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Spatial Analysis of Land Use/Land Cover Changes in Mardan, Pakistan: A Decadal Study Using GIS and Remote Sensing

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Abstract:
During the past decades, the district of Mardan has experienced remarkable expansion in terms of growth and development activities. The increasing population has resulted in drastic changes in the land use pattern. This study employs GIS and remote sensing methods to monitor the variations in land use and land cover between 2008 and 2018. The primary objective is to identify different land use and land cover classes within the area of interest and analyze the changes that have occurred over the past ten years. Landsat images sourced from the United States Geological Survey (USGS) database were utilized in this study, while vector data was derived from topographical sheets of the study area. ArcGIS was employed for data analysis, including band composition and other image enhancement techniques. The images were classified using supervised maximum likelihood classification, and accuracy assessment was carried out through the use of a confusion matrix. The findings reveal a decrease in vegetation cover from 35% to 24.01% of the total area over the past two decades. Conversely, the built-up area has witnessed an increase from 35% to 60%. Additionally, water coverage has decreased by 8% from 2008 to 2018. Furthermore, barren land has experienced a 17% increase over the ten-year period (2008-2018). In summary, this study provides valuable insights into the changing land use and land cover patterns in the district of Mardan. The results highlight a decline in vegetation cover, an increase in built-up areas, and changes in water coverage and barren land over the specified time frame.

Keywords: urban Expansion, Agriculture land use conversion, change detection, remote sensing, GIS.

