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CASE STUDY

Evaluation of Urban Sprawl and Land Use/Cover Variation Patterns through Remote Sensing Data: A Case Study in Kabul City, Afghanistan

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ABSTRACT

The objective of this study is to utilize geospatial technology and remote sensing data to assess the changes in land use and land cover, as well as urban sprawl, in Kabul city, which serves as the capital of Afghanistan, during the period spanning from 1993 to 2021. Urban sprawl has given rise to unsustainable patterns of urban growth when viewed from social, environmental, and economic perspectives. Hence, it is crucial to observe and regulate the city's expansion to uphold sustainable planning and development. In this research, Landsat 5 and Landsat 8 for the years 1993, 2008, and 2021, as well as the integration of Shannon's entropy model with GIS, were used to estimate changes in land cover and land use, as well as spatial dispersion and urban compactness. The results show that the built-up area increased dramatically from 137.7 km^2 to 212.0 km^2, which demonstrates 74.4 km^2 of expansion, while the vegetation cover decreased significantly from 208.5 km^2 to 173.7 km^2, which shows a 34.8 km^2 decline from 1993 to 2008. While between 2008 and 2021, the built-up area increased drastically from 212.0 km^2 to 364.8 km^2, which demonstrates 152.8 km^2 of expansion, the vegetation cover decreased significantly from 173.7 km^2 to 126.6 km^2, which shows a 47.1 km^2 decline. Furthermore, between 1993 and 2021, the built-up area expanded from 137.7 km^2 to 364.8 km^2, indicating a 227.2 km^2 expansion, whereas the vegetation cover reduced significantly from 208.5 km^2 to 126.6 km^2, showing a −81.9 km^2 reduction. Furthermore, the total values of relative Shannon's entropy for the years 1993, 2008, and 2021 are 0.68, 0.71, and 0.70, respectively, which are closer to the upper limit of 1 and hence indicate the spatial dispersion within the study area during the study period. The findings of this research will serve as valuable tools for urban policymakers. They will aid in comprehending the spatial patterns of urban sprawl in Kabul city and in formulating appropriate strategies and policies. These measures aim to curtail the wasteful utilization of nonrenewable resources, maintain environmental equilibrium, address social inequalities, and promote comprehensive and sustainable development.

Keywords: Land use change, Shannon entropy, urban sprawl, urban zones.

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1. Introduction

Swift urbanization poses a major challenge for developing countries due to its considerable environmental repercussions, including alterations in a region's land use and land cover, the conversion of agricultural and forested land, declining groundwater levels, and heightened land surface temperatures [1]. Land use and land cover have been altered by human activities in both developed and developing nations over the course of centuries [2]. Around 6.25 billion people (70% of the world's population) are anticipated to live in cities by 2050 [2]. The increasing rate of urban population growth in developing nations presents a noteworthy challenge for governments and planning entities worldwide [1]. This trend will pave the path for the emergence of both planned and unplanned urban regions. As unplanned areas expand, governmental and non-governmental organizations encounter difficulties in delivering sanitation, hygiene, and access to clean drinking water and electricity to the residents of these areas. Certainly, this trend exhibits a notable spatial structure and is anticipated to persist in the future. Consequently, for urban planners and policymakers, effective governance and planning are imperative to achieve a more sustainable urban configuration. In essence, it is necessary to regulate the growth and expansion of metropolitan areas to curtail the wasteful use of nonrenewable resources, uphold environmental equilibrium, address social inequalities, and foster comprehensive and sustainable development. There exists a direct correlation between population and urban development [1]–[3]. Unplanned urban development and population growth led to urbanization in India [1], [3], and [4]. Hence, following World War II, urban sprawl has progressively emerged as a dominant pattern of urban spatial development globally, marked by differing timelines, underlying reasons, and resultant effects [5], [6]. According to the analysis of existing literature, there is a lack of a unified definition for the concept of urban sprawl, as it greatly hinges on the cultural, geographic, and political context [3], [7]–[9]. Broadly, urban sprawl can be described as a particular form of urban expansion that extends into suburbs and outlying areas characterized by low population density, extensive road and highway networks, dependence on automobiles, substantial land coverage, scattered development, and linear growth within a single central urban structure [10], [11]. Therefore, the primary issue associated with urban sprawl and land use/land cover change pertains to adverse social, environmental, and economic outcomes [12], [13]. Consequently, it is of great importance to oversee the city's expansion to sustainably guide its development and planning [14]–[16]. Conventional methods of surveying and mapping for quantifying urban growth were arduous and required a significant amount of time [1]. In recent times, the integration of remote sensing technology and GIS with statistical methods has allowed urban planners and environmental researchers to calculate urban expansion more swiftly and with greater precision [1], [14], [17], [18]. Remote sensing and GIS technology can be employed to extract, map, and assess the spatial pattern of urban sprawl [1], [19]–[21].

This study focuses on Kabul city as the chosen research area. The population of Kabul city has experienced significant growth, surging from 1.5 million in 2001 to approximately 5 million residents in 2017, ranking it as the fifth fastest-growing city globally [22]. Kabul city functions as a central hub for Afghanistan's political, economic, cultural, and administrative activities [23]. Due to rapid urbanization in Kabul city, a significant portion of green spaces has consistently been substituted with impermeable surfaces [2]. Hence, it was essential to assess the spatial distribution of urban sprawl in Kabul city. In this regard, numerous traditional studies concerning urban development have been carried out in Kabul city [22], [24]. In the past, most research endeavours primarily concentrated on urban development in Kabul city. Nevertheless, when it comes to the analysis of urban sprawl utilizing Shannon's entropy algorithm in Kabul city, there remains a notable gap. A review of existing literature indicates the absence of any prior studies in Kabul city, Afghanistan, that have assessed urban sprawl using Shannon's entropy algorithm. In a broader context, entropy serves as a tool to gauge the extent of urban sprawl by determining whether urban expansion is characterized by compact or dispersed growth [1], [14]. Shannon's relative entropy falls within the range of 0 to 1, and the threshold value is typically set at 0.5 [25]. An output value exceeding 0.5 signifies urban sprawl, while a value below 0.5 indicates a compact urban area. Therefore, the unique aspect of this study lies in its utilization of remote sensing technology and the integration of GIS with statistical methods to assess the variations in urban development and urban sprawl in Kabul city. The research methodology and microscale techniques employed in this study can be effectively applied to analyze urban sprawl trends in cities of varying sizes, whether they are small, medium, or large.

