needs is called land use[2]. "Land use and land cover change are perhaps the most prominent forms of global environmental change since they occur at spatial and temporal scales immediately relevant to our daily existence" [3]. Climate change is another vital factor that influences the rate of land use/land cover change, and its effect will be more dangerous in the future because it is predicted to increase the temperature by 1.1 to 6.4 ℃ at the end of this century[2]. Additionally, the climatic and biophysical changes are projected to affect the land use/land cover change and may disturb the ability of the agroecosystem [4]. Land use/land cover change is a key topic of concern about change in the universal environment and has become a hot topic for researchers and decision-makers worldwide [4][5]. [6]. However, land cover change has an important effect on the ecosystem; as community development and population growth increase, land cover change will faster than ever, which will have a vulnerable impact on the ecosystem in many parts of the world, which put pressure to model, evaluate, and manage the ecosystem and natural capital [7]. In this regard, land use/land cover changes should be considered as the most basic information in environmental monitoring, management, and planning of the sources [8]; the change in land use/land cover over the period is only due to increasing the population on the Earth [1]. Various negative impacts arise as cumulative compensation for the imbalance between rapid economic development activity and environmental preservation [9]. Some problems have been caused by land use/land cover changes like soil erosion and degradation and a decline in forest area and biodiversity, which have had a significant influence on the regional and global atmosphere[10]; land use/land cover is an important factor that affects water yield of the basin as well [9] [11]. Most scientific articles claim that land use/land cover change influences water resources at various spatial and temporal scales, and any land cover changes in a region have an effect on atmospheric elements such as precipitation, temperature, and critical driving elements of the hydrological cycle [12] [11] [13]. Land cover is a fundamental variable for animate and inanimate creatures; however, any change in the land cover should be done carefully because the change can significantly affect the ecosystem. Change analysis of the Earth's surface features is essential for a better understanding of interactions and relationships between human activities and natural phenomena.

Land use/land cover classification can be effectively done by using Satellite images of various spatial and temporal resolutions and remote sensing data [2],[14] [15]. Remote Sensing and Geographic Information Systems (GIS) have the potential to provide accurate information regarding land use and land cover changes[16][17]. GIS and remote sensing have proved to be powerful tools in analyzing and assessing Land use/land cover changes as well as land surface temperature[18]. Time change detection is the calculation of changes in a region over a specific interval of time; furthermore, based on time change detection, we can evaluate land use change as well as changes that have occurred in the

agricultural areas of the region and can recognize any changes that are related to the natural state of the region. This increase in the urban population leads to the depopulation of remote areas; as a result, the urban area is expanding, and the other parts of the land are decreasing, which gives a non-compensatory change to the surface of the Earth. In Afghanistan, there have been significant changes in the land cover in the last two decades. The urban area considered a relatively safe region for life, was chosen by the people to live in due to necessity; this was why the urban area expanded rapidly. LULC changes affect the most important indicators of a region, such as temperature, water yield, surface runoff, evapotranspiration, and so on.

1-1 Research area

Afghanistan is a landlocked country located in the south of Asia and has a border with Iran, Pakistan, China, Tajikistan, Uzbekistan, and Turkmenistan, as illustrated in Figure 1. The total area of Afghanistan is 652860 km2, divided into 34 provinces. Helmand is one of the largest provinces located in the south of the country and has a border with Pakistan. The total territory of Helmand is 58486 Km^2 and an average of 780 meters above the mean sea level; its geographical location is (60° 61′, 30° 29′). As discussed, land cover change is a controversial issue; people and communities are trying to change the natural cover of the land for various purposes. These changes often have adverse climate effects. Land cover change is also felt in Helmand province, and the region's people are experiencing its negative effects. Some major problems caused by land use/ land cover change are: 1) Groundwater tables drop dramatically; most people in different parts of the province are suffering from a shortage of drinking water. 2) The Land product cost/benefit ratio is so high for formers. 3) The pastures are almost demolished, and most wild animals and birds have disappeared in Helmand. Therefore, there is an urgent need to understand how many changes have occurred in the Earth's cover over the past twenty years and how serious problems can occur if not controlled. This study will find out what changes have happened in the land cover of Helmand from 2000 to 2020. Furthermore, it will also investigate what problems have arisen from these changes in the short term, and it will discuss what positive and negative effects such changes have in the long term.