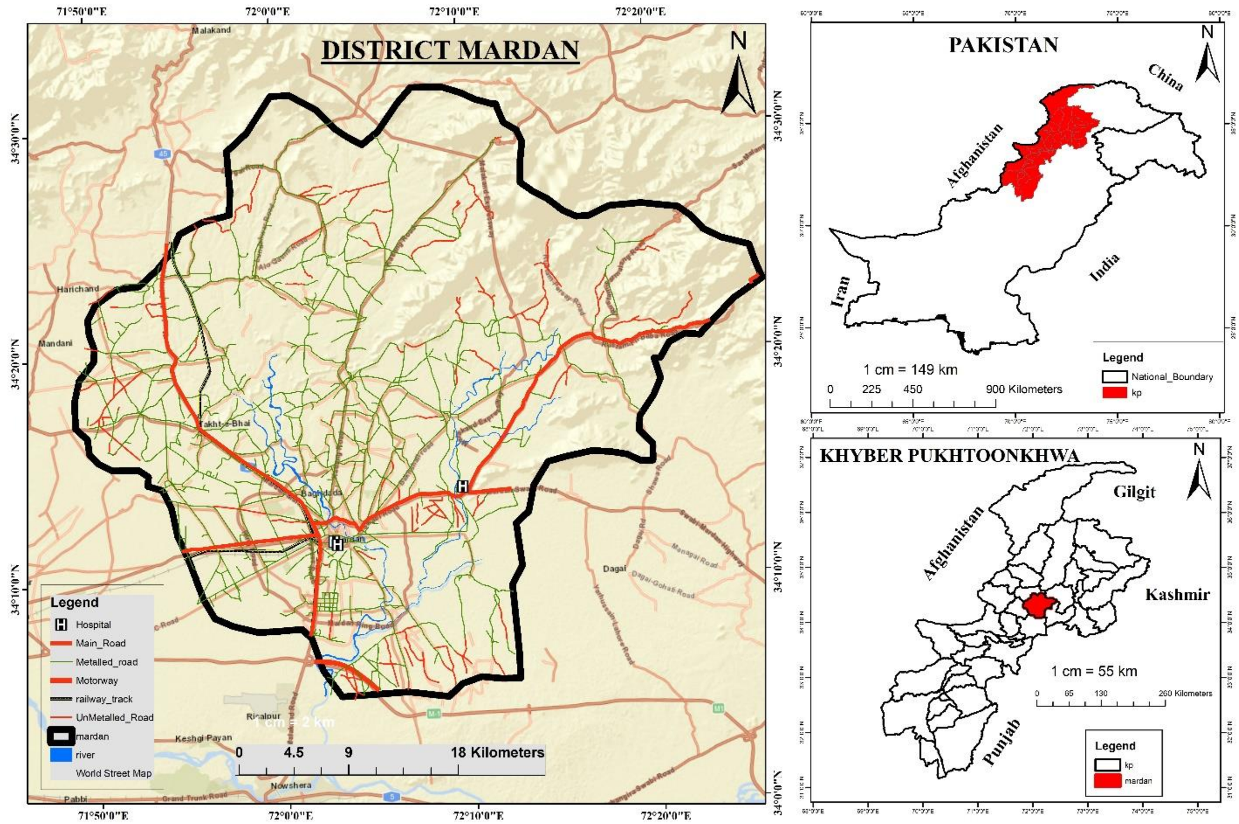
Introduction

Land use change is recognized as a key area of research within the context of global environmental change and sustainable development. The increasing intensity of land use change, driven by global population growth, has significant implications for the environment, necessitating comprehensive investigations into these transformations (Wu *et al*., 2006). To address this issue, numerous international interdisciplinary research initiatives have been launched in the past two decades, such as the International Geosphere-Biosphere Project (IGBP) and the International Human Dimensions Program (IHDP) (Messerli, 1997). These initiatives have emphasized the importance of constructing an up-to-date and accurate database to understand the nature, rate, and drivers of land use changes (Mather, 1999). Variations in land use and land cover are widely recognized as significant global environmental concerns (Guan *et al.*, 2011); (Li *et al*., 2018); (Powers and Jetz, 2019); (Veldkamp and Lambin, 2001) ;(Meyer and Turner, 1996); (Verburg *et al*., 1999); (Dai et al., 2001); (Geist and Lambin, 2001); (Veldkamp and Lambin, 2001). These studies have contributed to our understanding of the drivers, impacts, and implications of land use and land cover change. These variations frequently occur because of anthropogenic activities (eg deforestation, urbanization, intensification of agriculture and further land degradation), yet natural factors can contribute to these variations (Noszczyk, 2019). Changes such as conversion to intensive and large-scale farming, as well as overgrazing, are among the main factors contributing to land degradation in dry lands (Ajai and Dhinwa, 2018); (D'Odorico et al., 2019); (Farshad *et al*., 2019). These anthropogenic changes can lead to a decline in biodiversity (Isbell et al., 2017); (Mori *et al.,* 2018); (Sánchez-Bayo and Wyckhuys, 2019) and the depletion of natural resources. Consequently, they can severely impact the food supply in these areas, with significant social and political consequences (Creutzig *et al*., 2019); (Purswani *et al.,* 2020); (Ramankutty *et al.,* 2018);(Turner *et al*., 2007); (Shahid.I *et al*. 2023)

Changes in land cover, although not necessarily indicating land degradation, often result from various reasons within a community (Gibb et al., 2018). Alterations in land cover can affect variables such as vegetation diversity, water and radiation budgets, and trace gas emissions, ultimately influencing climate and the biosphere (Bawden, 2018; Vico and Davis, 2019; Yin et al., 2019). Land use dynamics in a given region reflect the characteristics of the natural and anthropogenic environment (Borrelli et al., 2017; Gerssen-Gondelach et al., 2017; Li et al., 2017). It encompasses the physical environment, including natural topography, land cover classification, and the availability of water and other natural resources (Issaka and Ashraf, 2017; Giri and Qiu, 2016). Furthermore, it encompasses human activities in the past, such as urban structures, main transportation routes, agricultural land use, road networks, urban development, and industrialization. Changes in land use patterns play a crucial role in managing natural resources and assessing environmental variations (Arnous et al., 2017; Hegazy and Kaloop, 2015). Therefore, understanding and documenting landscape change processes are essential for sustainable land management practices.

Patterns of landscape transformation result from complex interactions among physical, biological, and social forces (Turner, 1987). To ensure effective management of physical properties, it is crucial to recognize and evaluate the processes driving landscape changes. These changes not only reflect shifts in land cover but also provide insights into the natural and human environment dynamics. Various human activities are undertaken to exploit Earth's natural resources, which are rapidly depleting due to the heavy burden of agriculture and urbanization. Therefore, studying changes in land use and land cover is of paramount importance in order to meet the growing demands for basic human needs and well-being. Land, water, and vegetation are essential for fulfilling human needs. Remote sensing satellite data has proven to be a valuable tool for mapping and analyzing land cover (Levizzani and Cattani, 2019; Vadrevu and Lasko, 2018). Monitoring such changes can be accomplished using geographic information system (GIS) methods, even though the resulting spatial datasets may have different resolutions (Sarma et al., 2001). It is crucial to update land information to effectively control and plan resources for sustainable growth (Alphan, 2003).

