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SPATIAL AND TEMPORAL ANALYSIS OF LAND USE LAND COVER CHANGES IN SARGODHA DISTRICT PUNJAB

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ABSTRACT

This article discusses the change of land use and land cover (LULC) in Sargodha region of Punjab, Pakistan, for the period of 30 Years (1993-2023) using satellite imageries. The four major land cover categories that emerged were agricultural land, urban built-up land, barren land, and water bodies, using 1993, 2003, 2013, and 2023 Landsat high-resolution images. Compared to previous periods, there have been significant changes in the patterns of land use in the region. Agricultural areas which occupied an estimated 80% of the total area in the year 1993 experienced a decrease to 71% by the year 2023. This was occasioned by the rapid rate of urbanization that took place over that period. However, there was a significant change in built-up areas, during this period which rose from 5% in 1993 to 21% in 2023 indicating a significant increase in population density and built infrastructure. Barren land registered a decrease from 14% down to 7% indicating a change in land use patterns while the water bodies remained the same level at 1%. Auxiliary indicators such as the overall accuracy, user and producer accuracy, kappa coefficients, and other detailed accuracy measurements were undertaken to validate the classification. The results from the auxiliary indicators registered an overall accuracy of 93.53% in the year 2023. The results show the urgent necessity of the tools and approaches for balanced land management. The rezoning and reallocation of centrally planned activities is critical for the development of one the most important agricultural regions.

Keywords: Agriculture, Built-up, Land Management, Satellite Imageries

Introduction

The change in land use usually occurs to facilitate the increasing population of people in an area where the basic life needs are fulfilled (Farooq et al., 2023). The land covered with vegetation and agricultural products are transformed into built-up lands and the urban dwellers are provided suitable infrastructure through housings, commercial

areas and industries (Alfred et al., 2023). So, among the primary intensifiers of changes in land use and land covers, establishment of industries and shifting of agriculture are considered important (Aliani et al., 2019). Although the industries and commercial activities provide employment opportunities to the people and improve the economic conditions but on the other side it disturbs the biodiversity and natural ecosystem (Arsanjani et al., 2018). Intensification or rising prior facts towards understanding and supervising LULC changes is significant to reduce any negative effect and make sure strong and sustainable surroundings even with human interface (Anil et al., 2011).

The extreme alteration in the use of land use is the major source of the devastation of ecosystems and demolition of biodiversity. Activities such as clearing of forests to create more arable land or urban setting for residential purposes, negatively affect the habitats of several flora and fauna (Aljaddani et al., 2022). In addition to destruction of habitats, many ecosystems suffer from reduction of soil quality, changes in the water cycle and diminished ability of the ecosystem to store carbon emissions se resulting to increased earth global warming and climate change (Hashim et al., 2023).

Shifting from natural ecosystems to cities does not only affect biodiversity but also ecological equilibrium and stability (Hashim et al., 2024). Constructing new edifices where green space used to be reduced species diversity and imperils local fauna (Qasim et al., 2023). Such turbulence resulted in the disruption of crucial ecosystem services which encompasses cooling and chemical processes (Ashok & Pekkat, 2022). Also, the development of buildings and roads compounds these issues Indirectly these factors lead to increase in temperatures of regions and even more the normal frequency that comes with harsher regions (Bakr et al., 2010).

While these effects reveal the influx of the population in the metropolitan areas is also associated with use of land demolishing and using non-permeable materials (Zhang & Qi, 2005). For example, asphalt and concrete are used which has a negative impact on thermal dynamics expansion of urban regions (Bhalli, 2012) cause vegetation to be gone replaced by material that traps heat (Barlage et al., 2020). This causes urbanized portions of land to be much warmer than the areas that are rustic (Hashim et al., 2023). The hydrological process also faces disruption due to the sealing of soil (Arshad et al., 2022). The infiltration of water becomes limited and the surface runoff starts increasing which is prone to urban flooding in case of heavy rainfall. The level of water table within the ground also decreases due to this (Zak et al., 2008). The chance of urban heat island increases in the urban centers because of the compactness of soil (Yue et al., 2013). The increase of temperature in urban areas also excels the demand of cooling machines in summer to cope with the high temperature (Yasin & Qasim, 2020).

