Impact of Population Growth and Accessibility on Land Use Land Cover Dynamics of Ayubia National Park, Pakistan (2008 and 2018)

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Abstract

In the current study, the effects of accessibility and population increase on LULC modifications in Ayubia National Park, Abbottabad between 2008 and 2018 are being evaluated. Using Arc GIS 10.2 supervised classification algorithm, the SAS imagery from 2008 and 2018 (5m resolution) were classified into vegetation, barren land, and built-up area. By establishing buffers of 0–500 and 501–1000-m around significant roads and villages and extracting the LULC within these buffers, the effects of accessibility and population expansion were examined. For each class, the rate of variation is also determined. The suggested methodology worked well for mapping and assessing the rate and magnitude of changes in LULC at various distances from roadways and settlements. The analysis reveals that in ten years, the built environment has expanded while the barren land and vegetation cover shrank. In comparison to 501-1000-m, the LULC change within 0-500-m near significant roadways and settlements is rapid. The main factors influencing LULC changes include increases in the number of homes brought on by population expansion, tourism, and improved accessibility. According to the study's findings, it is crucial to continuously monitor LULC changes in order to comprehend the trends and patterns and also to provide evidence-based support for land management policies and practices that promote sustainable utilization of natural resources.

Keywords: Accessibility, population growth, LULC changes, Change detection.

Introduction

There are not many natural landscapes exist on the earth's surface. Since humans have altered the earth's surface, a discernible pattern in land use and cover (LULC) has developed over time (Ejaro and Abdullah, 2013). LULC change is a term used to describe how anthropogenic activities change the earth's surface (Hassan et al., 2016). The main driving causes behind LULC changes worldwide are the expansion of urban centers, the rapid rise in population, the shortage of land, and the factors for increased productivity (Barros, 2004). The three most significant LULC changes brought on by natural processes (flash floods, landslides, earthquakes) and anthropogenic activities (urbanization, excessive grazing, intensive

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farming, construction, and development) are the expanding agricultural areas, the rapid growth of the built environment, and the vegetation loss (Muttitanon and Tripathi, 2005; Raza et al., 2012; Shah et al., 2017).

According to Malik (2012), one of the main forces behind LULC modification is the increase in the human population. The growing population influences the LULC changes either in a direct or indirect manner (Parasad and Mahadevaprasad, 2019). The increasing human population places strain on the earth's resources and facilitates land surface modification at a speed, pressure, scale, and geographic extent that is unprecedented in history (Lambin et al., 2001). According to Xian and Crane (2005), the rising population is what converts a land's natural cover into an urban environment. Expanding agricultural land by the clearance of vegetation, raising agricultural productivity, and building the infrastructure required for the rapidly increasing population, encourages LU change (Ali et al., 2010).

Accessibility is thought to play a significant role in LULC transformation. According to Verburg et al. (2004), accessibility is an assessment of how far it is to go to a preferred destination. According to Lattman et al. (2016), accessibility means "living up to acceptable life with the help of the established means of transportation." The development of roads results in LULC alteration through facilitating migration, the extension of the built environment and farmland, and the degradation of vegetative areas. According to Ningal et al. (2006), forest decline occurs in places that are easily accessible, densely populated, and conducive to farming. Accessibility is a key determinant in the growth of built-up areas, which occurs more quickly near highways than away from them (Samiullah, 2012; Yar and Huafu, 2019). Biodiversity loss, environmental degradation, changing climates, reduced crop yields, natural disasters, food insecurity, global warming, and uncontrolled urban growth are the main feedbacks of LULC dynamics (Ningal et al., 2006; Musa and Odera, 2015). It is necessary to track and identify these LULC modifications in order to preserve ecological sustainability (Anil et al., 2011).

By utilizing Geographic Information System (GIS) and Remote Sensing (RS) based temporal image analysis, the approaches of digital change detection assist in understanding LULC changes (Raza et al., 2012; Rawat and Kumar, 2015). The satellite image analysis enables an updated overview of LULC changes at regular intervals (Olokeogon et al., 2014). The repeated nature of the remote sensing data has made them useful for quickly and affordably illustrating the changes in LULC (Sarma et al., 2001; Pandian et al., 2014). The present research makes an effort to assess how accessibility and population increase have affected the LULC dynamics in Ayubia

National Park (ANP), district Abbottabad between a period of 2008 and 2018.