Figure: 01 Location Map of Mardan, Pakistan



Materials and Methods

Study area

Mardan, located in the Khyber Pakhtunkhwa Province of Pakistan, serves as the headquarters of Mardan District. It holds the distinction of being the 19th largest city in the country. Geographically positioned at 34°12′4.4″ North latitude and 72°01′33″ East longitude, Mardan is the de facto headquarters of the Yousafzai tribe, although a significant number of Momands have also settled there in recent years. Spanning an area of 1,632 km2 (630 mi2) and situated at an elevation of 1,020 ft. (310 m) above sea level, the city lies approximately 45 km away from Peshawar.

Satellite Data

Imageries of 30 meter of Land-sat 7 and Land-sat 8 were downloaded from the United States Geological Survey (USGS): //earthexplorer.usgs.gov/. USGS delivers free of cost imageries for study purposes, but generally the images are of low resolution. One satellite image covers an area of 185 km ×185 km

Area of interest

A full raster image was downloaded and opened in ArcGIS 10.5, and the shapefile representing the study area was overlaid onto these images. The study area, delineated by its border, is distinct from the rest of the image. Satellite images of the study area for 2008, 2013, and 2018 were obtained."

Image Classification

The Object Based Image Analysis (OBIA) method of supervised classification was used to derive Land use for the year 2008, 2013, and 2018. A multiresolution segmentation technique, which is a bottom-up region merging technique that starts at a single pixel and continues in several steps until the fulfillment of user-defined homogeneity criteria, has been developed and implemented in e Cognition software. This technique segments the image at both fine and coarse scales, depending upon the scale of interest, in this case 200 scale was set. After segmentation new classes are made in the class hierarchy window i.e., barren land, Built-up area, Vegetation and waterbody. Now select samples simply by clicking on the classification tab in the menu bar and then samples and select samples now assign the samples to each class. Then append a new rule in the process tree right click in the append window and click append new then select the classification option and execute the project. The final classified image is exported to ArcMap 10.5 in a vector (polygon) format.

2.5 Area Calculation

After conversion from polygon to raster, a field named Area added in attribute table. Area of each sample calculated by using Field calculator. Total area of each class computed by summarizing all grid codes and obtained as a sum output table. Finally, area of four classes i.e., barren land, Built-up area, Vegetation, and waterbody calculated through image classification technique.

2.6 Supervised Classification

The satellite images for each year were classified using a supervised classification method. The supervised classification process involved several steps, including collection of training samples, definition of signatures, and construction of maximum supervised classification. To collect a representative sample for each class, an area of interest instrument was used. After the manuscript files were generated, the image pixels were classified into classes based on these patterns by the largest possible classification. It was a supervised segmentation command applied to a raster image, using the relevant signatures. The result was a raster image. The procedure for this process is shown in Figure 3.

2.7 Accuracy assessment

After classification, the results were validated. To assess accuracy, matrices of User Accuracy, Producer Accuracy, and Overall Accuracy were calculated. User accuracy was calculated by dividing the number of correctly classified cells by the total number of landmarks. For this study, landmarks were obtained from Google Earth. Producer accuracy was also determined by dividing the total number of correctly divided cells for each land use/land cover class by the total number of field truth pixels. Overall accuracy was obtained by dividing the total number of correctly classified cells by the total number of pixels in the searched area. The results of the accuracy assessment are shown in Table 1.

