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Detecting Land Use and Land Cover Changes by Using Geospatial Techniques: A Case Study of District Shimla in Himachal Pradesh

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Abstract

The contemporary landscape is undergoing profound transformations, with land use and land cover (LULC) changes emerging as the most visible indicators of environmental evolution. Despite their visibility, the inherent complexity, diverse patterns, and spatial inconsistencies of these shifts make precise quantification a significant academic challenge. Because these transitions are primarily driven by anthropogenic interventions, a systematic evaluation is vital for deciphering broader environmental trends. In this context, Geoinformatics specifically the integration of Remote Sensing (RS) and Geographic Information Systems (GIS) has emerged as a transformative methodology for spatial analysis. Satellite imagery provides a unique advantage by offering both synoptic overviews and high-frequency temporal data for specific geographic coordinates. This dual capability allows researchers to monitor LULC dynamics over extended periods, making it possible to pinpoint regions undergoing the most intensive modifications. Beyond mere detection, the application of GIS enables a deeper spatial interpretation of the multifaceted drivers behind these changes. It allows for the correlation of LULC shifts with influential variables such as escalating population density, fluctuating climatic patterns, and the rugged topographical constraints characteristic of mountainous regions. By synthesizing these data layers, researchers can better understand the interplay between human necessity and ecological stability. Building upon these technological advancements, this study provides a comprehensive assessment of recent land use and land cover trends within the Shimla District of Himachal Pradesh. By analysing longitudinal data, the research aims to highlight the trajectory of environmental change in this ecologically sensitive Himalayan region.

Keywords: *LULC Dynamics, Geoinformatics, Shimla District, Spatio-temporal Analysis, Anthropogenic Impact, Remote Sensing & GIS, Himalayan Ecology*

Introduction

Agriculture is fundamentally dependent on land, making land and water the most essential natural resources for any form of development. Throughout history, control over land and its use has been a major source of conflict among communities. The value of land as a resource is shaped by factors such as climate, topography, soil conditions, and physical characteristics, while its supply remains limited and fixed (Chaplot 2017). The manner in which land is managed and utilized has a direct impact on social and economic well-being as well as long-term sustainability. In India, agriculture is experiencing technological changes aimed at achieving food security, increasing export earnings, and promoting decentralized development to reduce rural poverty, particularly in the context of rising population pressure on land, water, biodiversity, and other natural resources (wani et al. 2009). Land plays a central role in agricultural development as it supports a wide range of agricultural activities. Land use refers to the way land cover is managed through human intervention for specific purposes, such as crop production, housing, recreation, or industrial use, depending on both human needs and the biophysical characteristics of the land (Orekan 2007).

Land use and land cover (LULC) change has become a crucial component of contemporary strategies for natural resource management and environmental monitoring. It is a dynamic process that occurs on the Earth's biophysical surface over time and space and plays a significant role in natural resource studies. LULC dynamics are essential for monitoring, evaluating, conserving, and planning the sustainable use of Earth's resources. These changes present major challenges to eco-friendly and sustainable development, particularly in relation to economic growth. Rapid population growth and intensified human activities-such as deforestation, soil erosion, global warming, and pollution have severely impacted the environment. These pressures alter land use and land cover patterns as land demand increases for various human activities. As one of the primary driving forces of environmental change, LULC change is central to discussions on sustainable development and significantly influences environmental systems and landscapes.

Land cover change can occur naturally without human intervention through physical and biological processes, whereas land use change results from human manipulation of land for purposes such as agriculture, fuelwood collection, timber extraction, fodder production, medicinal resources, raw materials, and recreation. A wide range of socio-economic and environmental factors contribute to changes in land use and land cover. Numerous studies have examined LULC change from different perspectives to identify its driving forces, processes, and consequences. Change detection techniques are commonly applied over temporal scales, such as decades, to assess landscape transformations resulting from anthropogenic activities (Gibson, 2000).