To manage the resources in effective and sustainable way with proper planning within urban centers, the monitoring of changes in land cover and land use is significant. To analyze the changes in urban land use temporally the use of GIS and associated remote sensing techniques play a vital role and also provide critical insights of the changes for the policymakers and concerned stakeholders. Such tools are considered important

for developmental strategies in balancing the conservation of natural environment with the infrastructure development. The use of land in sustainable way, focusing the vegetation as well as green spaces and protecting the natural ecosystem are essential to lessen the negative impacts if changes in land use. The well-being of local community and urban dwellers can only be protected by taking such actions. As Sargodha district is one of the rapidly changing districts in Punjab province of Pakistan in terms of infrastructure and urban development therefore the monitoring of land use changes in the district through satellite imageries using spatial GIS techniques is the need of time to make the changes sustainable.

Literature Review

The development of the physical environment in the city area usually results into urbanization which cuts across communities. Such patterns of development are often accompanied by a longer diffusion and increased traffic congestion and limited access to basic services with the low-income classes having to escape such problems. Furthermore, the conversion of green and leisure spaces into buildings greatly affects the quality of life of the people because such activities are essential for exercising, for mental health and for socialization. Bad city planning and policy more so excludes planning for the common places and social services deepens the problem of abuse and access to the resources. Poor land use planning in which the planners do not think ahead of how land could be used in future creates more division in the society without opportunities for community bonding and sharing universal resources. The urbanization affects cities in a way leaving no choice but to innovate and improve urbanization in a way that every person who lives in a city is able to feel respected and looked after (Yang & lo, 2003; Hasmadi et al., 2009).

The urbanization process in itself does not foster economic growth; rather, it is stimulated by the development of the economy (Xe et al., 2008). The era of explosive global urban growth has given rise to what is now called the urban century. There is more than just population growth in towns and cities; there is also physical growth, which is why there is growing human activity. These changes complement and simultaneously complement and illustrate the relationship between economic growth and the spatial structure of cities, which is the result of human activity (Anwar & Qasim, 2024)

Urbanization continues to be attributed to the growth stimulus, although productivity in larger cities tends to be boosted by the economies of agglomeration. However, these growths carry a range of challenges in their wake (Waddell, 2002). Hundreds of thousands of people pouring into cities lead to widespread traffic jams, environmental pollution, infrastructural bottlenecks, and a shortage of shelter for the poor. In developing countries, for example, these effects are exacerbated by uncontrolled urban sprawl and a shortage of sufficient funds and sufficient proper planning (Qasim et al., 2024). There are complex trade-offs between the social and environmental costs

of urban growth and its economic benefits, and these are the urban challenges that policymakers and planners face globally (Parveen et al., 2023).

The connection and association of industrialization and expansion in land use (Qasim et al., 2024) to facilitate the industries are closely interlinked and play a vital role in shaping the landscapes of urbanization (Waddell et al., 2003). The establishment of industries becomes the pivotal point for economic activities and employment which attracts people from surrounding and other regions and as a result the demand of urban environment increases (Haregeweyn et al., 2012; Wang et al., 2012).

The growth of constructed regions necessitated by the process of industrialization has produced both enforceable positive outcomes and applicable issues. Its expansion has also been a source of economic improvement, technological progress, and a higher quality of life for a considerable number of city inhabitants (Lambin et al., 2003). The concentration of industries resulted in enhanced economies of scale which made it possible to make goods more efficiently and provided them with many job opportunities thus aiding in the growth of the cities' economies. Yet the case of rapid urbanization had its negative aspects as well, dwelling units were in short supply as a result of the unprecedented influx of people to the existing units (Han et al., 2007). Services and infrastructure often found it difficult to adjust to increased needs causing overutilization. Also, urban health outcomes were affected due to industrialization rendering environmental issues such as air and water pollution. Mitigating measures against urbanization are needed to be implemented because currently there is an imbalance between the positive impact of industrialization and its overwhelming consequences (Lepers et al., 2005).