Figure. 2. Methodology flow chart

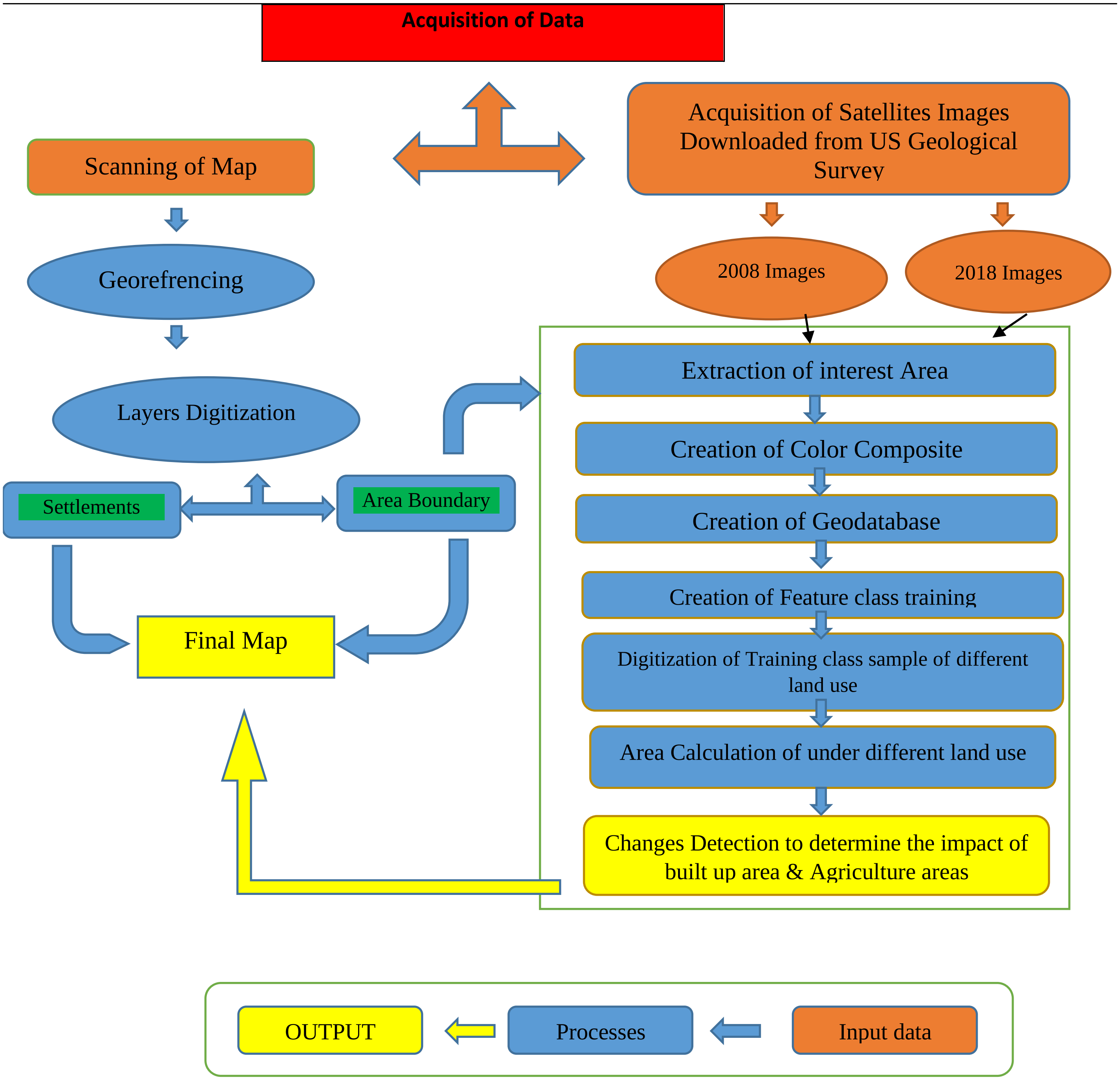


Table 01: Temporal Changes in the study area under different land use classes between 2008, 2018

Year	Built-up Area	Vegetation	Waterbody	Barren land
Area 2008 **(km-Sq.)**	141.2919	848.135	54.2925	597.5487
Area 2018 **(km-Sq.)**	226.8927	665.9379	50.0886	698.3514

Figure 03. Land use / Land cover Changes in (2008, 2013-2018) of District Mardan.