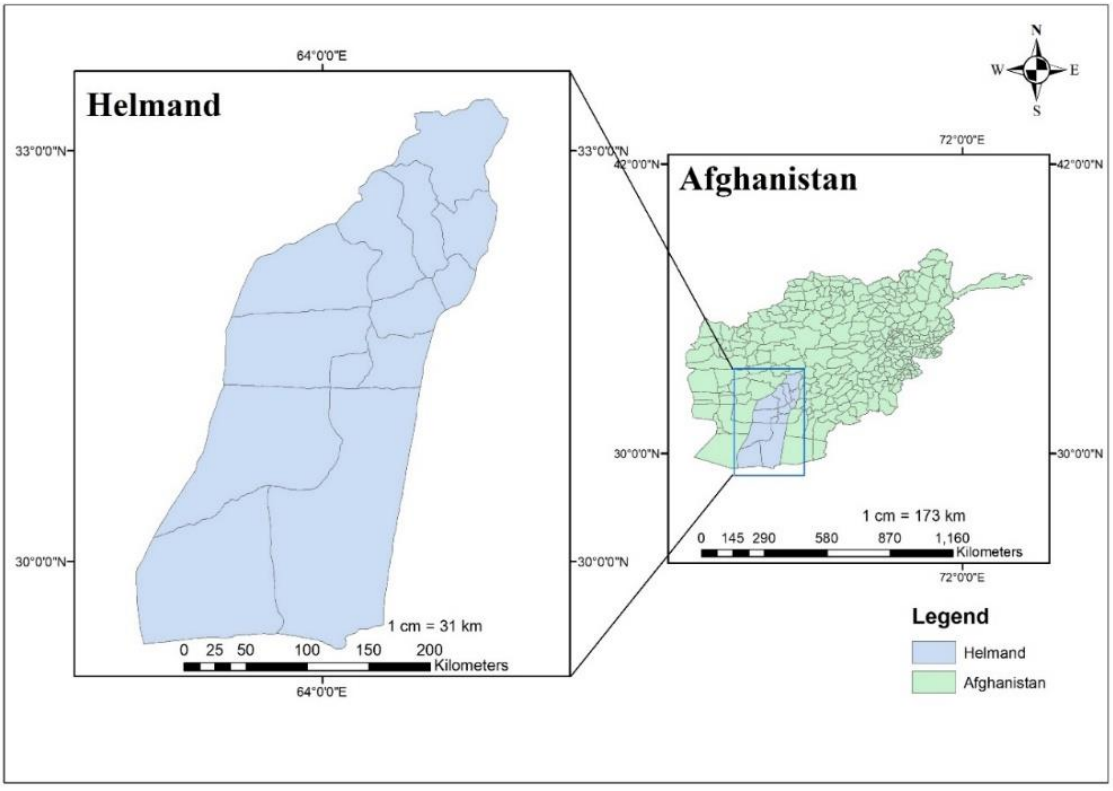


Figure 1: views of the study area, location of Helmand province

2. Material and Methods

2.1 Data Collection

Data collection is a critical step in a research cycle because any mistake in this process will endanger the study's outcome. Satellite images are the primary data used in analyzing land use/land cover change. Landsat 5 Thematic Mapper, Landsat 7 Thematic Mapper Plus, and Landsat 8 Operation Land Imager for the years 2000, 2010, 2015, and 2020, downloaded from the USGS website, were used for the study. However, Landsat 8 OLI is the most accurate and updated image that is used for the land cover change, but due to the non-availability of these images for all study period, we have had to use Landsat 7 TM+ and Landsat 5 TM for the rest of the years.

2.2 Pre Processing

It is a needed procedure in which the image has to be prepared for the classification stage. It has the unique aim of building a more direct association between the biophysical phenomena on the ground and the developed data[4]. Each image has a different number of spectral bands that must be composited; for example, the Landsat 5 image contains seven spectral bands, while the Landsat 8 OLI satellite image is composed of 11 spectral bands, and while composited, provides an image corresponding to the specific year. Figure 2 reveals the preprocessing procedure of the satellite images.