Study area

The Khyber Pakhtunkhwa government designated an area of a reserve forest in Abbottabad, Pakistan as a national park in 1984 in accordance with section 16 of the wildlife act of 1975 (Cousins and Witkowski, 2015; Jan et al., 2020). The Ayubia National Park (ANP) is one of 14 officially recognized national parks in Pakistan that are IUCN class "V" protected areas. ANP is situated in the Abbottabad district of Khyber Pakhtunkhwa province. The park bears Muhammad Ayub Khan's name, who served as Pakistan's second president from 1958 to 1969 (Nazakat et al., 2021). As shown in Figure 1, the park is located between 34°02' 01″ and 34°08' 05″ North latitude and 73°21' 15″ and 73°27' 05″ E longitude.

The park's initial acreage was 1684 ha, but in 1998 it was expanded to 3312 ha (Thomas et al., 2004). ANP and the neighboring region have a population of approximately 50,000 people, and that number is growing by 3% annually. The park provides the neighborhood's residents with wood, produce, medicinal herbs, and animal feed (Khan and Naqvi, 2000; Lodhi, 2007). The average annual temperature is 10°C and average annual rainfall is 1500mm. During the months of December through February, the precipitation is primarily in the form of snow (Ahmad and Afza, 2008). ANP is one of the most popular tourist sites in Pakistan. According to the available data, every year the park is visited by more than 120,000 visitors coming from various parts of Pakistan (Waseem et al., 2004).

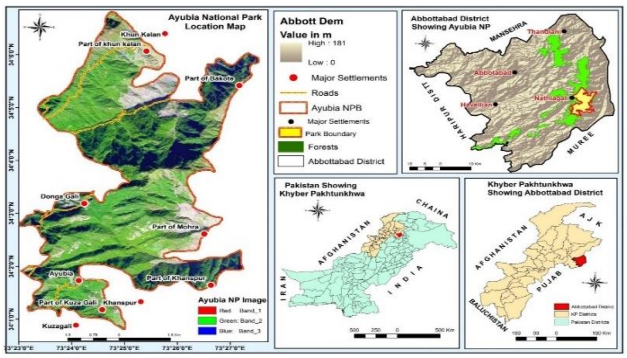


Figure 1: Location Map of Study Area

Materials and Methods

To accomplish the objectives of the study, secondary data concerning satellite images, the road network, and population statistics for the years 2008 and 2018 was gathered from a variety of sources.

From the SAS Planet website, 5-m resolution imagery for the year 2008 and 2018 were acquired. The DCR of district Abbottabad served as the source for demographic statistics for 1998 and 2017. Using Eq. 1, the population was estimated for 2008 and 2018 using the available census data. Google Earth was used to digitize the network of roads and settlements located inside the park.

$$Population\ projection = (Logp2 - Logp1/N * T + Logp2)\ Antilog \qquad Eq.1.$$

$$where\ N = Gap\ between\ two\ years$$

$$T = Time\ for\ Projection$$

$$P1 = Old\ Population$$

$$P2 = New\ Population$$

Focus group discussions and field surveys were used to gather demographic details for several communities located within the park. ArcMap was used for analyzing the 2008 and 2018 satellite images. With the help of the park boundaries, the area of interest was extracted from the satellite images. The next step in image processing was the creation of a feature class for the digitization of training samples and subsequent creation of signature file. For each LULC class, at least 50 samples were digitized. The next step of image analysis was comprised of image classification. Using Maximum Likelihood Classification algorithm in ArcMap Spatial Analyst environment the image was classified into three LULC classes i.e. built-up area, barren land and vegetation cover. In the next step the area covered by each LULC class is computed. To calculate the changes, the area under various LULC classes of 2008 and 2018 was compared. For each class, the single land use dynamic degree (SLUDD) were also computed. SLUDD is used to indicate the variation in one kind of LU during a given period in a certain area (Quan et al., 2013). The following equation can be used to determine the SLUDD:

$$SLUDD = \frac{Ub-Ua}{Ua} \times \frac{1}{T} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq.2$$

$$where\ \boldsymbol{Ua}\ is\ the\ area\ of\ land\ use\ type\ at\ the\ initial\ time\ (2008)$$

$$\boldsymbol{Ub}\ is\ the\ area\ of\ that\ land\ use\ type\ at\ the\ later\ time\ (2018)$$

$$\boldsymbol{T}\ is\ the\ gap\ between\ the\ initial\ time\ and\ the\ later\ time.$$

To determine the impact of accessibility and settlements on LULC changes, ArcMap Euclidian distance tool was used to create 0-500m and 501-1000m zones surrounding significant highways and settlements. Areas lying inside the 0-500m zone and the 501-1000m zone were extracted from the classified images of 2008 and 2018 and the area under each LULC class was computed. Additionally, the SLUDD was estimated for accessibility and population growth in the 0-500-m and 501-1000-m zones. The flow chart for the chosen research methodology is shown in Figure 2.