Therefore, the primary objective of this study is to assess urban sprawl and track the spatiotemporal alterations in land use and land cover within Kabul city. This assessment will be achieved by combining the Shannon entropy model with geospatial technologies and remote sensing data spanning from 1993, 2008, and 2021. The findings of this study will serve as valuable tools for aiding policymakers within the Afghan Ministry of Urban Development and Land, as well as other relevant national and international organizations. These insights will help in comprehending the spatial characteristics of urban sprawl, enabling the development of appropriate plans and policies to curb the wasteful utilization of nonrenewable resources, maintain environmental equilibrium, address social inequalities, and promote comprehensive and sustainable development.

2. Materials and Methods

2.1. *Study Area*

Kabul, which serves as Afghanistan's capital and is its largest city, is situated in the eastern region of the country at coordinates 34°31′31″ N and 69°10′42″ E (Fig. 1). Kabul is both a municipality and a constituent part of the larger Kabul Province. The city of Kabul is further subdivided into 22 districts [26]. Between 2001 and 2017, the population of Kabul city experienced a notable increase, surging from approximately 1.5 million residents to around 5 million individuals. This significant growth rate positioned Kabul as the fifth fastest-growing city globally. The swift pace of urbanization has struggled to adequately accommodate the expanding population within the capital despite its initial planning to house around 700,000 people [22]. For this reason, about 70% of housing in Kabul was built illegally [22]. One of the contributing factors to the rise in air pollution in 2020 in Kabul, a city with an approximate population of 6 million, is attributed to the unauthorized construction of housing [22]. The climate of Kabul city varies from dry to semi-arid, with warm summers and cold winters [2]. During the winter, ground surface temperatures may fall below −10 °C, whereas in the summer, they can soar to 40 °C [27]. Around 56% of Kabul's total land area consists of mountainous terrain, with the remaining 38% being predominantly flat or

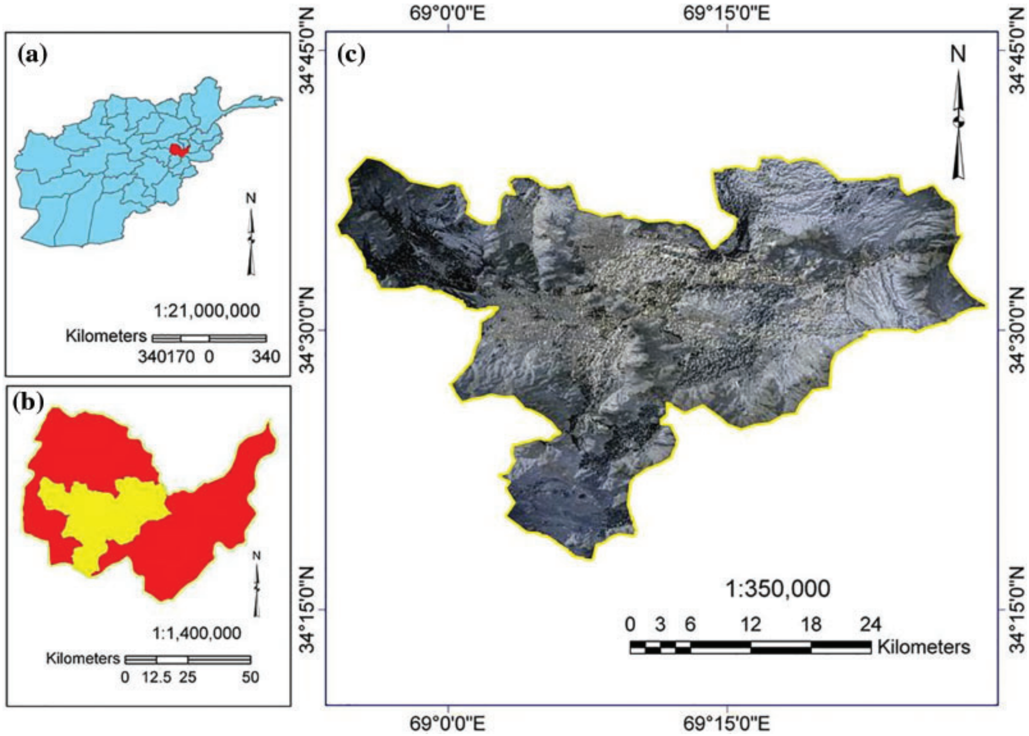

Fig. 1. Location map of the study area: (a) Kabul province in Afghanistan, (b) Kabul city in Kabul province, and (c) Kabul city.

TABLE I: Details of Multi-Temporal Satellite Data

Satellite/sensor	Date of acquisition	Number of bands	Spatial resolution
Landsat 5 thematic mapper (TM)	09.07.1993	8	30 m
Landsat 5 thematic mapper (TM)	23.08.2008	8	30 m
Landsat 8 operation land imager (OLI), thermal infrared sensor (TIR)	04.07.2021	11	30 m

plain [2]. Kabul experiences four distinct dry seasons, with the highest precipitation occurring in February, March, and April. The maximum annual recorded rainfall in Kabul is 400 mm [2], [28], and [29].

2.2. Data Source

In order to assess urban expansion and urban sprawl in the designated study area, three cloud-free satellite images were procured from paths 153 and 36 rows via the United States Geological Survey (USGS) website. To detect urban sprawl, the built-up areas were extracted from Landsat-5 TM images taken on July 9, 1993, and August 23, 2008, as well as from Landsat-8 OLI imagery captured on July 4, 2021 (Table I). The acquired images underwent corrections for geometric, atmospheric, and radiometric factors. The 2020 boundary shapefile of Kabul Municipality was employed to clip all three images, and these clipped images were subsequently used to identify changes in land use and land cover (LULC) and to isolate areas of urban sprawl.