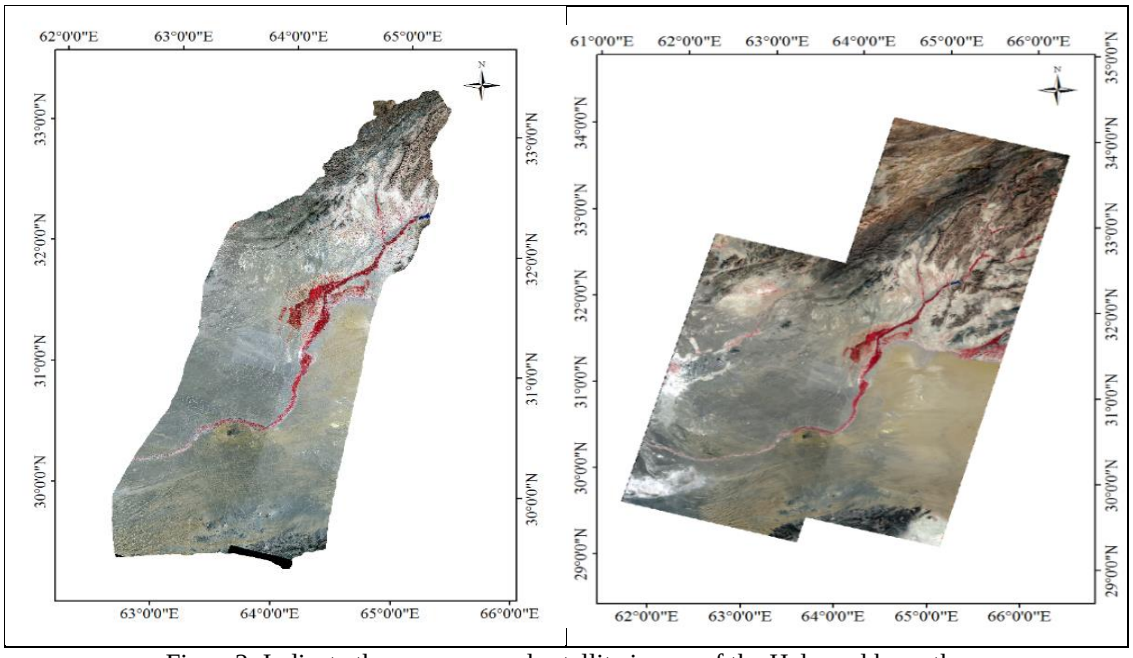


Figure2: Indicate the preprocessed satellite image of the Helmand by author

2.3 Land cover classification

The supervised classification method that effectively works in large areas is implemented with the ERDAS IMAGINE 2014 for the deduction of land cover change. In the classification process, the accuracy of identification increases as the number of classes increases. Therefore, the area was first divided into 100 different types, and these 100 classes were later changed into four main classes. Then, in the image, the mistakes that have been made in the classification by the software are eliminated; Figure 3 indicates the flow chart of the study.

2.4 Result and Accuracy Assessment

The LULC of Helmand province was classified through ERDAS for different periods of 2000, 2010, 2015, and 2020. The image processed will assign A land cover to each of these years. To detect the changes, the fields that are generated are compared with each other. Accuracy assessment is a necessary and critical part of image classification; thus, land use/land cover detection is needed to evaluate the changes accurately[4]. Two methods are generally used for accuracy assessment. One is Kappa Statistics, which measures how remote science data classification agrees with reference data, and overall accuracy is calculated in the following equations[18] and is done by ERDAS.

$$\text{Overall accuracy} = \frac{\text{Number of simple classified correctly}}{\text{number of reference simple classes}}$$

$$\text{Kappa Statistics} = \frac{\text{Observed accuracy} - \text{Chance assessment}}{1 - \text{Chance agreement}}$$