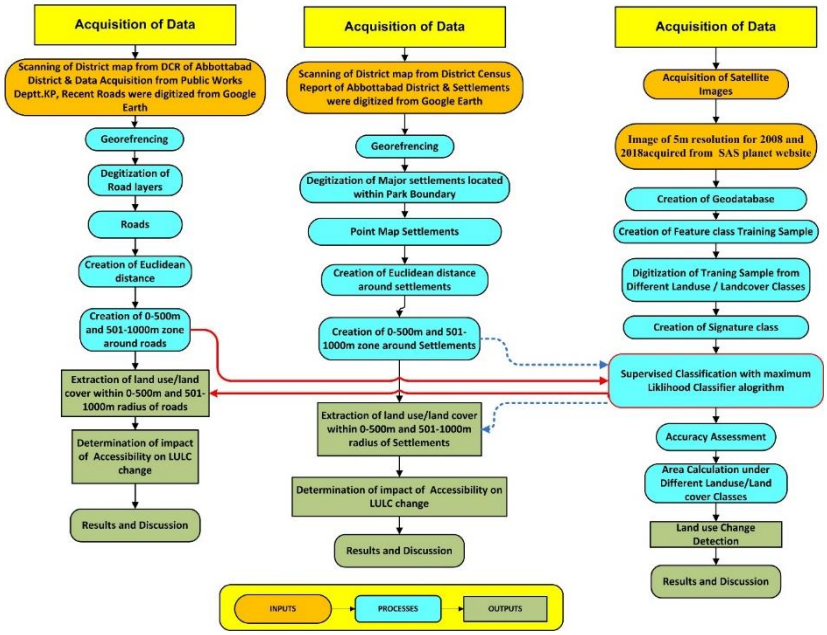


Figure 2: Illustrating the flow chart of the adopted research methodology

Results and Discussion

Land use land cover change 2008-2018.

The analysis reveals that between 2008-2018, the built-up area expanded from 2.61% of the total area to 6.91%. In 2008, the barren land accounted for 16.49% of the total area which decrease to 15.41 % in 2018. The vegetation cover accounted for 80.90% of the total area in 2008, which gradually decreased to 77.69% in 2018. Figures 3 display the area under various LULC classes and Figure 4 depicts the classified images of 2008 and 2018. The analysis's findings are reported in Table 1. According to the Single Land Use Dynamic Degree (SLUDD) calculation, the built-up area is expanding at an annual rate of 16.43%. Barren land has an annual variations rate of -0.65%, while vegetation has a rate of -0.39%.

Table 1

Land use land cover of Ayubia National Park, 2008-2018

LULC	2008		2018		Change	
	Area (Hectare)	%age	Area (Hectare)	%age	Area (Hectare)	%age
Vegetation	2679.46	80.90	2573.07	77.69	-106.39	-3.21
Barren Land	546.02	16.49	510.23	15.41	-35.79	-1.08
Built-Up Area	86.52	2.61	228.7	6.91	142.18	4.29