2.3. Research Methodology

In this research, urban sprawl and the dynamic changes of urban built-up areas of Kabul city were evaluated. The city of Kabul has experienced a significant population increase due to various reasons, such as increasing migrations from abroad and from neighboring provinces to the city of Kabul. On the other hand, from a geomorphological and topographical point of view, the city of Kabul is surrounded by mountains. Geomorphological and topographic factors have played a significant role in urban sprawl. Shannon's entropy was used to measure urban sprawl and the dynamic changes of the built areas of the city and to identify the characteristics of urban sprawl. Landsat-5 TM from August 2, 1993, Landsat-5, August 23, 2008, and Landsat-8 OLI/TIR from July 4, 2021, were used to detect urban sprawl. In this research, a nine-year interval between the data of two periods has been used to evaluate the urban sprawl and the dynamic changes of the built-up area of the city. The specifications of satellite images are shown in (Table I). Landsat-5 for 1993 and 2008, and Landsat-8 for 2021. Further processing of satellite images was done in ENVI and ArcGIS Pro programs. Satellite images need to be atmospherically corrected before processing. Therefore, the FLAASH algorithm was used to make atmospheric corrections. ENVI 5.6 software was used to apply the pre-processing step. The methodological flow chart for this study is shown in Fig. 2.

2.3.1. Images Processing and Classification

Prior to classifying the Landsat satellite images, pre-processing activities were carried out, and all images were aligned with the UTM-WGS84 coordinate system. The rectified images were then subject to classification, categorizing into four classes: built-up areas, vegetation, barren areas, and water. This classification was accomplished using the support vector machine-supervised classification

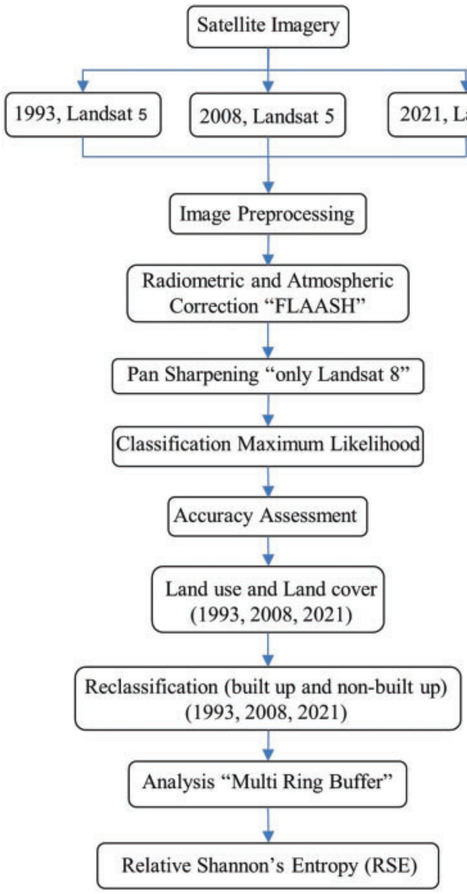

Fig. 2. Methodological flowchart.

algorithm. For the purposes of this current study, these classes were further reclassified into built-up and non-built-up areas. This reclassification served to evaluate the changes in urban development and urban sprawl throughout the entire study period. The images were initially categorized into two groups: built-up areas and non-built-up areas. The built-up category encompassed subdivisions, roads, streets, airports, housing, and commercial or industrial zones, while the non-built-up category included vegetation, barren land, water bodies, soil, and mountainous regions. Following this reclassification, smoothing was applied to the images representing built-up and non-built-up areas for all three time periods, namely, 1993, 2008, and 2021. The study included a classification accuracy assessment to gauge the precision of the classified maps and assess the effectiveness of the classifier algorithm. In this research, the Kappa coefficient was employed to evaluate the accuracy of the land use and land cover maps. This evaluation involved the selection of over 300 control points on the classified maps. The kappa values are 0.86, 0.89, and 0.91 for the years 1993, 2008, and 2021, respectively. According to [2], a higher than 0.85 Kappa coefficient indicates strong agreement between images.

2.3.2. *Shannon's Entropy and Measuring Urban Sprawl*

Shannon's entropy quantifies the level of spatial concentration and dispersal on the surface [30]. The relative entropy can be applied to normalize the entropy value, scaling it to fall within the range of 0 to 1 according to (1) [20], [31].

The built-up areas exhibit their highest compactness (concentration or aggregation) within a particular region when the entropy value is 0. Conversely, an entropy value of 1 indicates that the built-up area displays a spatial distribution that is irregular and dispersed [30]. The 0.5 of entropy value is considered as the threshold value [31], [32]. When the entropy value exceeds this threshold of 0.5, the city is categorized as experiencing urban sprawl [31].

$$En = \sum_{i=1}^{n} P_i \log(1/P_i)/\log(n) \tag{1}$$

where En is the relative entropy, P_i is the probability or percentage of development in the area or $P_i = X_i/\sum_{i=1}^{n} X_i$ which x_i is the density of land development, which is equal to the amount of built-up area divided by the total amount of built-up area in the i^{th} of n total zones [30]–[33], and n is the zone number.

In this study, various geospatial analysis techniques, including the use of multi-ring buffers, reclassification, zone statistics, and Relative Shannon's Entropy (RSE), were employed to assess urban sprawl. To evaluate the density and expansion of built-up regions in the study area across three distinct time periods, the images were first reclassified into built-up and non-built-up areas, and corresponding maps were generated. This approach was consistently applied to all the selected images from 1993, 2008, and 2021. In order to compute the Shannon entropy values that determine the compactness or dispersal of the built-up areas, a multi-ring buffer analysis was conducted on the maps representing the built-up and non-built-up areas within ArcGIS Pro.

