A Comparative Study of Land Use Land Cover (LULC) Change Detection: A Case Study of Tehsil Babuzai, Swat (Pakistan)

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Abstract

Tehsil Babuzai, District Swat, Khyber Pakhtunkhwa, Pakistan, has experienced a fast population increase, substantially influencing land use and land cover (LULC), raising ecological and environmental issues. This study examines changes in LULC between 2001 and 2020 using US Geological Survey (USGS) satellite images. The paper analyses six primary land cover classes: farmland, built-up area, woodland, water bodies, rangeland, and barren Land using maximum likelihood supervised classification. The findings show a significant rise in rangeland (from 49.1% to 53.7%), built-up areas (from 8.5% to 13.7%), and barren Land (from 5.1% to 11.1%). On the other hand, there is a noticeable decline in the number of water bodies (from 2.1% to 1.6%), agriculture (from 21.2% to 12.2%), and forest cover (from 13.7% to 7.5%). These alterations underscore the detrimental consequences of urban growth on the area's natural resources, demanding prompt and deliberate planning to protect the ecosystem and guarantee sustainable development. This research is crucial for understanding land use changes' dynamics and impacts, providing valuable insights for policymakers and urban planners. It highlights the need for sustainable land management practices to mitigate adverse environmental effects and promote balanced regional development.

Keywords: Land Use, Sustainable Land Management, Satellite Imageries.

Introduction

Reduction in biodiversity has been caused by the change in land use and land cover, which directly impacts the area's climatic condition at the local and regional levels (Yadeta & Asefa, 2022). Worldwide, Land Use Land Cover (LULC) is a dynamic and consistent process (Brown & Tait, 2022). It is evident from the LULC analysis that in the less-developed worlds, such changes are at an exponential pace (Khan & Rahman, 2023). Parallel to this, the natural ecosystem's land features and prospects provide environmental services to a large section of the society (Capitani & Marchant, 2015). The different types of activities carried out by human beings on the earth's surface refer to land use, including agriculture, commercial, recreation, settlement and

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Industrialization. Land cover (LC) means the covering of the earth's surface either naturally or culturally; it most likely refers to natural features like water bodies, forest cover, and barren land grass (Madinga, 2021).

The spatial and temporal arrangement of Land use land cover (LULC) modifications of any specific land surface is the advent of the interaction between man and environment (Southworth & Tucker, 2001). The observable changes over the earth's surface are a process in which a phenomenon and or an object is visualized at various intervals and times to explore the variations in the type of changes (Ganasria & Dwarakish, 2015). The most significant natural events that result in land change are floods, climate change, earthquakes, forest fires and desertification. Population growth, economic development, urbanization, government policies, and Industrialization are the artificial factors responsible for LULC changes (Ganasria & Dwarakish, 2015). With the increase in population, more food, settlements, harvesting and raw materials are required, resulting in enormous pressure on the earth's limited resources and causing more cultivation expansion and deforestation in cities (Zahir & Iyoob, 2021).

Land cultivation is the oldest livelihood and the first land utilization by humans on the earth's surface (Ramankutty & Foley, 1999). Cultivation of Land is the main source of raw material and food, but there is a decrease in the cultivation of Land throughout the world, causing food scarcity; the main factors of this decrease in agricultural Land are waterlogging and salinization, built-up area extension (Olagunju, 2015).

The world's population is increasing rapidly, and more houses, food, and other basic facilities are needed. All these will be achieved by bringing more Land under cultivation or increasing the yield per unit production, but this will affect the world's available resources (Shalaby & Tateishi, 2007). Understanding the relationship between humans and the environment requires understanding land use and land cover (LULC). While land cover comprises natural components like water, rocks, and flora, land usage refers to how humans use Land for different activities. Both greatly influence one another and are intimately related despite their distinctions. Because of human activity, land cover has been continuously changed, turning once-natural landscapes into metropolitan areas and agricultural regions to accommodate an expanding population. The environmental effects of this transition are significant, resulting in ecological shifts and land degradation. Because it facilitates the identification of patterns and dynamics of land use and cover across time, the analysis of LULC changes is essential to sustainable resource management and planning. The significance of understanding these changes has been underscored by researchers, given their impact on soil distribution, hydrological processes, and the general equilibrium of the ecosystem. Conventional techniques for detecting LULC changes are frequently expensive and have a narrow focus. However, the availability of precise, comprehensive, and repeatable data for tracking changes has allowed remote sensing and GIS technology to transform this profession completely. Research has demonstrated that several variables, such as economic activity, population increase, and technological developments, influence LULC variations. Effective land management now depends on integrating remote sensing data with GIS, which enables in-depth modelling and analysis of LULC dynamics. Technical advancements are essential to ensure the sustainable development of natural resources and meet the environmental difficulties created by fast land use changes.

