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EXPLORING THE SPATIO-TEMPORAL VARIATION OF LAND USE AND LAND COVER IN HIMACHAL PRADESH, INDIA, UTILIZING GEOSPATIAL TECHNOLOGY

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Abstract: Human-induced disturbances like altered land use and contamination of air, water, and soil, along with the loss of productive areas, are increasingly threatening ecosystem health on local, regional and global levels. Changes in land use and cover are among the main drivers of ecosystem degradation. Observing Earth from space is crucial for understanding how human activities have impacted natural resources over time. Satellite data provide unbiased information on land use, especially in rapidly changing and undocumented areas. This study is an attempt to analyse the land use land cover in Himachal Pradesh. The study taken the time span of 2010 to 2020 time period. In order to understand the land use land cover dynamics, study prepared the map of LULC of himachal Pradesh in 2010, 2015 and 2020. The This research utilizes Geographic Information System (GIS) and remote sensing techniques to analyse the transformations that occurred during this period. Changes in Land Use/Land Cover (LULC) in the Himachal Pradesh, India, have been significant over time. The study discovers that population growth led to the expansion of built-up area hence reduction in the forest cover as well as in the other categories in Himachal Pradesh. Central parts of the state show significant changes in land use land cover from 2010 to 2020. A remarkable shift occurs in the central part from forest area to build up area and agriculture land. Recommendations for sustainable land management practices and legislative adjustments to mitigate adverse impacts are provided in the study.
Keywords: Land Use/Land Cover (LULC), Geographic Information System (GIS), Human Induced, Sustainable.

Introduction

"Land cover" refers to the distribution of plants, water, soil, and other physical features on the Earth's surface, while "land use" describes how humans utilize land, such as for agriculture, settlements, and industries. Although land cover often reflects land use, the terms are used interchangeably due to their close relationship. For instance, a settlement can include residential or commercial buildings, showing both cover and use aspects (Chaudhary et al., 2008). Managing natural resources and tracking environmental changes increasingly focuses on changes in land use and cover. Observing Earth from space is crucial for understanding how human activities have impacted natural resources over time. Satellite data provide unbiased information on land use,

especially in rapidly changing and undocumented areas. In recent years, satellite data have become essential for studying environmental change, managing resources, and mapping the planet's features and infrastructure (Zubair, 2006).

Human-induced disturbances like altered land use, and contamination of air, water, and soil, along with the loss of productive areas, are increasingly threatening ecosystem health on local, regional, and global levels. Changes in land use and cover are among the main drivers of ecosystem degradation. Various factors, including socioeconomic status, climate, and technology, influence these changes at different historical and spatial scales. Farmers often adapt their land use to cope with climate variability. Globally, the area for traditional crops like barley, oats, and millets is decreasing, while the area for cereals, vegetables, fruit, and oil crops is increasing. Many studies have predicted the impact of climate change on land use and cover (Backlund et al., 2008; Iverson et al., 2008). Urbanization is encroaching on agricultural, forest, and grassland at an alarming rate of 20,000 km^2/year, with 80% of agricultural land and 10% of forests and grasslands being affected annually (Holmgren, 2006). India is also experiencing significant land use changes. Over the last 50 years, India's net sown area has increased from 41.8% to 46.1%, and forest area has grown from 14.2% to 22.8% (Anonymous, 2013). Non-agricultural land use, including industrial areas, transport networks, mining, heritage sites, water bodies, and urban and rural settlements, has increased from 3.3% to 8.5%. Meanwhile, other uncultivated lands, excluding fallow ones, have decreased by nearly half, from 40.7% to 22.6%. According to the United Nations' World Population Prospects, 55% of India's population will be urban by 2050, with the urban population growing from 377 million in 2011 to 915 million by 2050. With rapid industrialization, urbanization, and infrastructure development, the demand for land is projected to increase. This demand will likely lead to converting agricultural or forest lands, which would harm ecosystem functioning (Pratima Vaidya, Satish Kumar Bhardwaj, and Sahil Sood, April 2018).