To establish specific zones around the city center, the multi-ring buffer analysis technique was implemented, resulting in the creation of buffer zones extending 4 kilometers from the city center. The presidential palace served as the reference point for the city center. In this study, eight concentric ring buffers were generated around the city center, each separated by 4-kilometer intervals to encompass the entire study area. To guarantee the proper alignment of these ring buffers with the study area's limits, they underwent clipping and adjustment processes utilizing the geoprocessing tools provided by ArcGIS Pro. Subsequently, the classified images were overlaid with the buffer layers, allowing for the calculation of the built-up area within each 4-kilometer interval. This approach was consistently applied to the data covering the entire study period, spanning from 1993, 2008, and 2021, to analyze the urban growth within the study area. The combination of Shannon entropy with GIS tools stands out as the most efficient and frequently employed method for evaluating urban sprawl. Shannon's entropy is instrumental in calculating urban density, providing a means to assess the extent of concentration or dispersal among multiple areas [34].

Consequently, the Relative Shannon's Entropy (RSE) value was computed for each buffer ring for all three years (1993, 2008, and 2021). This calculation was performed to gauge urban sprawl in the study area employing the formula (1).

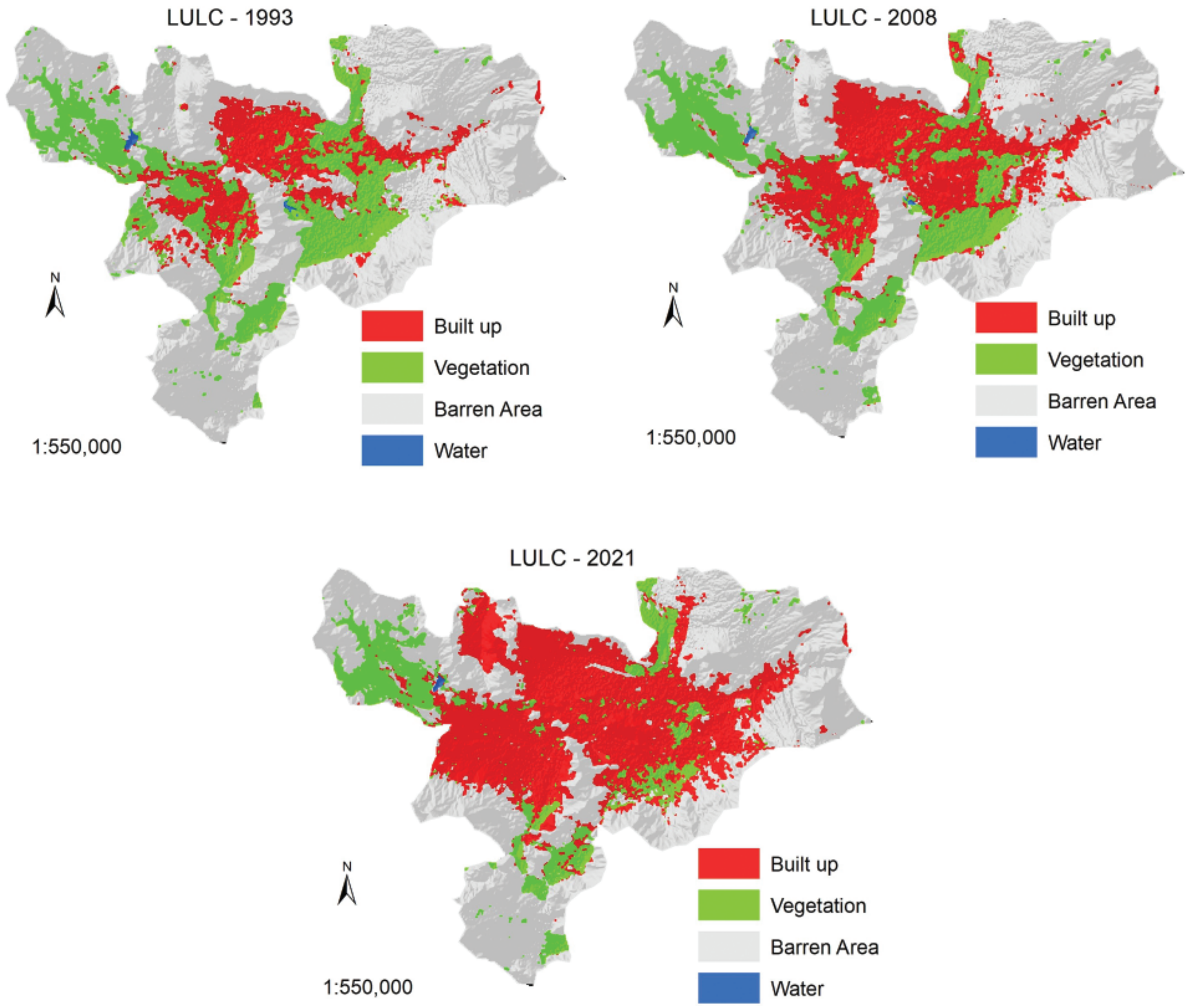

Fig. 3. LU/LC maps of Kabul city for the period of study (a) 1993, (b) 2008, and (c) 2021 years.

3. Results and Discussion

3.1. *Land Use and Land Cover Change Detection*

The results of land use and land cover classification, utilizing the support vector machine algorithm, are presented in Fig. 3 for the study area across three different time periods (1993, 2008, and 2021). For all three sets of images, four distinct classes were chosen for classification: built-up areas, vegetation, barren land, and water. These class selections were made in accordance with Landsat-5 and Landsat-8 data, and the corresponding outcomes were generated. Furthermore, a statistical analysis was conducted for each land use and land cover category across the three years, as indicated in Table II.