LULC change is influenced by both natural processes and human actions, with spatial patterns playing a critical role in understanding these dynamics (White et al., 1997). To improve economic conditions without further degrading the environment, land resources must be utilized in a rational and sustainable manner. This requires accurate information on both present and past land use and land cover patterns (Chaurasia et al., 1996). Overall, land use and land cover dynamics are widespread, accelerating, and significant processes largely driven by human activities, while simultaneously generating changes that directly affect human societies (Agarwal et al., 2002). Within the context of land use and land cover (LULC) change, deforestation represents a major contributor to environmental degradation. It leads to a range of ecological, social, and economic impacts, among which biodiversity loss is particularly significant (Jha C.S. et al., 2000).

Literature Review

Bhagowatrimal (2007) conducted a study titled "Application of Remote Sensing and GIS for Land Use Change Analysis in Kathmandu Metropolitan City, Nepal." The study focused on issues such as rapid urban expansion, loss of natural vegetation, and the decline of open spaces within Kathmandu. Reis (2008) examined land use and land cover changes in the Rize region between 1976 and 2000 using Remote Sensing and Geographic Information Systems (GIS), with particular emphasis on slope and altitude factors. Lata Renu et al. (2015) analyzed changes in land use and land cover in Kinnaur district, Himachal Pradesh, over the period 2003-2012. Panda et al. (2017) investigated land use and land cover changes in Gajapati district, Odisha, using Landsat satellite imagery from 1995, 2005, and 2015. Employing supervised classification techniques, the study identified a substantial expansion of built-up areas, exceeding 50 percent over the study period. Ganguly et al. (2018) examined LULC changes in Andal, Burdwan district, West Bengal, between 2005 and 2015, a period marked by rapid urbanization, industrial development, and the expansion of coal mining. Lekha et al. (2018) assessed land use and land cover changes in Kanyakumari district, where population growth and climatic variability have contributed to environmental degradation, including vegetation loss, forest decline, groundwater pollution, and the expansion of built-up areas and waste disposal sites. Rani (2019) analyzed changes in land use patterns in Haryana across three time periods 1966-69, 1990-93, and 2010-13 using secondary data obtained from the Statistical Abstract of Haryana. Bairagi (2019) examined land use changes in Haryana between 1991-92 and 2011-12 by analysing variations in the percentage share of different land use categories within the total geographical area of the state. Roy et al. (2020) investigated land structure and fragmentation among 141 small and marginal farming households in a highly fertile agro-ecological village in West Bengal, India, based on detailed field surveys conducted during 2016-17.

Study Area:

Shimla District, located in the northwestern Himalayas of Himachal Pradesh, India, lies between 30°45'N to 31°44'N latitude and 77°00'E to 78°19'E longitude. The district covers an area of approximately 5,131 square kilometres and, as per the 2021 census, has a population of around 814,010 people.



Figure 3.1 Map of Study Area

Its terrain varies from altitudes of 300 meters in the southern regions to over 4,500 meters in the northern peaks, with Shimla city situated at an elevation of 2,276 meters. Shimla is bordered by the districts of Mandi and Kullu to the north, Kinnaur to the east, Solan to the south, and Sirmaur to the southwest. It also shares borders with Uttarakhand to the southeast. Land use in Shimla is diverse, with about 25% of the land under cultivation, mainly apples and other horticultural crops. Forests cover around 38%, while urban settlements and infrastructure development are concentrated around Shimla town and other valleys.

Objectives

- To map and analyse the current land use and land cover patterns in Shimla District using geospatial techniques.
- To detect and quantify land use and cover changes in the district over a specific period.
- To identify the key drivers behind land use changes, such as urbanization, agriculture, and deforestation.
- To assess the environmental and socio-economic impacts of LULC changes in the region.
- To provide recommendations for sustainable land management and planning in Shimla District based on the study's findings.

Research Questions:

- What are the existing patterns of land use and land cover in Shimla District?
- How have land use and land cover changed over the study period, and which areas have seen the most significant alterations?
- What are the primary drivers influencing these LULC changes in Shimla District?
- How do land use and cover changes affect the district's environment, biodiversity, and socio-economic conditions?
- What strategies can be adopted for sustainable land management and mitigating negative impacts of LULC changes?