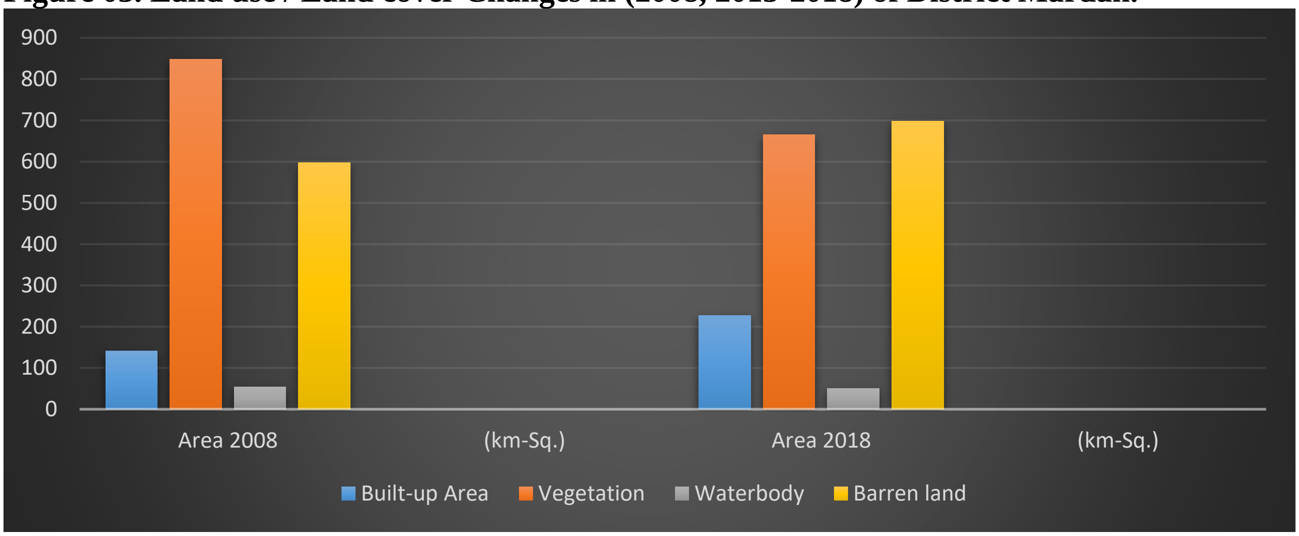
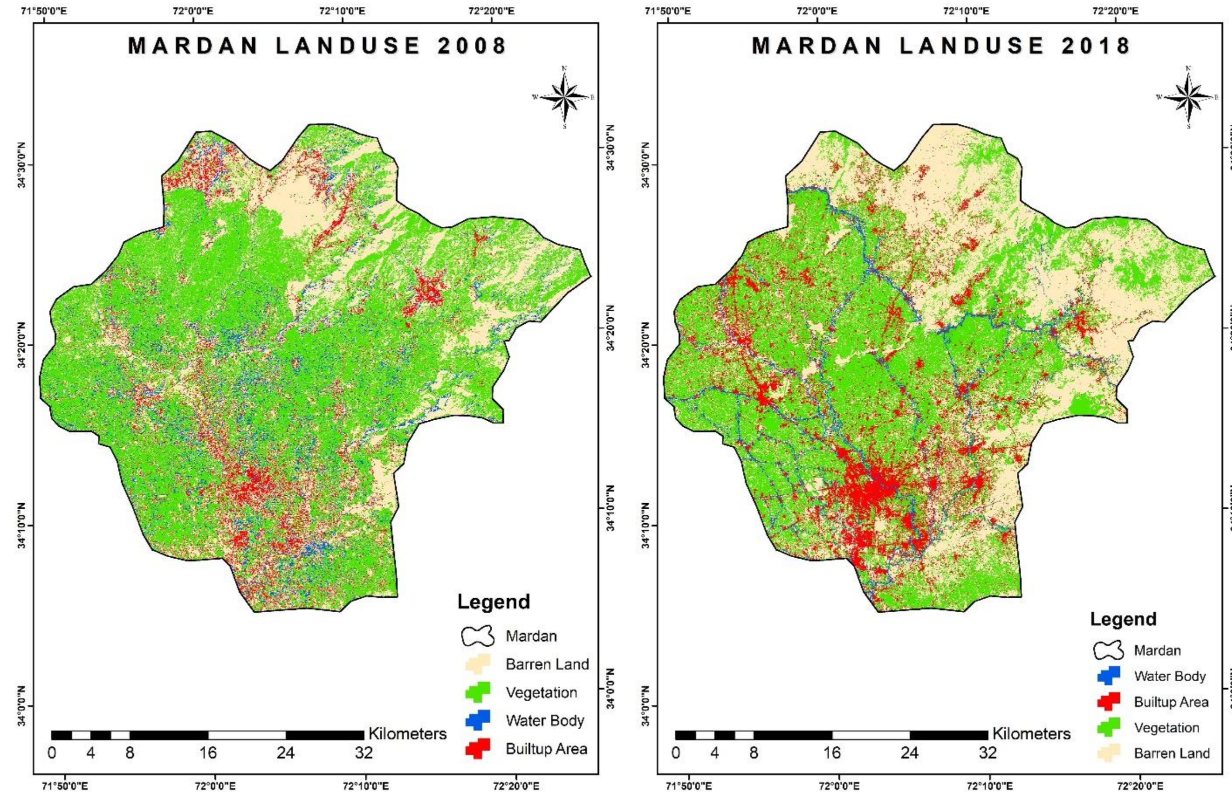