According to Table III and Fig. 4, the built-up area increased significantly from 137.7 km^2 to 212.0 km^2 between 1993 and 2008, which shows 74.4 km^2 (54.0%+) expansion. At the same time, during this period, a decrease in vegetation cover was also observed, the vegetation cover decreased from 208.4 km^2 to 173.7 km^2 between 1993 and 2008, which demonstrates 34.8 km^2 (16.7%−) reduction. Furthermore, the barren area decreased from 682.4 km^2 to 643.3 km^2 between 1993 and 2008, which shows 39.9 km^2 (5.7%−) reduction. The built-up area increased dramatically from 212.0 km^2 to 364.8 km^2 between 2008 and 2021, which indicates 152.8 km^2 (72.1%+) increasing, while the vegetation cover decreased from 173.7 km^2 to 126.6 km^2 between 2008 and 2021, which demonstrates 47.1 km^2 (27.1%−) decline. On the other hand, the barren area declined from 643.3 km^2 to 538.1 km^2 between 2008 and 2021, which shows 105.2 km^2 (16.4 %−) reduction. Based on the overall assessment, the outputs revealed that, between 1993 and 2021, the built-up area drastically developed from 137.7 km^2 to 364.8 km^2, which shows 227.2 km^2 developments, while the vegetation area decreased from 208.5 km^2 to 126.6 km^2, which shows 81.9 km^2 declines.

3.2. *Accuracy Assessment of LU/LC Classification*

The accuracy of the land use and land cover maps, which includes the Producer's accuracy, the User's accuracy, and the Kappa coefficient, was computed based on the error matrix for each classified dataset, as demonstrated in Table IV. For the years 1993, 2008, and 2021, the overall accuracy of the land use and land cover classification was found to be 0.86, 0.89, and 0.91, respectively. These accuracy levels exceeded the established Anderson standard of 0.85, which corresponds to 85%, and are generally accepted as a benchmark for accuracy in land use and land cover assessments [35].

TABLE II: Statistical Analysis of LU/LC (1993, 2008, and 2021)

LULC class	1993		2008		2021	
	km^2	%	km^2	%	km^2	%
Built up	137.7	13.4	212.0	20.6	364.8	35.4
Vegetation	208.5	20.2	173.7	16.9	126.6	12.3
Barren	682.4	66.2	643.3	62.4	538.1	52.2
Water	1.8	0.2	1.3	0.1	0.9	0.1
Total	1030.4	100.0	1030.4	100.0	1030.4	100.0

TABLE III: Analysis of LU/LC Change Detection of the Study Area in (1993, 2008, and 2021)

LULC class	1993–2008		2008–2021		1993–2021	
	km^2	%	km^2	%	km^2	%
Built-up	74.4	54.0	152.8	72.1	227.2	165.0
Vegetation	−34.8	−16.7	−47.1	−27.1	−81.9	−39.3
Barren area	−39.0	−5.7	−105.2	−16.4	−144.2	−21.1
Water	−0.5	−26.5	−0.5	−36.1	−1.0	−53.0

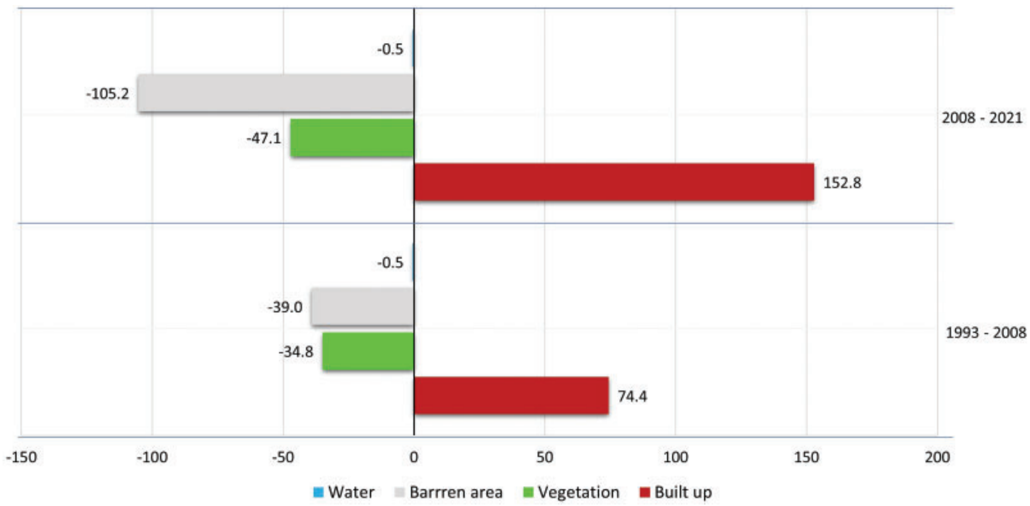

Fig. 4. Change detection analysis between 1993, 2008, and 2021 of the study area.

TABLE IV: Accuracy Assessment of LU/LC Classification

Classes	Producer accuracy			User accuracy		
	1993	2008	2021	1993	2008	2021
Built up	87.16	80.51	85.40	81.22	88.79	86.36
Vegetation	87.83	86.51	90.83	82.58	85.83	86.82
Barren area	77.39	89.90	94.68	84.76	88.12	88.21
Water	76.06	79.14	79.41	84.38	76.60	80.60
Total accuracy	1993		2008		2021	
	0.86	0.89		0.91		

3.3. *Assessment of Urban Sprawl*

3.3.1. *Evaluation of Built-Up Area Changes*

To assess urban expansion and conduct a more thorough analysis of urban sprawl within the study area, the images were reclassified into two distinct categories: built-up and non-built-up areas, as shown in Figs. 5 and 6. The overall evaluation reveals that the built-up area of Kabul city measured 137.7 km^2, 212.0 km^2, and 364.8 km^2 in the years 1993, 2008, and 2021, respectively. In a comprehensive analysis spanning from 1993 to 2021, it becomes evident that the total built-up area in Kabul city saw a substantial increase, expanding from 137.7 km^2 to 364.8 km^2, signifying a growth of 227.2 km^2. This underscores a notable and rapid expansion of built-up areas overall from 1993 to 2021, with a particularly significant increase observed from 2008 to 2021.