Source: Image Analysis in ArcMap 10.5

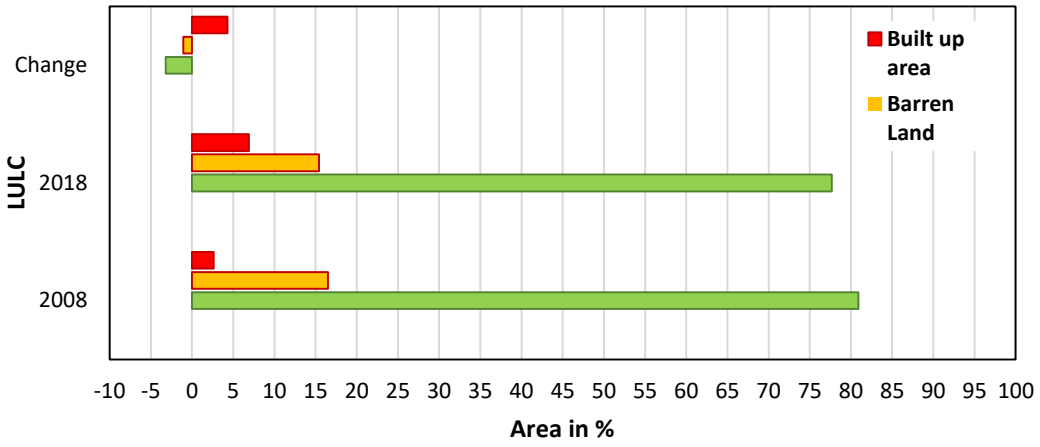


Figure 3: Land use land cover of Ayubia National Park 2008-2018

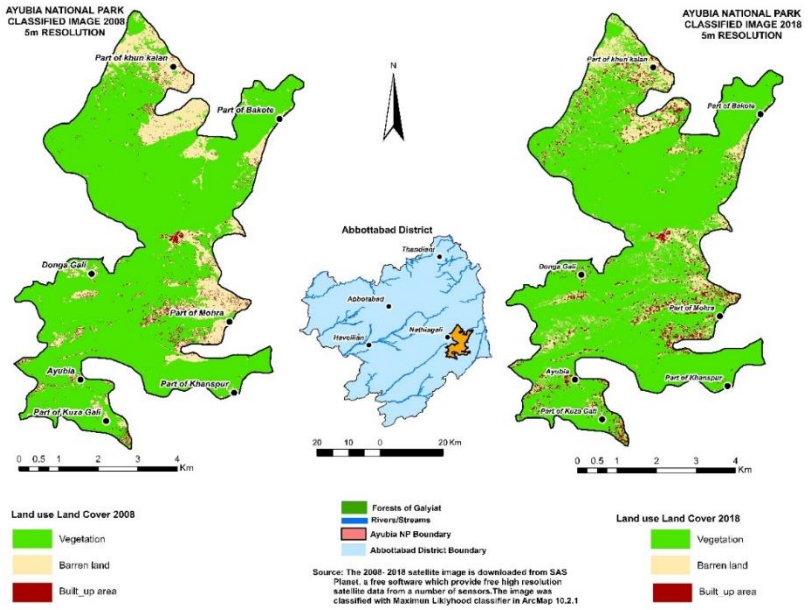


Figure 4: Ayubia National Park LULC Change 2008-2018

Land Use Land Cover of ANP within 0-500 and 501-1000 meters of major roads (2008-18)

Based on the analysis results depicted in Table 2, it appears that there has been a significant increase in built-up areas within a radius of 0-500-m of the roads in the study area between 2008 and 2018. Specifically, the built-up area increased from 2.20% to 4.37% of the total area, indicating a considerable shift in land use and land cover (LULC) patterns over the 10-year period. In contrast, the percentage of barren land decreased from 17.60% to 17.26%, while vegetation cover decreased from 80.20% to 78.18% of the total area, suggesting that natural habitats have been gradually replaced by built-up areas (Figure 5).

The results of the analysis for the 501-1000-m radius of the roads suggest that the changes in LULC are still significant, albeit to a lesser extent than in the 0-500-m radius. In 2018, the built-up area

increased by 1.30%, while the barren land decreased by 0.26% and vegetation decreased by 1.04% of the total area within the 501-1000-m radius. These results suggest that while the impact of accessibility on LULC change decreases with distance from the roads, it is still significant up to 1000-m. The more pronounced and quicker alteration in LULC in the vicinity of the roads highlights the importance of understanding the role of transportation infrastructure in driving changes in land use patterns and associated ecological impacts (Figures 6 and 7).

The results of the analysis suggest that the SLUDD index values for the different land cover categories vary significantly within the 0-500-m and 501-1000-m radii of the roads. The negative SLUDD values for vegetation (-2.29 and -0.12) and barren land (-0.19% and -0.18%) suggest that these land cover categories are being displaced by built-up areas in both the 0-500-m and 501-1000-m radii. In contrast, the positive SLUDD values for built-up areas (+10.78 and +10.18) indicate that they are expanding and displacing other land cover categories, particularly within the 0-500-m radius of the roads. The higher SLUDD value for built-up areas within the 0-500-m radius indicates a more pronounced displacement effect in this area. The SLUDD of the LULC within 0-500 and 501-1000-m of the major roads is depicted in Table 3 and Figure 8 respectively.

Table 2
LULC in the vicinity of Major roads in percentage

LULC Classes	LULC within0-500 m of the Roads in %			LULC within 501-1000 m of the Roads in %		
	2008	**2018**	**Change**	**2008**	**2018**	**Change**
Vegetation	80.2	78.18	-2.02	84.96	83.93	-1.04
Barren Land	17.60	17.26	-0.34	13.76	13.50	-0.26
Built-Up Area	2.20	4.57	2.37	1.27	2.57	1.30

Source: Image Analysis in ArcMap 10.5

Overall, the results of the analysis highlight the importance of considering the potential impacts of transportation infrastructure on LULC patterns and biodiversity conservation in land-use planning and management. The findings could be relevant for policymakers and planners in the study area and other regions to develop effective strategies for mitigating the negative impacts of transportation infrastructure on the natural environment.

Land Use Land Cover of ANP within 0-500 and 501-1000 meters of major Settlements

Seven communities have been selected in order to assess the effects of population expansion on LULC in the research area. Since Ayubia National Park was established in 1984, these villages have

been there. These communities are part of larger communities that are situated outside the park's boundaries. Table 4 includes information about these communities' population growth.