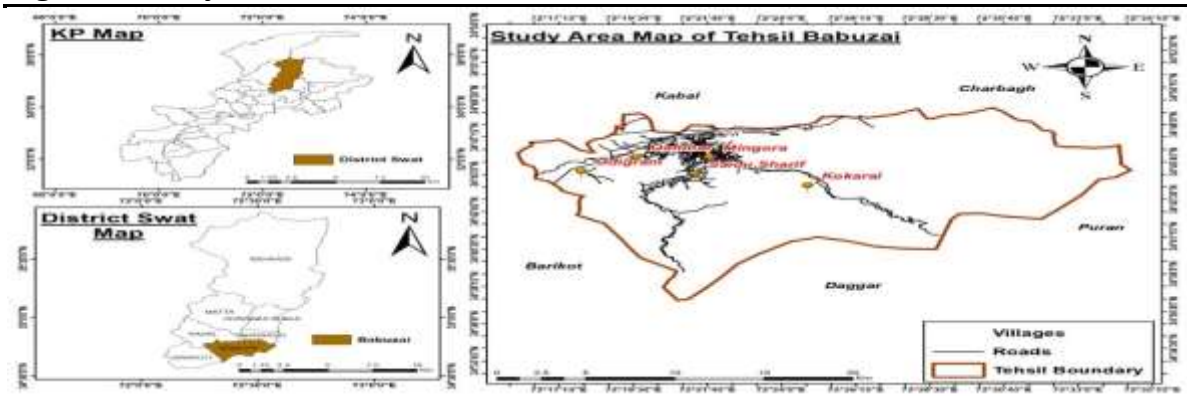
Study Area

Tehsil Babuzai is the administrative unit of district Swat, Khyber Pakhtunkhwa, Pakistan. It is situated at 34° 37' 23" to 34° 49' 1" of north Latitude and 72° 15' 59" to 72° 34' 36" of east Longitude. The Total Area covered by Tehsil Babuzai is 297 SqKm. Relatively, the tehsil of

Barikot is located west of the tehsil Babuzai, Kabal tehsil at the northwest, tehsil Charbagh at the northeast and tehsil Puran and Daggar at the east and southeast of the tehsil Babuzai. According to the 2017 census report, the population of tehsil Babuzai was 599324. The natural beauty of Babuzai and its surroundings make it inherently attractive, and it used to be a highly popular tourist destination. The best time to visit Babuzai is between March and November when visitors can enjoy its magnificent mountains, lush green forests, flowing rivers, and vast grasslands.

The Region has a long history that spans over 2000 years. Originally called Udyana, the name was eventually changed to Suvastu. Until the eleventh century, the region was a fairly tranquil place to live. The area was disrupted due to the power struggle, and Mahmood of Ghazni became the first to take control of it. The Yusufzais eventually took control of Swat Valley after the practice of obtaining the territory proceeded. The practice of obtaining the territories proceeded, and the Yusufzais eventually took control of Swat Valley. Swat Region was ruled by Akhund Sahib in the late nineteenth century, who adhered to Muslim law. Because of the agricultural boom at this period, the Swat area's economy prospered, and it was one of the important commercial hubs for companies. Around 1,257,602 people call the Swat Valley home. Of the many ethnic groups here, the Pashtuns, Yusufzais, Kohistan, Gujars, and Awans are among the most notable. The "little Switzerland" is Swat Valley.

Figure 1: Study Area of Tehsil Babuzai District Swat



Methodology

Data Collection

The research is totally based on satellite imagery to examine the land use land over changes in the Study area for the period of 20 years from 2001 to 2020. Two imageries were acquired for the year 2001 and 2020 (table 1 for details). The imageries were downloaded from United State Geological Survey (USGS). While the Tehsil boundary was Obtain from the Pakistan tehsil shape file downloaded from open source DIVA.GIS (http://www.diva-gis.org/gdata).