Technology and modernization of economies have caused a substantial change to industrialization in the last few decades. A shift from resource-based heavy industries to technologically advanced, service-based ones has changed the shape of cities drastically (Waqas et al., 2017). This shifting trend directly caused decline in the older industrial practices and the economic benefits associated with such industries also faded. The industries related to the technology started to emerge and provided base for growth of urban economy. The modern infrastructure and innovation also reached to zenith and the use of land for this purpose increased. This dynamic change shows that the change of land use is closely associated with the technological progress (Qasim et al., 2024).

Research Methodology

The methodology of the study analyzes land use and land cover (LULC) changes that have occurred in the Sargodha district of Punjab, Pakistan, for a period of thirty years (1993 – 2023) utilized a supervised classification of satellite images. In the present study, four years: 1993, 2003, 2013 and 2023, were selected with a time hierarchy of 10 years for each. The satellite images from these years were ordered and comprehensive preprocessing of the images to correct the geometry, radiometric and atmospheric was performed on the images. Other geographical, spatial or temporal

alignments issues were also removed to allow for uniformity of the data across the datasets. Historical maps and field observations were also collected as supplementary data.

GIS tools were utilized in the study to delineate the study area and mask out the non-affected areas in order to focus on the target areas that required analysis. Built up areas, agricultural lands, barren lands and water bodies were identified as LULC categories using high-resolution images for each year of study. Image analysis for these categories was performed for each study year, that involved supervised classification where algorithms such as the Maximum Likelihood Classifier MLC were employed to assign photographs of the building true pixels to its corresponding signatures.

Surveillance data that is independent of each other of the dependent variable were used to gauge the accuracy of classification. Some of the indicators that were used include the kappa coefficient and overall accuracy of the data sets.

Results and Discussions

Land use in the Study year 1993

The land use distribution in Sargodha District was predominantly agricultural, with farmland covering 4609 square kilometers, accounting for 80% of the total area in 1993. Built-up land occupied 308 square kilometers, representing 5% of the district, reflecting limited urban development during that period. Barren land, characterized by unused or unproductive terrain, spanned 805 square kilometers, making up 14% of the total area. Water bodies, including rivers, lakes, and ponds, covered a relatively small portion of the district, with an area of 33 square kilometers, which equated to 1% of the overall land. The total area of Sargodha District was 5755 square kilometers, showcasing a landscape primarily dominated by agricultural activities.

Table 1 Specified land use classes in Sargodha District 1993

Specified Classes	Covered Area in km^2	Covered Area in Percentage
Built up land	308	5%
Agricultural land	4609	80%
Land with Water bodies	33	1%
Barren Land	805	14%
Overall Area	5755	100%