The built-up area accounted for 3.72% of the overall area in 2008, whilst barren land made up 29.51% and vegetation made up 66.77%, of the total area within 0-500-m along major settlements. Table 5 and Figure 7 illustrate the changes in the built-up area, barren land, and vegetation cover in 2018. The built-up area increased by 9.48%, while barren land and vegetation cover decreased by 24.98% and 65.54% respectively.

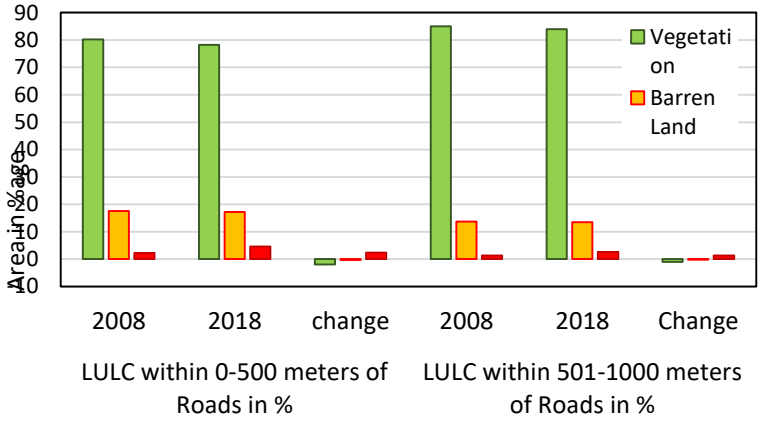
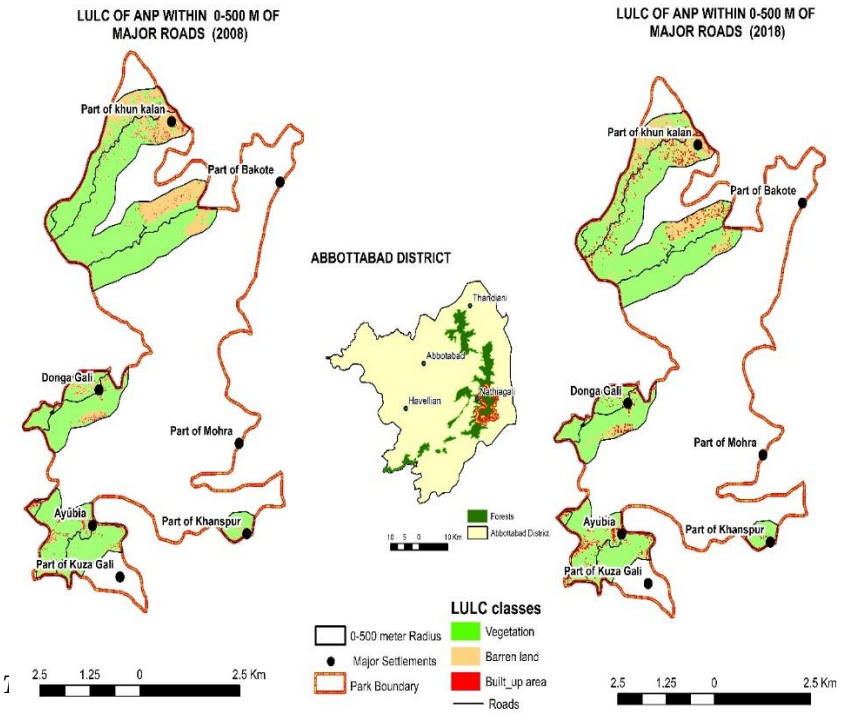