In 1984, the Landsat 5 (TM) satellite sensor was launched in California, sharing similarities with Landsat 4 as it also incorporates the Multispectral Scanner (MSS) and the Thematic Mapper (TM) mechanisms. Landsat 5 (TM) captures imagery using seven spectral bands, with bands 5 and 7 featuring a spatial resolution of 30 meters. However, Band 6 (thermal infrared) has a lower spatial resolution of 120 meters, which is later resampled to 30 meters. The covered scene extends approximately 170 km from north to south and 185 km from east to west. While in 2013, the Landsat 8 (OLI/TIRS) satellite sensor was launched from California, encompassing both the Thermal Infrared Sensor (TIRS) and Operational Land Imager (OLI) missions. This advanced

satellite is equipped with eleven spectral bands, each providing a spatial resolution of 30 meters. Notably, Landsat 8 offers a higher spectral resolution compared to its predecessors, and its radiometric resolution is 16-bit. The captured images cover an extensive area of approximately 170 kilometers north-south by 185 kilometers east-west (106 miles by 115 miles).

Table 1: Details of satellite images used in analysis

Sensor	Path/Row	Image Date	Scenes ID#	Number Of Band	Spatial Resolution
LANDSAT 5	151/036	5/14/2001	TM	7	30m
LANDSAT 8	151/036	5/26/2020	OLI_TIRS	11	30m

Image Classification

Image classification is the process in GIS to classify the satellite imagery into different land Cover. It is a technique used in GIS for the comparative analysis of temporal satellite imagery to detect changes in the same area of interest. There are three types of classification a) supervised b) unsupervised and c) object base image analysis. For the general study we mostly used supervised and unsupervised classification while the object base image analysis are used for the detail study because it requires a high resolution images. In this study we have used supervised classification by using Maximum likelihood algorithm to detect the spatial and temporal distribution of land use land cover for the period of 2001 and 2020 in the tehsil Babuzai. The process was performed on Arc Map 10.7

Supervised Classification

The given task involved using a supervised classification method to identify changes in Land Use and Land Cover (LULC) over a specific period. The classification was performed using the maximum likelihood technique in ArcGIS 10.7. This technique assumes that the sample class data follows a normal distribution and takes into account the characteristics, covariance matrix, and mean vector for each class. To classify the images from 2001 and 2020, a maximum likelihood classifier was employed. The classifier calculates the probability of each cell belonging to a particular class based on its characteristics (such as pixel values) and assigns the membership of each cell accordingly. The data processing involved the following algorithmic steps to accomplish the classification task.

Post-Processing

The results of classification were classified into 6 major land use land cover classes (Water, Built-up, Barren Land, Rangeland, Forest, Crop land). Furthermore, the analysis involved calculating the area covered by each specific Land Use/Land Cover (LULC) category using the generated images. A map detecting changes was created to cover the time span between 2001 and 2020.

Accuracy Assessment

The accuracy of the classified images was evaluated in order to determine their dependability. The evaluation process included comparing the identified images with ground truth data, which is typically derived from satellite imaging due to its accessibility. The precision dataset analysis was the evaluation technique used in this work. From the images, test pixels were taken out that were not part of the training samples used for the supervised classification. A total of 300 pixels were available each image (60 pixels for each of the four classifications). The evaluation's findings cover

both the general accuracy of the map and the particular accuracy of each class on the map. The following formula can be used to determine the total accuracy:
Total Accuracy = (Total Correct Samples / Total Samples) * 100%.