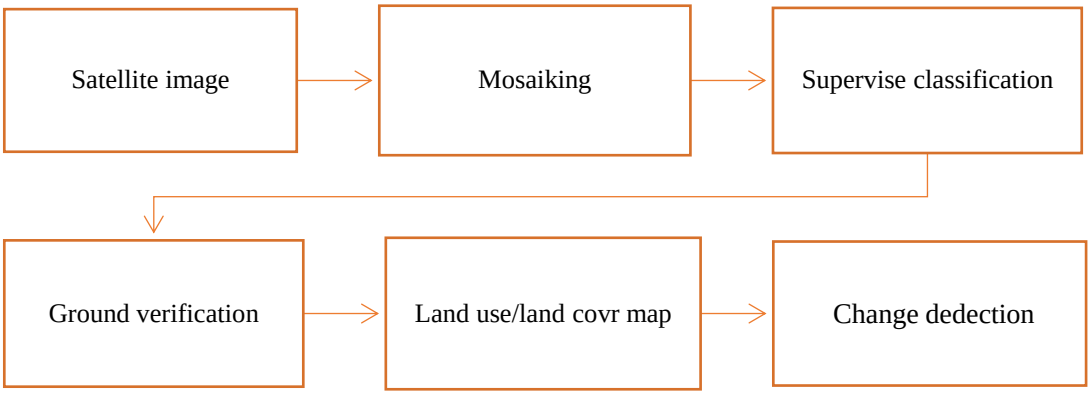


Figure 3: Flow chart of the Method that is used in this study

3. Results and discussion

In this study, only four main covers, urban, desert, agricultural, and water, have been considered for the entire province of Helmand in the classification process. The changes in these four covers are evaluated from 2000 to 2020, as illustrated in Table 1. Water is the only cover that has not yet encountered significant changes during this period; it only covers 0.17 percent of the total area, approximately 100 km^2. Most of the water cover is formed by the Helmand River, and the Kajaki reservoir, so the minor changes in this cover are due to differences in satellite images based on downloaded data and in the variation of the Kajaki reservoir area in corresponding years.

Table1: Area of the four main land use/land cover

Land use/ Land cover classes	2000	2010	2015	2020
	km2 Area of Land use/Land cover			
Water	99.873	99.4005	75.4974	85.0284
Bare land	57215.696	56531.4	55805.9041	54200
Agriculture	1127.98	1691.43	2378.75	3909.1
Build up	42.7689	164.088	226.167	292.54

Table 2: Area in percentage of the four main classes

Land use/ Land cover classes	2000	2010	2015	2020
	Area in percentage of Land use/Land cover			
Water	0.17	0.17	0.13	0.14
Bare land	97.82	96.66	95.42	92.67
Agriculture	1.92	2.89	4.068	6.68
Build up	0.073	0.28	0.39	0.5

Urban or residential area: This cover has extended significantly in the last 20 years, as shown in Table 1 above. In 2000, the cover was about 42 km^2; however, ten years later, it reached 164 km^2, which indicates a three times increase in the cover area compared to 2000. In addition, in 2015 and 2020, the entire urban area of Helmand covered 226 and 292 km^2, respectively, which make up about 0.5 percent of the total Helmand land cover. The arrival of refugees and the rapid population growth are two main factors that have led to the rapid increase in the urban cover. Based on this investigation, approximately 12.5 km^2 of area has been added to the urban cover annually during this period. As can be seen in Figure 4, the urbanization was faster between 2015 and 2020.