Figure 6: LULC change in ANP within 0-500 meters along major road 2008-18



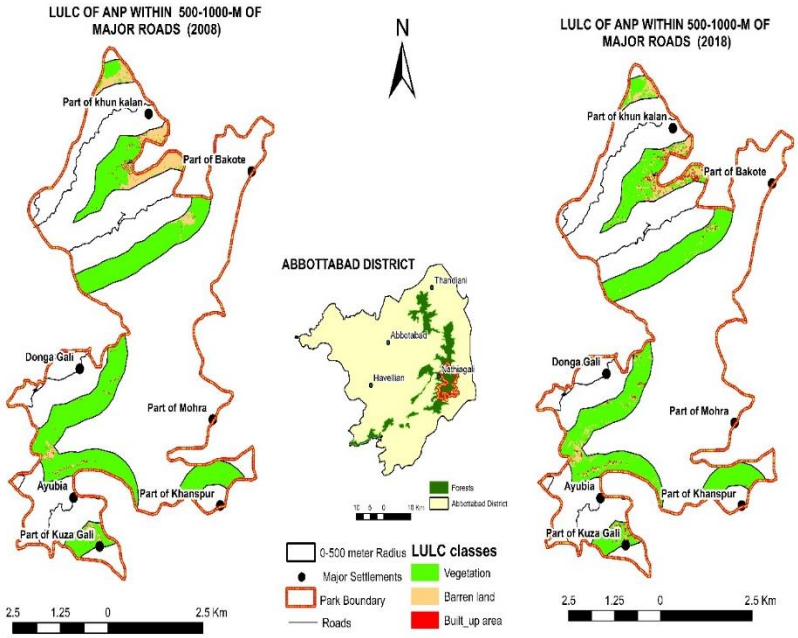


Figure 7: LULC change in ANP from 501-1000m along major roads (2008-18)

Table 3
SLUDD of 01-500m and 501-1000m vicinity of Roads

LULC classes	Single Land Use Dynamic Degree%	
	0-500 m of the Roads	**501-1000 m of the Roads**
Vegetation	-2.29	-0.12
Barren Land	-0.19	-0.18
Built-Up Area	10.78	10.18

Source: Image Analysis in ArcMap 10.5

According to the analysis, in 2008 the built-up areas within 501 to 1000-m of the roads was 3.35% of the total area; the barren land was 19.89%; while vegetation covered an area of 76.76%. However, the built-up areas increased to 5.46% of the total area in 2018 as shown in Table 5 and Figure 8. While the area occupied by barren land and vegetation cover decreased to 18.26% and 76.28% respectively. The SLUDD reveals that the built-up area is growing at an annual rate of 6.31%, vegetation and barren land are declining at annual rates of 0.06% and 0.82%, respectively. Table 6 and Figure 10 display the SLUDD of LULC within 501 and 1000-m of major settlements respectively.

It is evident by comparing the maps from 2008 and 2018 that the LULC change along settlements between 501 and 1000-m is less pronounced than the LULC change between 0 and 500-m (figures 11

and 12). This suggests that LULC change is occurring more frequently close to the major settlements and is waning away from Settlements.

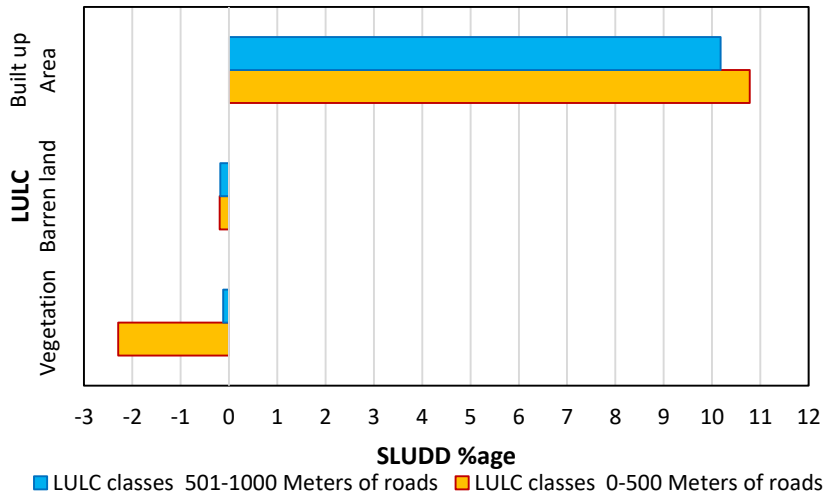


Figure 8: Single L and Use Dynamic Degree of 01-500m and 501-1000m vicinity of Roads

Table 4

Population growth of ANP 2008-2018

S.No	Name of Settlements	Population 2008	Population 2018	Change in Population 2008-2018
1	Khun Kalam	1300**	1600**	300
2	Bakote	15150**	17700*	2550
3	Donga Gali	35**	37*	02
4	Ayubia	500**	740*	240
5	KOza Gali	1700**	2200**	500
6	Khanpur	2600**	3000**	400
7	Mohra	8000**	9000**	1000

Projected * Field Survey **

CONCLUSION

The study analyzed the impact of population growth and accessibility on land use and land cover change in a Ayubia National Park. The results of the analysis indicated that there were significant changes in the land use and land cover of the study area during the study period. Specifically, the study found that the built-up area of the study area increased from 2.61% to 6.91% of the total area from 2008 to 2018. This indicates a significant increase in urbanization and development in the area. At the same time, the proportion of barren land decreased slightly from 16.49% to 15.41% while vegetation decreased from 80.90% to 77.69% of the total area. This indicates that there has been some loss of natural habitat in the study area. The Single Land Use Dynamic Degree (SLUDD) analysis revealed that the built-

up area is increasing at a rate of 16.43% per year, while the barren land and vegetation are decreasing at the rate of 0.65% and 0.39% per year, respectively.