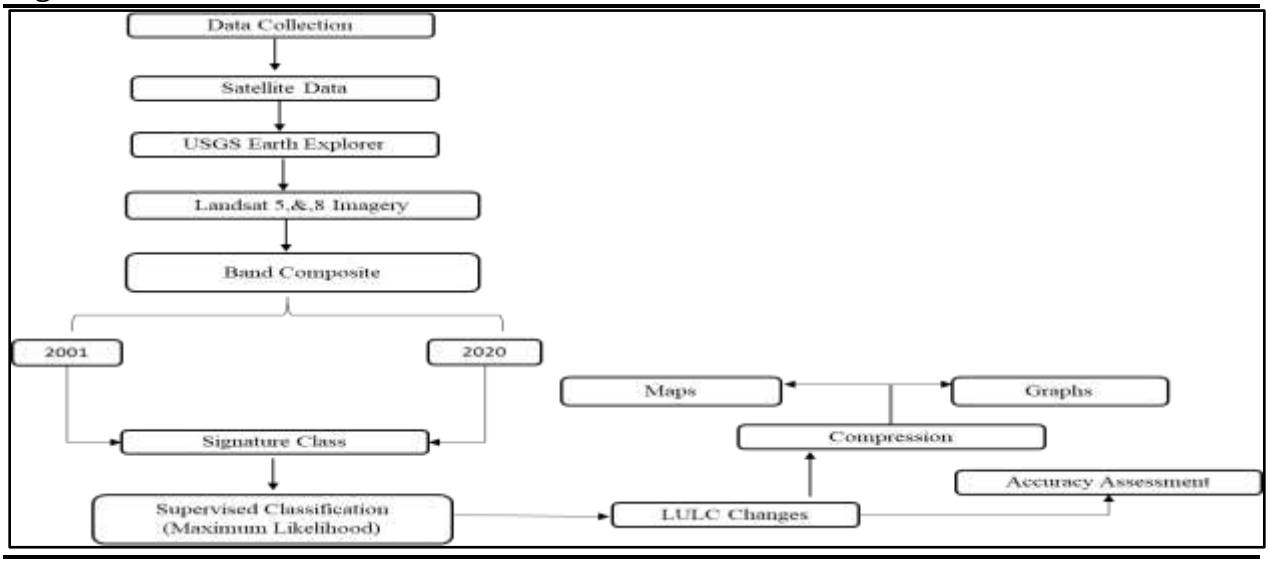
Table 2: Accuracy assessment of 2001

2001							
Land Cover	Reference Point						Ground Truth
Water	52	0	0	7	3	0	62
Forest	0	58	0	2	0	0	60
Rangeland	1	0	0	50	6	0	59
Crop	0	4	0	0	51	0	55
Built-up	2	0	51	0	0	1	54
Barren Land	0	0	9	0	5	56	70
Total	55	62	60	59	65	57	360
Percentage =	88.6%						

Table 3: Accuracy assessment of 2020

2020							
LULC2020	Reference Point						Ground Truth
Water	59	0	0	5	3	0	67
Forest	0	60	0	1	0	0	61
Rangeland	1	0	0	54	2	0	57
Crop	0	0	0	0	53	0	53
Built-up	0	0	51	0	0	1	52
Barren Land	0	0	9	0	2	59	70
Total	60	60	60	60	60	60	360
Percentage=	93.3%						

Figure 2: Flow chart



Results

The results of the classification conducted for Tehsil Babuzai in 2001 and 2020 shows significant changes in the landscape. Analysis of the data shows a decrease in water bodies, reducing by 5% from 2.1% in 2001 to 1.6% in 2020. However, the area covered by water bodies in 2001 was 6.8 SqKm it reduced to 5.22 SqKm in 2020, a notable alteration was observed in other land categories. The forest area experienced a decline of 7.78%, dropping from 13.78% in 2001 to 7% in 2020. Decrease in the area of forest cover from 44.47 SqKm in 2001 to 24.22 SqKm in 2020. Conversely, the rangeland expanded by 4.7%, increasing from 49% in 2001 to 53.7% in 2020. Area wise the rangeland increases from 158 SqKm in 2001 to 173 SqKm in 2020. The built-up area also witnessed a growth of 5%, rising from 9% in 2001 to 14% in 2020. Built-up increases from 27 SqKm in 2001 to 44.4 SqKm in 2020. Crop land, on the other hand, experienced a decrease of 9% from 21% in 2001 to 12% in 2020. Crop land area decreases from 68.6 SqKm in 2001 to 39.40 SqKm in 2020. Additionally, barren land saw an increase of 6%, soaring from 5% in 2010 to 11% in 2020 of the total landscape in 2020. Area of Barren Land increases from 16.70 SqKm in 2001 to 35.8 SqKm in 2020. The results show that Tehsil Babuzai landscape changed significantly between 2001 and 2020.