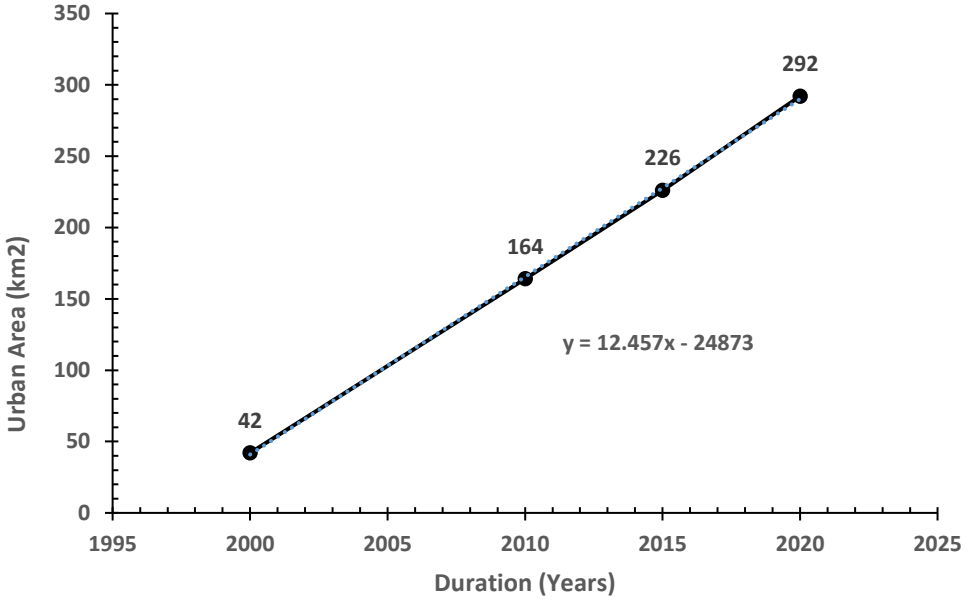


Figure 4: Increasing the urban cover change in the study period

Agricultural cover: Helmand is one of the agrarian provinces of Afghanistan; in 2020, only 1128 km$^{2\ of}$ area was cultivated, making 1.92 percent of the entire province. At the end of 2020, the space occupied by agriculture was around 3909 km2, which indicates a more than three times increase compared to that in 2000, as illustrated in Table 1. Moreover, the rapid change in the agriculture cover for Helmand between 2015 and 2020 is shown in Figure 5.

From the economic point of view, the extension of agricultural land is a positive development since it provides direct and indirect employment opportunities to thousands of people, while the poor plane of agriculture sector extension has some negative impact as well. There is no proper water supply and irrigation planning for the 2781-km^2 area, which has been converted from desert to agricultural land. Farmers, rudely and unprofessionally, use the groundwater resources for irrigation purposes of newly established farms; because of this, the water level in this region is dropping tens of meters annually. If it continues as such, in the next few years, it will be difficult for the residents

to have drinking water in most of the parts of the province, and the people of the region will face a migration crisis.

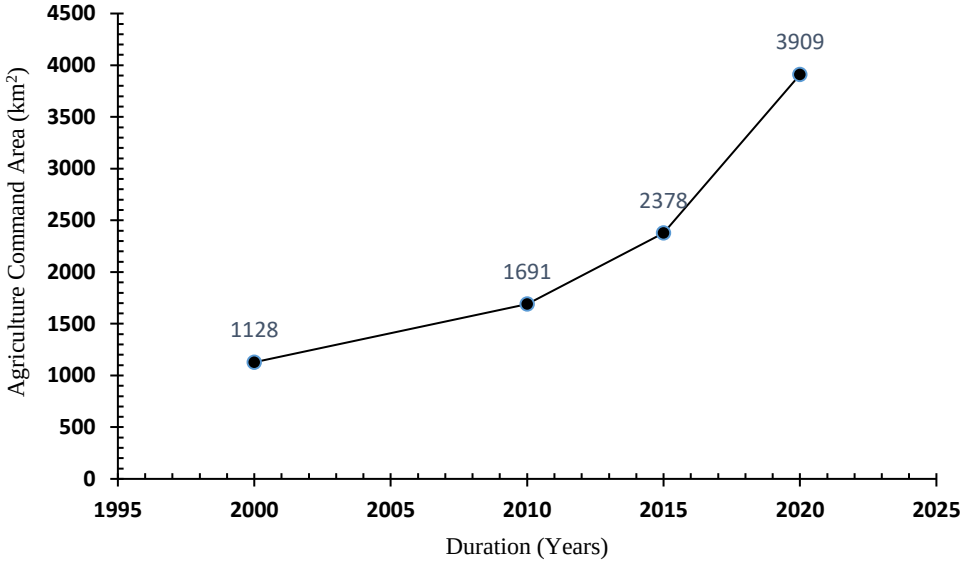


Figure 5: Changing pattern of agriculture cover in the study period

Desert cover: Out of the four main covers discussed in this study, the desert area is the only cover that has decreased in the study period, and most of this cover has converted to agriculture cover. As illustrated in Table 1, in 2000, this cover measured 57,215 km^2, which made 97.82 percent of the total land of the entire Helmand, but in 2020, this cover decreased to 54,200 km^2, which illustrates 93 percent of the whole region. In this period, the desert cover decreased by 3015 km^2, as shown in Figure 6; this conversion was most rapid between 2015 and 2020.