Land use refers to the economic utilization of land related to land rights, while land cover describes the physical appearance of the Earth's surface (Kanga et al., 2011; Nagarajan and Poongothai, 2011). Remotely sensed data's ability to identify various land features offers significant potential for quickly generating precise LULC maps (Homer et al., 2004; Yadav et al., 2015; Singh et al., 2014a; Singh et al., 2014b). LULC classes categorize crucial aspects of the Earth's surface, including human activity and the natural environment (Gong et al., 2011; Kanga et al., 2013). Recently, remote sensing data has been increasingly used to understand land use and cover, such as wetland extent, forest degradation, urbanization rates, agricultural activity levels, and other human-induced changes. Understanding both land use and land cover is essential for effective land planning and management. The United States Geological Survey (USGS) developed a hierarchical classification system to create a land use and land cover classification based on aerial photography taken between 1970 and 1980, at a scale of 1:250,000 (Anderson et al., 1976). The multi-spectral bands of IRS-LISS III data provide reflectance across different regions such as green, red, near-infrared, and shortwave infrared. This spectral data across different seasons allows for more reliable differentiation between crops and other vegetation through various methodologies (Nathawat et al., 2010).

Objective of the study

- To study the land use land cover of Himachal Pradesh in 2010
- To analyse the changes in land use land cover in 2015 and 2020 in Himachal Pradesh
- To suggest the future repercussion of land use land cover in Himachal Pradesh

Study Area

Himachal Pradesh encompasses an area of 55,673 square kilo meters and is segmented into 12 administrative districts. The state's elevation varies from approximately 350 meters to over 6,000 meters above sea level, leading to a diverse range of climate conditions and vegetation types. This varied terrain consists of snow-covered peaks, dense woodlands, high-altitude meadows, and river valleys. Situated in the northern part of India, Himachal Pradesh is renowned for its diverse climate and stunning landscapes. The state shares borders with Jammu and Kashmir to the north, Punjab to the west, Haryana to the southwest, Uttarakhand to the southeast, and Tibet to the east. Positioned between latitudes 30.38° N and 33.12° N, and longitudes 75.77° E and 79.07° E, the state features a wide range of elevations, from lush valleys to towering summits, owing to its location within the Western Himalayas. The geographical location of Himachal Pradesh significantly influences its climate, hydrology, and flora. The state is characterized by the Shivalik range, the lesser Himalayas, and the greater Himalayas as its primary geographical regions. The Shivalik range's lower elevation results in a mild climate, while the lesser Himalayas exhibit more moderate temperatures. In contrast, the greater Himalayas, towering above 6,000 meters, experience a frigid alpine climate. This diversity in altitude and climate fosters a variety of ecosystems and abundant biodiversity, positioning Himachal Pradesh as a valuable site for ecological and environmental research.

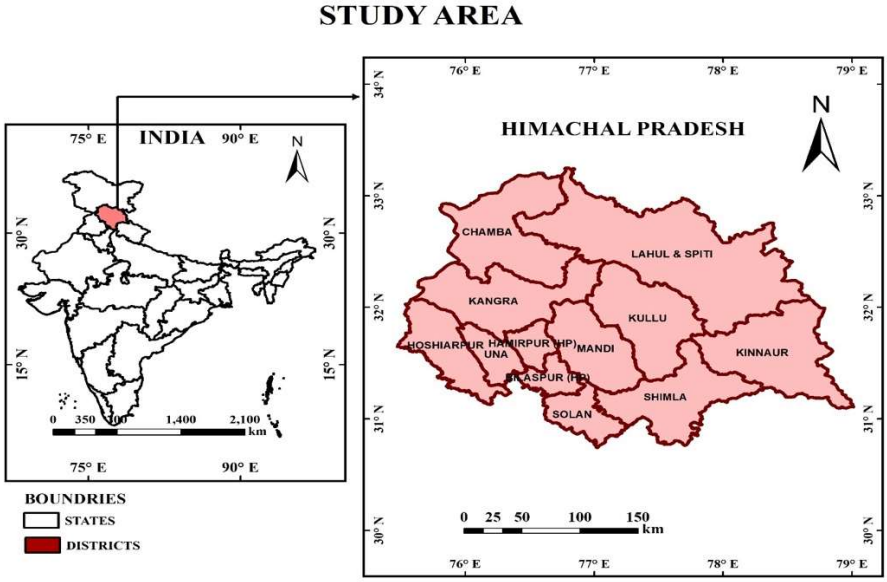


Figure 1: Map of study area

The state is crisscrossed by numerous rivers and streams, nourished by glacial meltwater and monsoon precipitation. Prominent rivers flowing through Himachal Pradesh include the Beas, Sutlej, Ravi, and Chenab, providing essential water resources for daily activities, hydroelectric power generation, and agriculture. The unique topography and climatic conditions in the region present both opportunities and challenges for disaster response, conservation efforts, and sustainable development. Himachal Pradesh's distinctive geographical coordinates, coupled with its diverse landscapes and climatic zones, render it a highly significant area for geographical and environmental investigations.