Table 4: LULC of 2001

2001		
Land Cover	Area(sq.km)	%age
Water	6.80	2.11
Forest	44.47	13.78
Rangeland	158.67	49.15
Crop Land	68.68	21.27
Built-up	27.51	8.52
Barren Land	16.70	5.17

Figure 3: Spatial distribution of land use land cover map of 2001

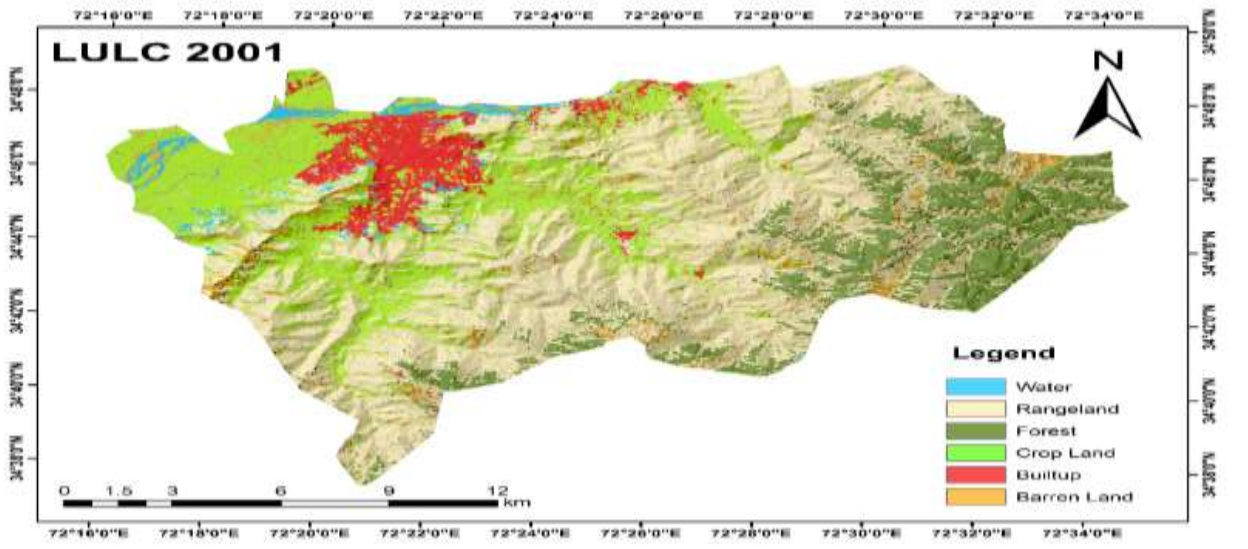


Table 5: LULC of 2020

2020		
Land Cover	Area(sq.km)	%age
Water	5.22	1.62
Forest	24.22	7.50
Rangeland	173.67	53.79
Crop Land	39.40	12.20
Built-up	44.49	13.78
Barren Land	35.84	11.10