Table 5

LULC in the vicinity of Major settlements

LULC classes	LULC within 0-500 m radius of the Settlements (Area in %)			LULC within 501-1000 m radius of the Settlements (Area in %)		
	2008	2018	Change	2008	2018	Change
Vegetation	66.77	65.54	-1.23	76.76	76.28	-0.47
Barren Land	29.51	24.98	-4.53	19.89	18.26	-1.64
Built-Up Area	3.75	9,48	5.76	3.35	5.46	2.11

Source: Image Analysis in ArcMap 10.5

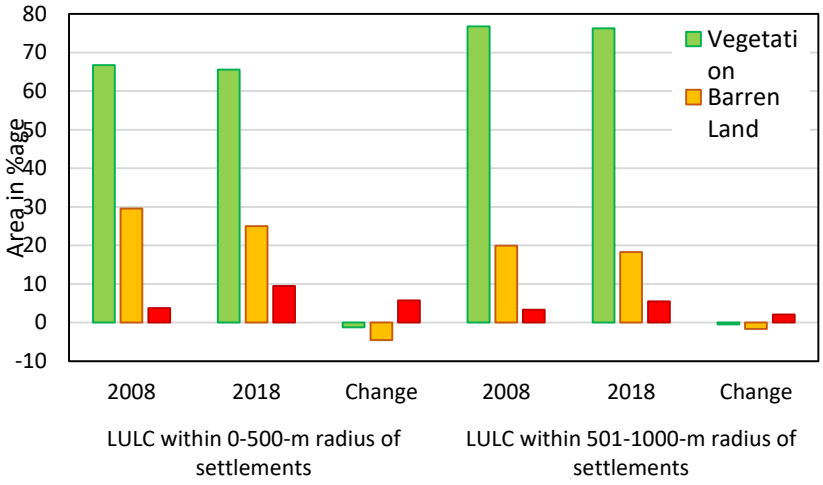


Figure 9: LULC in the vicinity of Major settlements

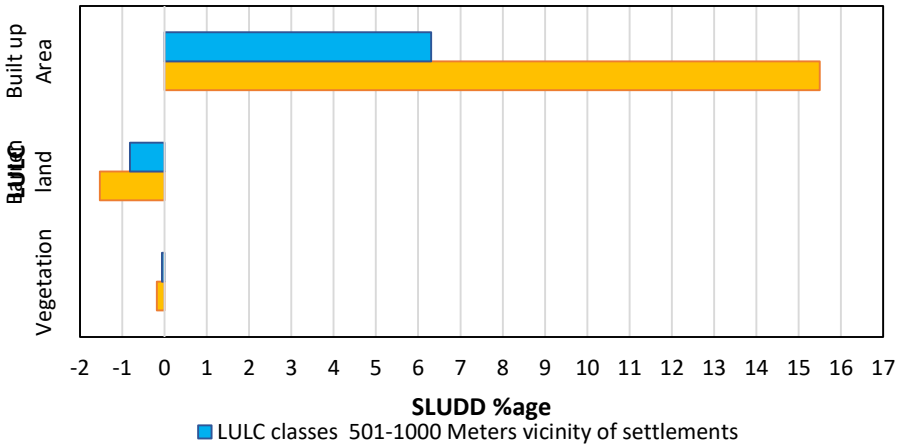


Figure 10: Single land Use Dynamic Degree of 01-500m and 501-1000m vicinity of settlements

Table 6

SLUDD of 01-500m and 501-1000m vicinity of settlements

LULC classes	Single Land Use Dynamic Degree%	
	0-500 m vicinity of the Settlements	501-1000 m vicinity of the Settlements
Vegetation	-0.18	-0.06
Barren Land	-1.53	-0.82
Built-Up Area	15.50	6.31