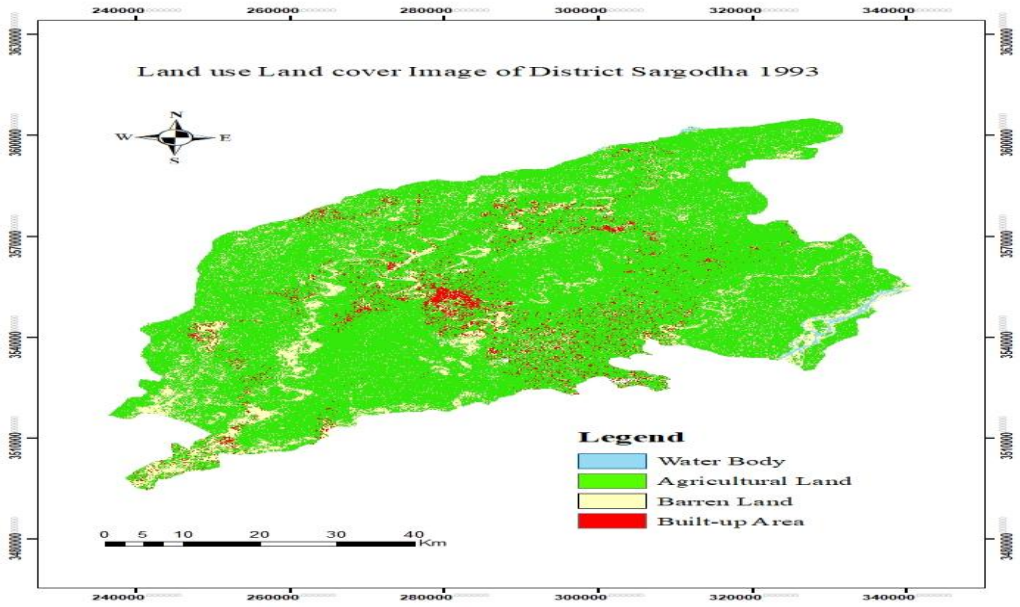

Figure 1 Land use of 1993 in Sargodha District

Land use statistics in the year 2003

The statistics of 2003 shows the agricultural domination in the study area as 84% of the area in the district was under agricultural practices with 4840 km^2 covered area. Built-up land expanded to 453 square kilometers, representing 7% of the district, indicating increased urban development over the decade. Barren land decreased to 446 square kilometers, comprising 8% of the overall area, while water bodies occupied a reduced area of 16 square kilometers, maintaining a minimal share of 1%. The district's total area remained unchanged at 5755 square kilometers, reflecting a slight shift towards urbanization and a marginal decline in barren land and water coverage.

Table 2 Specified land use classes in Sargodha District 2003

Specified Classes	Covered Area in km^2	Covered Area in Percentage
Built up land	453	7%
Agricultural land	4840	84%
Land with Water bodies	16	1%
Barren Land	446	8%
Overall Area	5755	100%