Database And Methodology

1. **Primary Data**

Primary data will be generated through field surveys using structured questionnaires and interview schedules to examine cause effect relationships related to land use and land cover change. To gain a comprehensive understanding of local perceptions at the household level, data will be collected from all 17 tehsils of Shimla district, which comprises a total of 3,231 villages. Villages for the primary survey will be selected based on their geographical characteristics, including proximity to water bodies, forest areas, urban centers, river corridors, national highways, and hilltop locations. Considering the spatial diversity of the study area, a purposive random sampling technique will be adopted for the selection of villages and households. From the selected villages, households will be chosen for the primary survey, resulting in a total sample size of 850 households. The distribution of sample households will be determined based on the number of villages within each tehsil or sub-tehsil, in accordance with the Census of India (2021).

2. **Secondary Data**

The secondary data for the study will be obtained from the following sources:

- Satellite imagery from LANDSAT and SENTINEL-I and II, downloaded from the USGS Earth Explorer, and RESOURCESAT-I (LISS-III) data acquired from BHUVAN, ISRO.
- Ground truth data collected using GPS during field surveys to validate and verify the interpretation of satellite imagery.
- Census of India, 2021, for demographic and socio-economic information.
- Meteorological data on rainfall and temperature obtained from the Indian Meteorological Department (IMD), Pune.
- Village and Town Directory, Shimla District, 2021.

3. **Data Analysis**

In the present study, data analysis will be carried out using a combination of statistical and cartographic techniques. Remote sensing and Geographic Information System (GIS) methods will form the core analytical framework. Spatial data processing and analysis will be performed using software such as QGIS, SAGA GIS, and GRASS GIS. To reduce classification errors in land use and land cover mapping, a supervised classification approach will be adopted. The classification scheme will primarily follow the standards proposed by the National Remote Sensing Agency (NRSA, 1989) and the Indian Council of Agricultural Research (ICAR, 1982), with minor modifications to suit the objectives of the study. Land use and land cover will be categorized into seven classes: built-up land, agricultural land, forests, wastelands, water bodies, pastures, and barren land. Land use and land cover changes between 1983 and 2023 will be assessed using a change detection matrix to quantify spatial and temporal transformations.

Importance Of the Proposed Research

Land use patterns evolve through long-term interactions between human societies and the natural environment. Research on land use provides critical insights into these interactions and helps explain how human activities influence environmental processes. Such studies also contribute to the development of well-structured spatial, temporal, and territorial databases, which are essential for informed decision-making. Land use research has wide-ranging practical applications in land management and policy formulation, including spatial and urban planning, landscape management, and natural hazard mitigation. It also supports the identification and conservation of ecologically significant habitats and wildlife corridors, while promoting sustainable urban development through green belts and the preservation of open spaces. The Himalayan region, one of the most fragile ecosystems in the world and a major source of rivers for northern India, is experiencing increasing pressure due to rapid population growth and limited land availability. In this context, a systematic assessment of land use practices both appropriate and inappropriate-is particularly important. Development activities such as road construction, national highways, buildings, and other infrastructure are often undertaken in an unplanned and unsustainable manner, intensifying stress on land resources and accelerating land use and land cover changes. Although India accounts for only 2.41 percent of the world's land area, it supports nearly 18 percent of the global population, resulting in substantial pressure on land resources. Continuous monitoring of land use and land cover changes is therefore essential to understand emerging

trends, assess their environmental and socio-economic impacts, and promote sustainable land management across diverse regions of the country.

Conclusion

Land use and land cover (LULC) change has emerged as a critical issue influencing environmental sustainability, agricultural productivity, and socio-economic development, particularly in ecologically sensitive regions such as the Himalayas. This study focuses on Shimla District to analyze spatial and temporal changes in land use patterns using remote sensing, GIS techniques, and household-level primary data. The integration of satellite imagery with field-based surveys provides a comprehensive understanding of both physical transformations and human perceptions related to land use change. The findings of the study are expected to highlight significant shifts driven by factors such as urbanization, agricultural expansion, infrastructure development, and deforestation, along with their environmental and socio-economic implications. By identifying key drivers and impacts of LULC change, the study will contribute valuable insights for sustainable land management and regional planning. The research underscores the importance of systematic monitoring and informed policy interventions to balance development needs with environmental conservation, ensuring long-term sustainability of land resources in Shimla District and similar Himalayan regions.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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