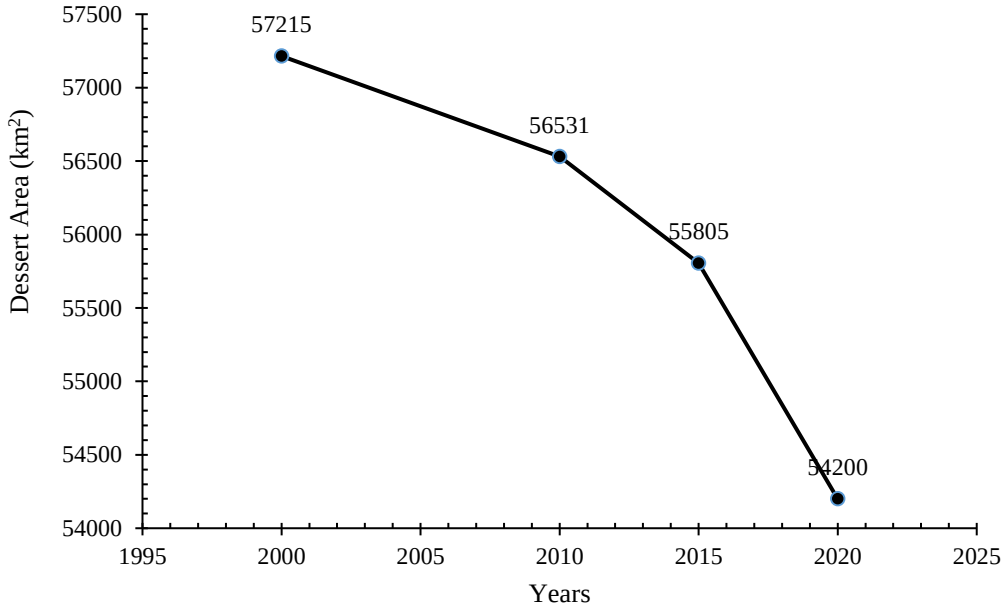


Figure 6: Decreasing pattern of desert cover

Change deduction

The general changes or deductions in a specific cover in a period are called change deduction. The land cover is constantly changing based on environmental circumstances and human interference, so some areas may be reduced while some areas may be added to the same cover in a specific period of time. The summation of these deductions shows us that, overall, this particular cover has changed positively or negatively. Table 3 illustrates the calculated deduction of the study area from 2015 to 2020.

Table 3: Change deductions of all covers from 2000 to 2020

Land use/Land cover change deduction	water	Bare land	Agriculture	Built-up	LULC 2020
Water	49.53	1.53	25.48	8.47	85.028
Bare land	9.87	39.96	400.02	53356.91	53806.77
Agriculture	16.29	81.16	1877.20	1934.44	3909.1
Built-up	0.546	103.51	75.28	113.19	292.54
LULC 2015	76.25	226.16	2377.99	55805.90	58486.317

Accuracy assessment

In this research, we have used the ERDAS IMAGIN2014 program to determine the accuracy assessment of the study; the values of the Kappa coefficient for the years 2000, 20010, 2015, and 2020 are 0.833, 0.85, 0.855, and 0.7833 respectively, If the value of Kappa coefficient was above 0.75, then the result is acceptable. In addition, the overall

accuracy of the study for the years 2000, 20010, 2015, and 2020 are 87.5, 88.75, 88.75, and 83.75 percent, respectively, hoverer if the value of overall accuracy is higher than 80 percent, which means the result of the study is satisfied.