METHODOLOGY

The process of selecting the study area is an initial stage in a systematic and comprehensive examination of alterations in land use and land cover (LULC) in Himachal Pradesh. Himachal Pradesh, a state in northern India, is positioned between latitudes 30.22° N and 33.12° N, and longitudes 75.47° E and 79.04° E. The state presents an intriguing case for LULC investigation due to its diverse terrain characterized by the Himalayan mountains and its varied climate spanning from subtropical in the south to alpine in the north.

A crucial aspect of this investigation involves collecting data, encompassing ancillary and remote sensing data. To facilitate a comprehensive temporal evaluation, multi-temporal satellite images, such as those from Sentinel-2, will be obtained for several years, specifically 2010, 2015, and 2020. These detailed images, with a resolution of 10 meters, will furnish the necessary information for accurate LULC classification.

The key findings of the research on LULC variations in Himachal Pradesh and their implications will be delineated. Recommendations for sustainable land management practices and legislative adjustments to mitigate adverse impacts will be proposed. Throughout the research, ethical guidelines will be adhered to, encompassing data confidentiality and compliance with environmental conservation protocols during field investigations. To present an unbiased perspective, the study's constraints, such as data accessibility and resolution constraints, along with potential biases in classification and analysis, will be recognized. This approach establishes a comprehensive framework for a systematic and rigorous examination of shifts in LULC in Himachal Pradesh.

Result & Discussion

This research utilizes Geographic Information System (GIS) and remote sensing techniques to analyse the transformations that occurred during this period. Changes in Land Use/Land Cover (LULC) in the Himachal Pradesh, India, have been significant over time, particularly in 2010. The year 2010 witnessed substantial LULC changes in the state in almost all the categories. A