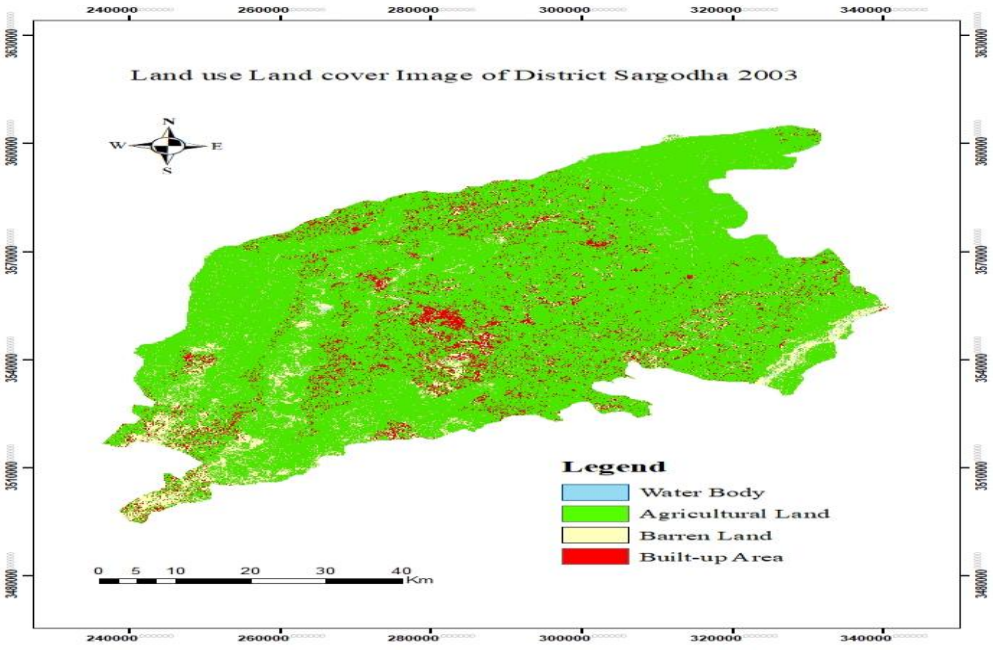

Figure 2 Land use of District Sargodha, 2003

The Study year 2013 and the land use changes

The table outlines the land use and land cover (LULC) classifications for a given area, presenting their respective extents in square kilometers (km²) and percentages. Agriculture emerges as the dominant land use type, spanning 4413 km² and accounting for about 76% total area. This shows the region's heavy reliance on agricultural practices, including farming, cultivation, and livestock rearing. Barren land comprises the second-largest category, covering 785 km², or roughly 13% of the area. These lands, characterized by sparse or without vegetation, such as rocky surfaces or deserts, indicate that a significant portion of the region is unsuitable for agricultural use. Built-up areas, which represent spaces occupied by human-made structures like residential, commercial, and industrial developments, cover 541 km², equating to approximately 9% of the total area. The presence of these developed zones reflects the urbanization and infrastructural growth within the region. Water bodies, including rivers, lakes, ponds, and reservoirs, occupy 35 km², making up around 1% of the total area. These water features provide ecological, recreational, and aesthetic benefits, highlighting their value within the region.

Table 3 Specified land use classes in Sargodha District 2013

Specified Classes	Covered Area in km²	Covered Area in Percentage
Built up land	541	9%
Agricultural land	4394	76%
Land with Water bodies	35	1%
Barren Land	785	13%
Overall Area	5755	100%

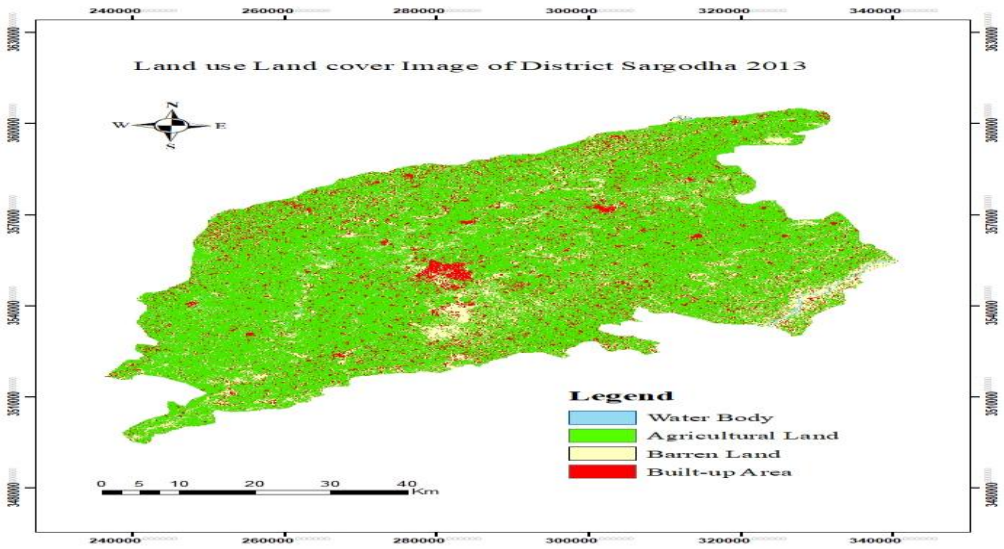

Figure 3 Land use of District Sargodha, 2013

The land use land cover changes in District Sargodha in study year 2023

In 2023, the land use and land cover of Sargodha District showed significant changes, reflecting evolving patterns of land utilization. Agricultural land remained the dominant category, covering 4082 square kilometers, which constituted 71% of the total area. However, this marked a decline in agricultural coverage compared to previous years, likely due to increased urbanization. Built-up land expanded considerably to 1246 square kilometers, accounting for 21% of the district, indicating substantial growth in urban and developed areas. Barren land occupied 406 square kilometers, representing 7% of the total area, showing a slight reduction over time. Water bodies continued to occupy a minimal portion of the district, covering 21 square kilometers or 1% of the total area. The total area of the district remained constant at 5755 square kilometers, with the data highlighting a significant shift from agricultural to urban land use over the years.