Figure 4: Land use land area of 2001

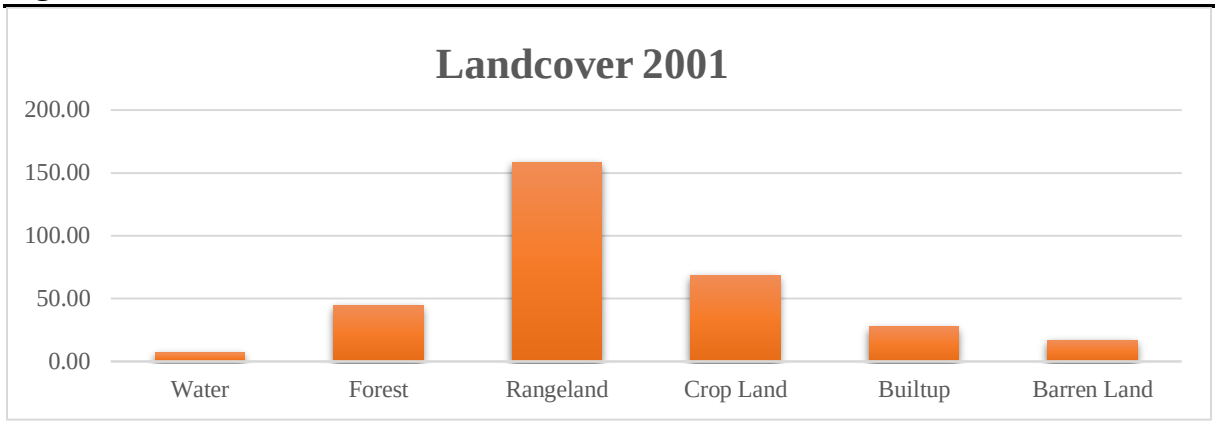


Figure 5: Spatial distribution of land use land cover map of 2000

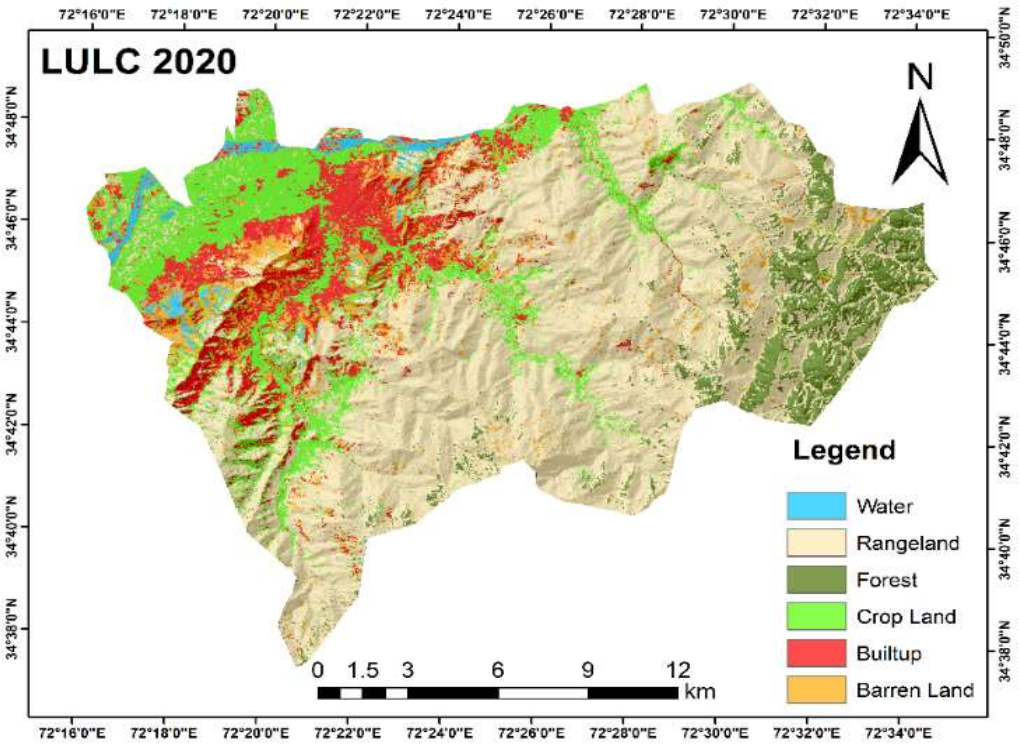
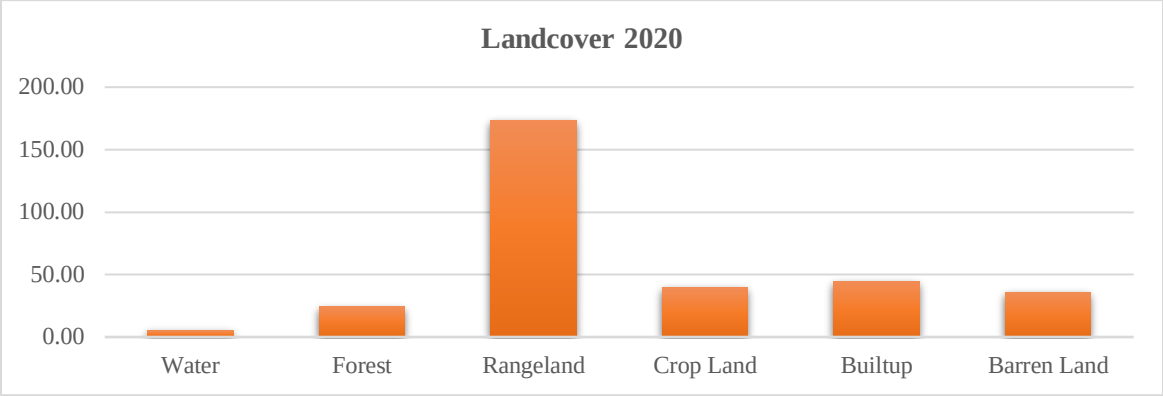