Table 02: The accuracy matrix for classified images 2008, 2018

Class name	User accuracy%	Procedure accuracy%	Overall accuracy%
2008 Images			
Water body	100	100	93.50
Barren land	92.80	100	
Vegetation	100	96	
Built-up Area	100	93	
2018 Images			
Water body	100	72.5	91.01
Barren land	75	60	
Vegetation	80	90	
Built-up Area	62	73	

Figure 04: Classified land use Maps of District Mardan (2008, 2018).



3. Results and Discussion

After applying GIS techniques, the satellite images of the study area for the years 2008 and 2018 were classified. The classification process involved four land use/land cover (LULC) classes: built-up area, water bodies, natural vegetation, and barren land. The overall land use change between the two maps for 2008 and 2018 is depicted in Figures 3 and 4. The accuracy of the classified images was assessed and found to be 91.01% for the year 2008 and 93.5% for the year 2018. The overall kappa coefficients were 0.91 and 0.93, respectively. According to Lea and Curtis (2010), an accuracy assessment report is typically required for Landsat images with an accuracy above or equal to 90%, which was successfully achieved in this study.

Table 1 displays the classification results for the years 2008 and 2018. The results reveal a decrease in vegetation cover and an increase in urban areas over the years. Specifically, the urban area expanded by 46.49% from 2008 to 2018, while the vegetation cover decreased by 24.067% during the same period. The water class, which represents the smallest cover area, experienced an 8% change likely due to recent floods and high annual rainfall in the area."

The manner and shape of urban area increased very rapidly from 2008 to 2018. The comparison of both years shows drastic change in land use for last 10 years. Same study were carried out by (Butt, et al, 2015) for Smiley Watershed, Islamabad, Pakistan. They reported that vegetation land shrank from 69% to 43% of the total area while Water class, which was least area covering class in 1992, further lost area under its cover and reduced from 4% to 1%. The share of Settlements was 6% of the total area which increased up to 11%. The Agriculture class was increased from a share of 11% to 29% and the bare soil/rocks faced an increment in the total share from 10% to 16%. The achieved overall classification accuracies were 95.32% and 95.13% and overall kappa statistics were 0.9237 and 0.9070 respectively for the classification of 1992 and 2012 images.

District Mardan land use land covers change 2008-2018

From the 2008 and 2018 image analysis, it was observed that the urban area experienced a 60% increase from 2008 to 2018. The coverage of water bodies also decreased by 8% during the same period. Additionally, the vegetation land declined from 35% in 2008 to 24% in 2018.

Conclusion

The objective of this study was to provide a recent perspective on land cover and land use changes that have taken place over the past sixteen years in District Mardan. Advanced tools of Geographic Information System (GIS) were used to assess these changes in the study area. The analysis revealed significant variations in land cover due to agricultural and infrastructure development projects. There has been a substantial increase in built-up areas and a significant decrease in agricultural land. The area covered by natural vegetation has also considerably declined.

The primary cause of agricultural land degradation is the unplanned development of towns and commercial markets. People from surrounding villages have been migrating to District Mardan for business opportunities, as it is one of the busiest markets in Khyber Pakhtunkhwa, Pakistan. The integration of GIS and remote sensing has provided valuable information on land cover changes, as depicted in Figure 3 for the years 2008 and 2018. It highlights the nature, area, and spatial distribution of different land cover changes.

The analysis of the classified images for 2008 and 2018 reveals that the built-up area increased by 60%, while vegetation decreased by 24.01%. The dominant land use class in Mardan is categorized as urban, covering 39.6% of the total area in 2008 and increasing to 57.5% in 2018. The second major land use category is vegetation cover, which accounted for 35.4% of the total area in 2008 but decreased to 24.01% in 2018. Arid lands experienced a 17% increase from 2008 to 2018. Additionally, the area covered by bodies of water decreased by 8% during the same period.

Proper planning is crucial to protect and preserve agricultural lands from excessive industrialization. This is essential for meeting basic needs such as food and water in the future. This study can be further expanded using different programs and methodologies.

List of Abbreviations:

GIS, Geographic information system;
RS, remote sensing;
USGS, United States Geological Survey.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request

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