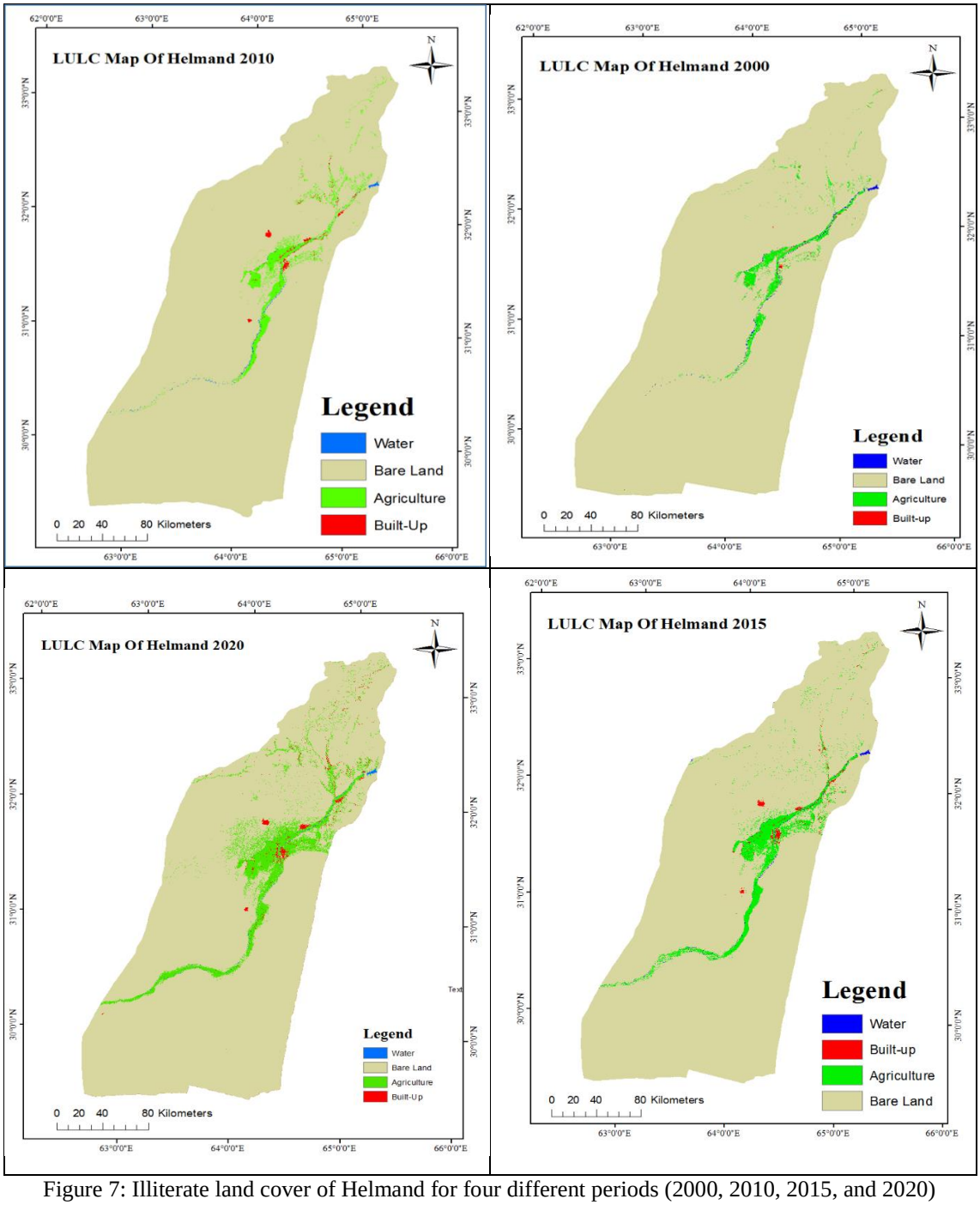


Figure 7: Illiterate land cover of Helmand for four different periods (2000, 2010, 2015, and 2020)

4. Conclusion

As the land-use and land-cover (LULC) changes rapidly occurring globally, it can be concluded that during the last 20 years, significant changes have occurred in the land cover of Helmand province; most of these changes happened in the central parts of the province. Out of the four main covers studied in this research, water is the only cover that has stayed the same. Still, the other three covers (urban, agriculture, and desert) have significantly changed in the time interval. At the beginning of 2000, the urban region covered only 42 km^2 of land, while in 2020, the urban cover reached 292 km^2, and around 12.5 km^2 of area per year was converted to urbanization during the study period. The increase in the urban area usually causes an increase in the surface flow; on the contrary, it causes a decrease in the absorption of the soils to the ground. Moreover, the agricultural cover increased significantly during this period; in the year 2000, only 1128 km^2 area was occupied by this cover across Helmand, while after 20 years, it is indicated that this cover has extended to 3909-km^2, meanly it increased to 139 km^2 per year, and the transmission was very fast from 2015 to 2020. Groundwater is used as a source of irrigation for the area that has converted to agriculture in this region; this is the reason for the drop-down in the groundwater level in Helmand in recent years. During this period, the desert cover was considerably reduced; nearly 3015 km^2 changed to urban and agrarian. Due to this change, a massive variety of habitats and pastures of various animals have disappeared or are facing the threat of extinction. Moreover, Kappa statistic and overall accuracy are used for accuracy assessment; both methods gave a good result of the evaluation; the average value of the kappa statistic for all periods was about 0.829, while the overall accuracy value for all study periods was 87.18 %, which are in the range of acceptance.

Recommendation

Expansion of agricultural land is a basic need with increasing population. Therefore, to prevent the use of underground water for agricultural purposes, a regular water supply system for agrarian lands in the region is needed.

This study calculated land use/land cover variables for Helmand province. Another important topic related to this, which should be researched in the future, is to evaluate its effects on surface and underground water.

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