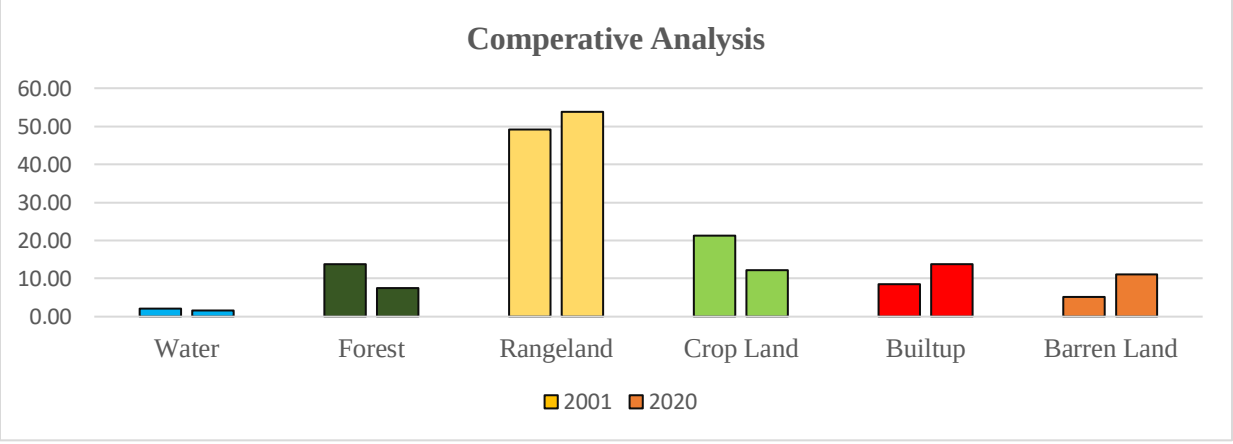
Figure 6: Land use land area of 2001



The comparative analysis between 2001 and 2020 reveals some interesting findings. Firstly, there was a minor decline observed in water resources. However, the most significant decrease was recorded in forest cover and crop land. On the other hand, there was a noticeable increase in Built-up areas, rangelands, and barren land during the same period.

The drastic reduction in forest cover and cropland is quite concerning as forests play a crucial role in maintaining ecological balance, and their decline can lead to adverse environmental impacts such as increased soil erosion, loss of biodiversity, and changes in local climate patterns. Similarly, the decrease in cropland might indicate a shift in land use patterns, potentially impacting local agriculture and food security. The increase in built-up areas suggests urbanization and infrastructure development, which, while indicative of economic growth, also poses challenges such as habitat destruction and increased pollution. The expansion of rangelands might reflect changes in land management practices, possibly aimed at supporting livestock. The rise in barren land is alarming as it signifies land degradation, which could be a result of overgrazing, deforestation, or poor agricultural practices. This trend needs to be addressed urgently to prevent further environmental degradation and to promote sustainable land use practices. Overall, these findings highlight the need for integrated land management strategies that balance development and conservation to ensure the sustainable use of natural resources in Tehsil Babuzai.

Figure 7: Comparative analysis of land use land cover of 2001 & 2020



Conclusion

The study has observed significant changes in the land use and land cover of Tehsil Babuzai. The analysis indicates that the most prominent changes occurred in the built-up, crop land and forest areas. The reason behind this transformation is the rapid population growth, which has led to an increased demand for housing and infrastructure to accommodate the growing population. Consequently, the crop land has been increasingly converted into built-up areas. The current research approach strongly endorses the value of GIS and remote sensing methods for examining and detecting changes in LULC patterns. It is recommended that these techniques be used to identify LULC changes not just in other parts of Pakistan but also globally.

The findings of Tehsil Babuzai landscape classification between 2001 and 2020 show significant changes in land use and cover, which are consistent with broader environmental and socioeconomic developments. Water bodies have decreased by 0.5% from 6.8 SqKm in 2001 to 5.22 SqKm in 2020, which can be attributed to human activity and climate change. Deforestation and land degradation caused the forest cover to significantly decline, from 44.47 SqKm to 24.22 SqKm, a 7.78% loss. On the other hand, rangeland increased from 158 SqKm to 173 SqKm, a 4.7% increase, perhaps as a result of increased grazing pressure and the conversion of other land uses. The 5% increase in built-up areas from 27 SqKm to 44.4 SqKm reflects the growth of infrastructure and urbanization.. Due to land degradation and urbanization, crops shrank dramatically by 9%, from 68.6 SqKm to 39.4 SqKm. Barren land grew by 6%, from 16.7 SqKm to 35.8 SqKm, probably as a result of climate variability and desertification. These modifications underscore the difficulties in striking a balance between economic growth and environmental preservation and are consistent with theoretical frameworks like the Land Use Transition Theory, the Environmental Kuznets Curve, and the Sustainable Development Theory. The changes to the landscape highlight the necessity of sustainable land management techniques to mitigate the effects of environmental change and development in Tehsil Babuzai.

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