Table 4 Specified land use classes in Sargodha District 2023

Specified Classes	Covered Area in km^2	Covered Area in Percentage
Built up land	1246	21%
Agricultural land	4082	71%
Land with Water bodies	21	1%
Barren Land	406	7%
Overall Area	5755	100%

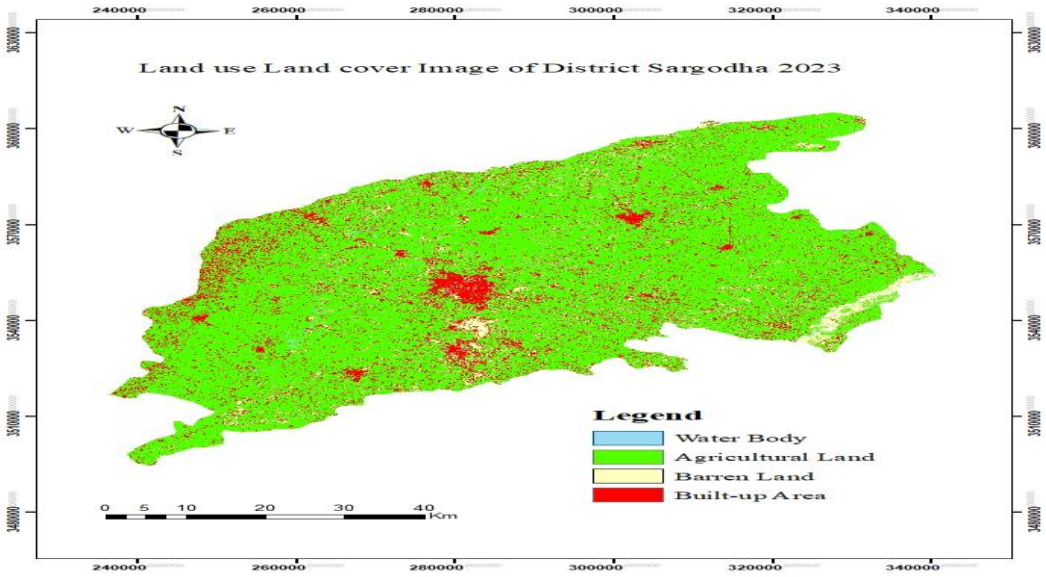

Figure 4 Land use of District Sargodha, 2023

Assessments for Accuracy for the study period 1993 - 2023

The data having algorithm and accessed through remote sensing can have some limitations in classification because of few factors including training areas mislabeling, classification methods shortcomings and similar classes distinguishing. The errors can be there in the images and the accuracy becomes reduced if these errors are not properly tackled. To evaluate the accuracy of the classification, the results are compared with maps or data derived from alternative, reliable sources. Given the dynamic nature of landscapes, an error matrix—also referred to as a confusion matrix or contingency table—is commonly used to quantify accuracy in classification.

Table 5 Accuracy Assessment for the satellite images

Assessment	1993	2003	2013	2023
Accuracy overall	88.96	92.21	91.16	93.35
User Accuracy	91.42	92.37	92.23	92.54
Procedure accuracy	92.16	93.32	93.43	91.12
Kappa Coefficient	0.83	0.88	0.89	0.92

Conclusion

The assessment of LULC shifts in Sargodha district during the years 1993–2023 demonstrates drastic changes owing to the socio-economic conditions and environmental aspects. There was visible reduction in the agricultural area which in 1993 stood at approximately 80% down to about 71% in 2023. The main contributors to the decrease in agricultural space were the improved urbanization as well as growth in resource demand. The region shows increasing urbanization related growth due to population increase on rural areas. Conversely, built up land expansion had a modest beginning, but there was a considerable increase as a result of accelerated

urbanization and improvement in infrastructure. These facets of urbanization and spatial development showcase the complexities of unregulated expansion of cities at the heavens and the increasing need for effective management programs at the core. An interesting trend was also observed with barren land which declined from 14% to 7% between 1993 and 23 respectively. This aspect could imply more efficient management of unutilized land or allocation of different types of land. However, it should be emphasized that the water bodies were not overshot but maintained at low percentage which means adequate hydrological measures had to be established in the areas or regions. These developments add to understanding of how land use systems behave in nonlinear manner in relation to the development pressures exerted in the district.

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