This growth can be attributed to elevated immigration rates to Kabul city and a swift rise in population. Additionally, various other factors have played a role in propelling urban sprawl in Kabul. As the central, commercial, and administrative hub of Afghanistan, Kabul city has become a magnet for employment, business, education,

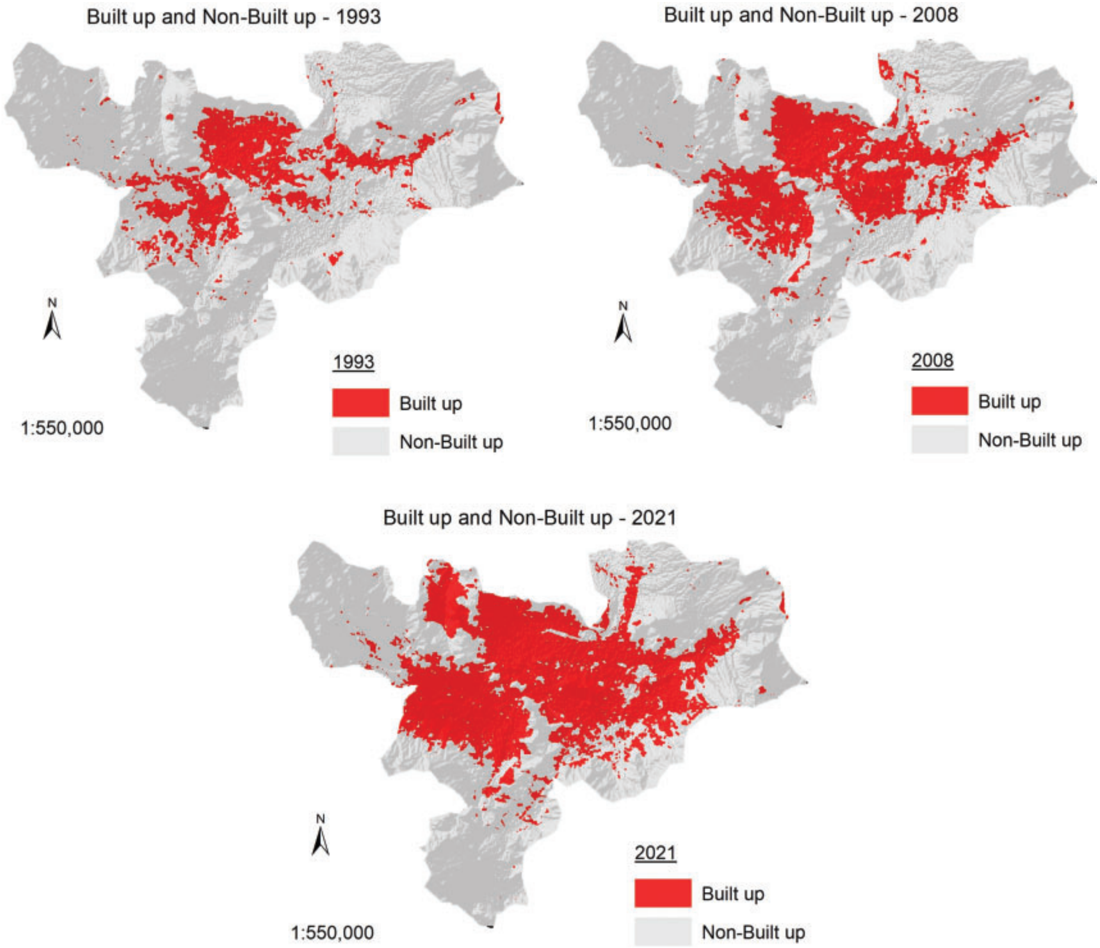

Fig. 5. Built-up and non-built-up area of the study area for: (a) 1993, (b) 2008, and (d) 2021 years.

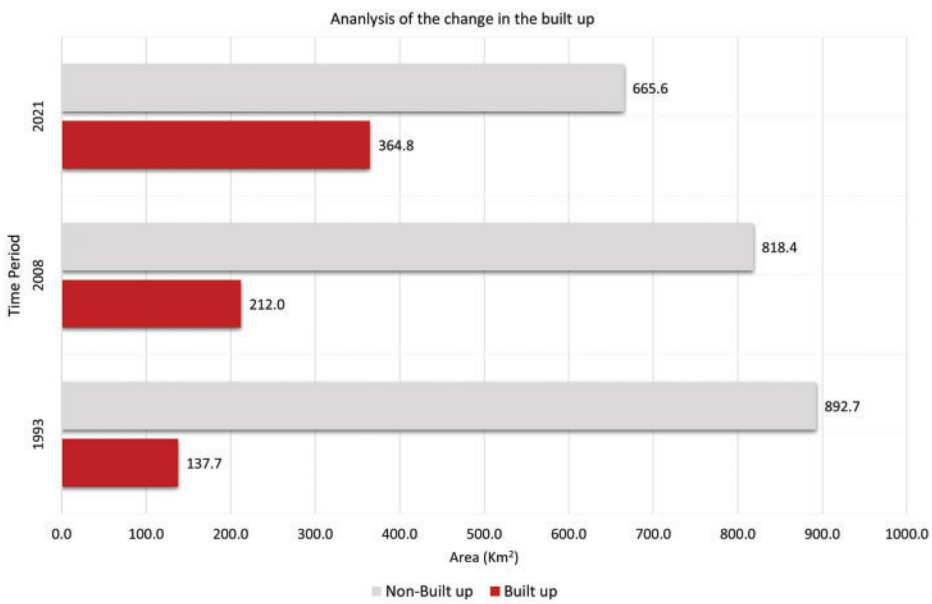

Fig. 6. Graph of analysis of the changes of built-up and non-built-up area.

healthcare, and various services, attracting people from different provinces across Afghanistan. Moreover, the seasonal migration of individuals from provinces with hot climates in the southern and eastern parts of the country, driven by the more favourable weather conditions in Kabul, has further accelerated urban sprawl in the city.