Source: Image Analysis in ArcMap 10.5

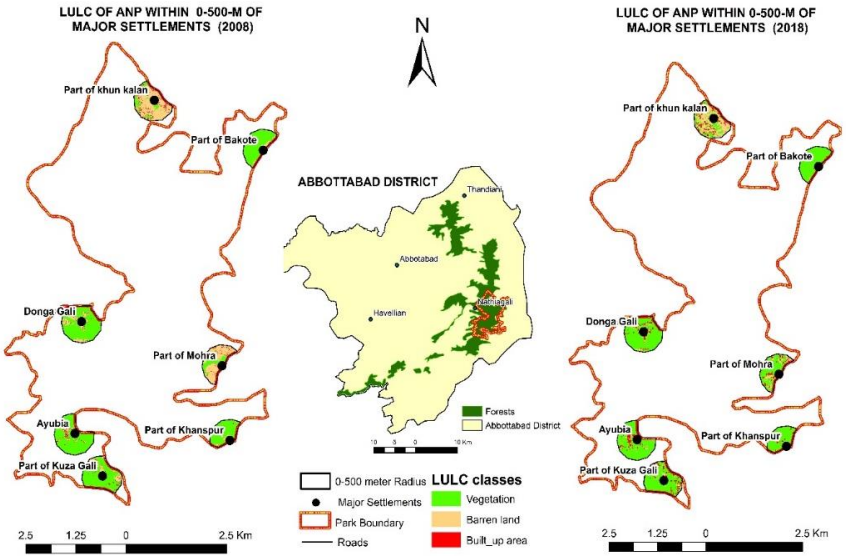


Figure 11: LULC change in ANP within 0-500 meters along major settlements 2008-18.

This suggests that the trend towards urbanization and development is continuing at a rapid pace in the study area. The study evaluated the impact of accessibility on LULC change. The results of this analysis may shed light on how proximity to major roads and accessibility may be influencing LULC changes in the study area.

The study also looked at how the population expansion impacted the LULC dynamics in the study area. The findings suggest that the built-up area expanded by a net amount of 5.76% within 0-500-m of the settlements, whereas the area under barren land and vegetation declined by 4.53% and 1.23%, respectively. similar results were demonstrated by 501-1000m analysis. The built-up area is increased by a net amount of 2.11% between 501 and 1000-m of the settlements, whereas the total area of barren land and vegetation decreased by net amounts of 1.64% and 0.47%, respectively. This suggests that as we move away from built-up areas, the impact of population expansion on land use and land cover changes is reducing.

Overall, the results of the analysis suggest that population growth has a significant impact on LULC changes in the ANP.

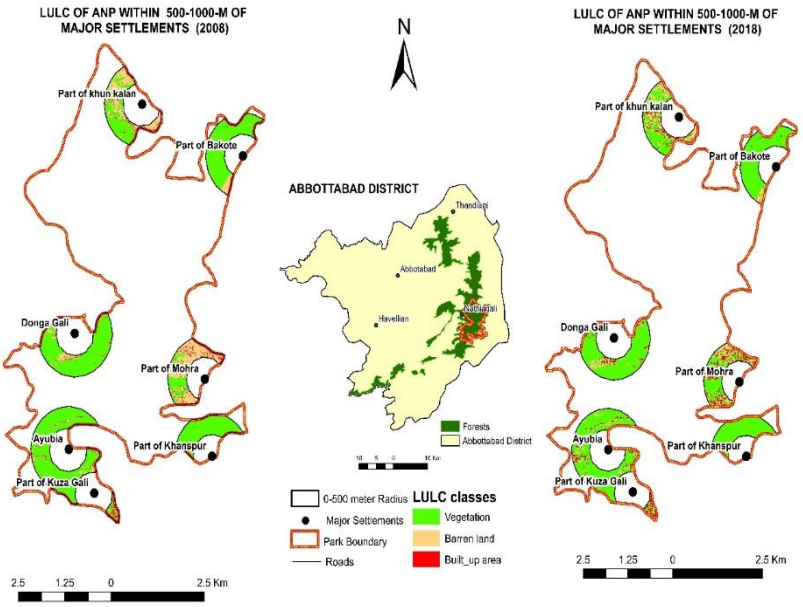


Figure 12: LULC change in ANP within 501-1000 meters along major settlements 2008-18

The tendency to build houses close to already developed areas is contributing to the rapid urbanization and development of the study area. The findings could be useful for policymakers and land managers who are interested in developing strategies to manage and mitigate the negative impacts of population growth on land use and land cover changes.

The results of the study indicate that the population growth, accessibility, and tourism are the major driving forces behind the land use land cover changes in Ayubia National Park. The increase in dwelling units and commercial areas due to population growth and tourism has resulted in the expansion of constructed land and reduction of vegetation cover and bare land, which has led to soil erosion, land degradation, and extinction of wildlife species. The reduction of grazing grounds and medicinal plants has also been observed due to these changes. Moreover, the respondents noted that the ban on grazing and cutting of grasses in the park has led to a decrease in the number of livestock. This change in land use and land cover may have consequences for the drainage pattern and overflow of the park, which can alter the vegetation, nutrient levels, and related processes, ultimately damaging the biodiversity of ANP. Therefore, the study

highlights the urgent need for restoration actions to save the park from further damage.

Overall, the study shows that the land use land cover changes in ANP are a complex issue that requires a multi-dimensional approach. The study findings may provide insights for policymakers and stakeholders to formulate strategies for sustainable land use and conservation of biodiversity in the park.

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