3.3.2. *Evaluation of Urban Zones*

To conduct a more comprehensive assessment of urban sprawl within Kabul city, the multi-ring buffer analysis method was employed. This approach facilitates an in-depth exploration of urban expansion by creating buffer zones on the map and obtaining statistical information

TABLE V: Statistically Urban Area Zone Analysis

Zones (km)	1993			2008			2021		
	Total	Built-up		Total	Built-up		Total	Built-up	
	km^2	km^2	%	km^2	km^2	%	km^2	km^2	%
0–4	50.3	26.1	51.9	50.3	31.3	62.2	50.3	43.9	87.3
4–8	150.6	65.3	43.4	150.6	94.9	63.0	150.3	120.6	80.2
8–12	205.0	26.8	13.1	205.0	52.9	25.8	205.4	107.1	52.1
12–16	247.5	12.3	5.0	247.5	21.9	8.8	247.3	71.9	29.1
16–20	168.2	5.5	3.3	168.2	10.2	6.1	168.3	17.0	10.1
20–24	146.4	0.8	0.5	146.4	0.9	0.6	146.4	3.3	2.3
24–28	62.6	1.0	1.6	62.6	0.3	0.5	62.3	0.9	1.4

TABLE VI: Zone Analysis for Shannon's Relative Entropy Values

Zones (km)	1993			2008			2021		
	Total km^2	Built-up km^2	RSE	Total km^2	Built-up km^2	RSE	Total km^2	Built-up km^2	RSE
0–4	50.3	26.1	0.17	50.3	31.3	0.15	50.3	43.9	0.06
4–8	150.6	65.3	0.19	150.6	94.9	0.15	150.3	120.6	0.09
8–12	205.0	26.8	0.14	205.0	52.9	0.18	205.4	107.1	0.17
12–16	247.5	12.3	0.08	247.5	21.9	0.11	247.3	71.9	0.18
16–20	168.2	5.5	0.06	168.2	10.2	0.09	168.3	17.0	0.12
20–24	146.4	0.8	0.01	146.4	0.9	0.02	146.4	3.3	0.04
24–28	62.6	1.0	0.03	62.6	0.3	0.01	62.3	0.9	0.03

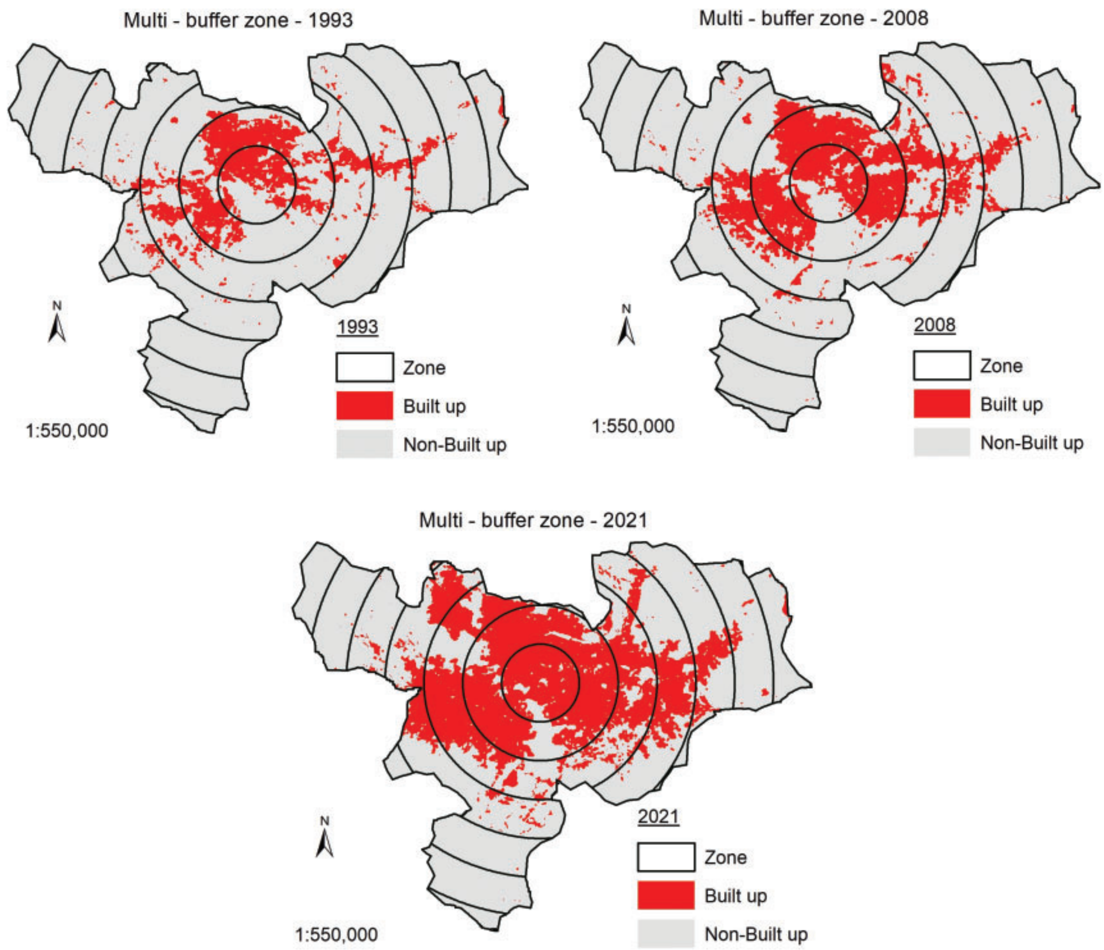

Fig. 7. Zone analysis of study area for: (a) 1993, (b) 2008, and (d) 2021 years.

for each zone or circular area within the study region (Table V). The multi-ring buffer technique, implemented using ArcGIS, was utilized to estimate the expansion of built-up areas for each ring buffer (zone) and subsequently analyze the data with Shannon entropy. Simultaneously, eight ring buffers were generated at 4-kilometer intervals

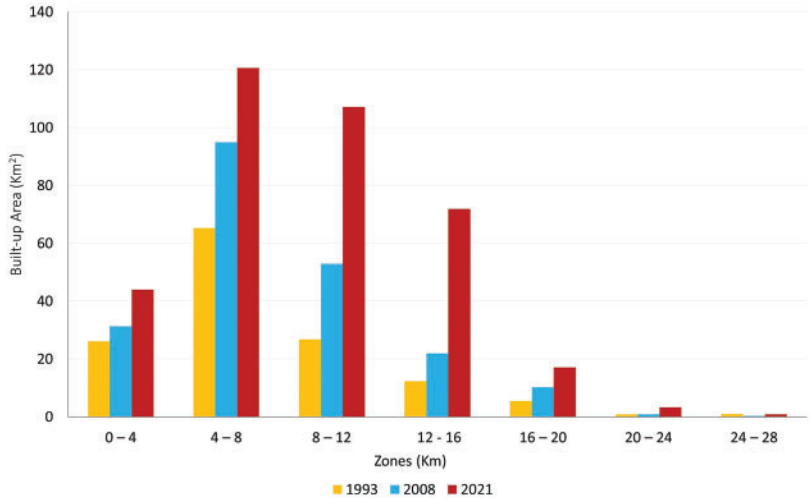

Fig. 8. Graph of zone analysis for built-up area in: (a) 1993, (b) 2008, and (d) 2021.

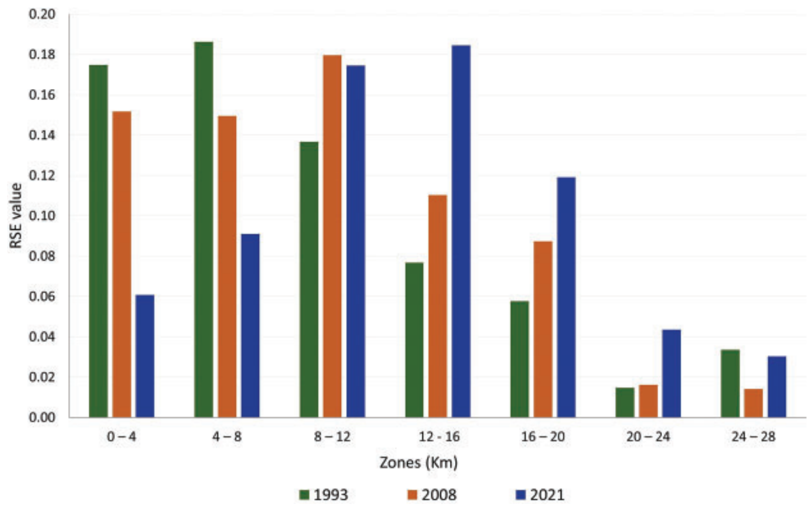

Fig. 9. Graph of zone values for Shannon's relative entropy in 1993, 2008, and 2021 years.

TABLE VII: Relative Shannon Entropy Values

Years	Built-up (km^2)	Relative shannon entropy (RSE)
1993	137.9	0.68
2008	212.0	0.71
2021	364.8	0.70

around the city center, represented by the presidential palace, to encompass the entirety of the study area.

Based on Table VI, Figs. 7 and 8, the outputs revealed that, in 1993 and 2021 the first zone (0–4 km) was the most urbanized and populated among all other zones, within this zone the built-up area was 26.1 km^2 and 43.9 km^2, respectively. Whereas, in 2008 outputs revealed that the second zone (4–8 km) was the most urbanized and populated among all other zones, within this zone the built-up area was 94.9 km^2. Based on the overall evaluation the outputs demonstrated that the development of built-up area decreases with increasing distance from the city center.

3.3.3. Result of Shannon Entropy

Shannon entropy serves as a measure for assessing the concentration or distribution of urban land development growth [34]. The relative Shannon entropy values for each zone, along with the total entropy values for the years 1993, 2008, and 2021, were calculated to estimate urban sprawl within the study area, as presented in Table VI and Fig. 9. The total entropy values for 1993, 2008, and 2021 were determined to be 0.72, 0.72, and 0.77, respectively. These values are close to the upper limit of entropy, which is 1, as depicted in Table VII. This indicates that urban sprawl within Kabul city was observed in all three selected years. The total entropy value outcome underscores the degree of dispersion of built-up areas in the city, revealing that the expansion of built-up land diminishes as the distance from the city center increases.

4. Conclusion

The utilization of geospatial technologies and remote sensing has demonstrated significant effectiveness and efficiency in evaluating and tracking changes in land use, land cover, urbanization, and urban sprawl. This research, spanning a duration of 28 years (1993, 2008, and 2021), assessed the dynamics of land use and land cover while measuring urban sprawl in Kabul city. This assessment relied on remote sensing data, geographic information systems, and the Shannon entropy model. Our research findings indicate a substantial rise in built-up areas and a reduction in vegetation cover within Kabul city. Moreover, the relative Shannon entropy values suggest the occurrence of urban sprawl over the past thirty years. The urban expansion demonstrates higher density in the vicinity of the city center, particularly within the 8-kilometer buffer ring, while it becomes more dispersed as the distance from Kabul's city center increases. Among all the zones within Kabul city, the 0-8 km zones exhibited the largest extent of built-up areas. The findings from this study highlight the serious challenges arising from unplanned, unregulated, and rapid urbanization in the city. The utilization of geospatial technologies and remote sensing for assessing and monitoring urban sprawl, as well as the dynamics of land use and land cover in Kabul city, can serve as essential tools for managing and overseeing the uncontrolled and haphazard urban growth and sprawl. Furthermore, there is an urgent need for the development of a comprehensive master plan for Kabul city. Future research endeavours can focus on predicting changes in land use, land cover dynamics, and urban sprawl using geospatial and remote sensing technologies. The results from this study shed light on deficiencies in the urban planning and management processes. Therefore, it is crucial for decision-makers, prominent investors, and planners in various departments related to planning and development to take proactive measures in addressing the unregulated urban expansion and sprawl in Kabul city. Enhancing the capacity of these relevant departments is essential for effectively regulating and managing the city's development.

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Author Contributions

Karimullah Ahmadi and Ahmad Shakib Sahak carried out the methodology, conceptualization, software, formal analysis, and validation; Karimullah Ahmadi carried out the writing original draft preparation. Ahmad Tamim Sahak and Ahmad Shakib Sahak reviewed, and edited. All authors read and approved the final manuscript.

Availability of Data and Materials

The Landsat satellite data images used to support the findings of this study are accessible through https://earthexplorer.usgs.gov.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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