significant expansion of forest area in the western and south western parts of

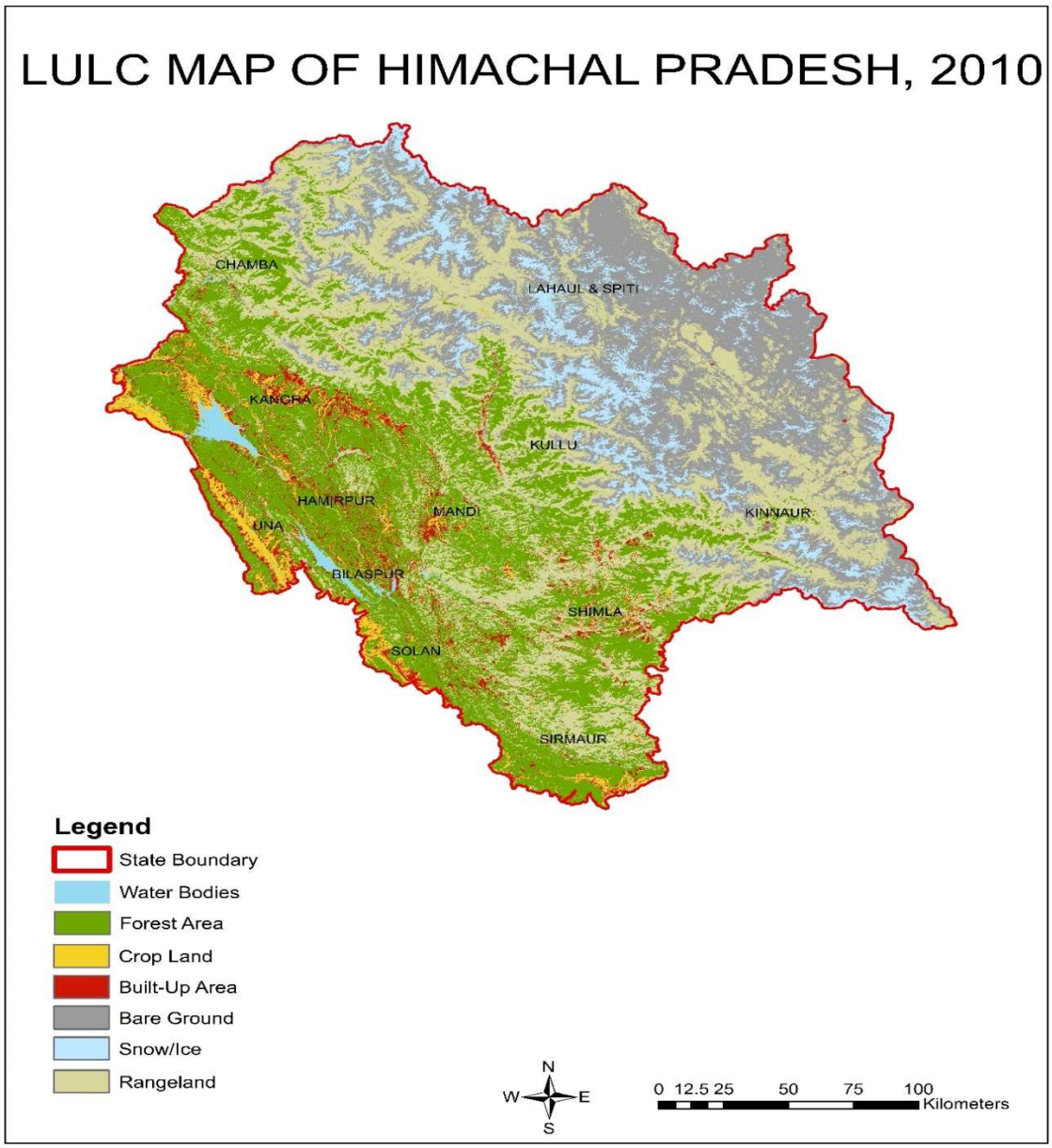


Figure 2: LULC of Himachal Pradesh in 2010

Himachal Pradesh can be seen clearly in the LULC map of himachal Pradesh in 2010. However, the northern and north eastern parts of himachal Pradesh are lies under the category of bare ground. The map also presents the area of snow in the central part of the state. It is interesting to know that the expansion of build-up area can be seen in the western and south western parts of the state. However, the other parts of the state show negligible built-up area during 2010. The crop land in the state also lies at the boundaries of western and south western parts of the state. It is also notable

that although the northern and north eastern parts of the state did not have any crop land and built-up area yet there is a significant expansion of rangeland available in this part during 2010. The map illustrates that eastern district of the state i.e., lahaul and spiti have highest expansion of bare ground in comparison to the other districts of the state. Lahaul and spiti also stand at first in term of having highest area under snow cover in the state in comparison to other districts. It is also noteworthy that Una and Solan districts of the state have highest area of crop land in the state and the built-up area is also concentrated alongside the crop land in these districts. Chamba district shows the highest forest area in the state during 2010 time period. LULC alterations signify human-induced modifications to the natural terrain and are essential for formulating strategies related to natural resource management and environmental surveillance. By evaluating the utilization and exploitation of resources like land, forests, and water, as well as determining the underlying causes for such exploitation, it is possible to pinpoint and implement measures for sustainable resource development in vulnerable Himalayan state. To analyse the LULC alterations in state, the map of LULC during 2015 and 2020 are also prepared in this study.

Figure 3 describes the land use land cover dynamics in himachal Pradesh in 2015. This investigation reveals that during this period, human activities such as the expansion of agriculture, particularly horticulture, tourism, and infrastructure development, led to considerable deforestation and a reduction in snow cover. It is demonstrated in this study that the aforementioned time period experienced a noteworthy amount of deforestation and retreat of snow cover due to human activities like agricultural growth, especially horticulture, tourism, and infrastructure development. The unplanned nature of these LULC changes has resulted in substantial challenges, including ecological concerns such as deforestation, soil erosion, landslides, loss of biodiversity, altered hydrological processes, land degradation, and increased food insecurity. The land use and land cover status of a given watershed are influenced by the intricate interplay between its natural land attributes and its cultural legacy. In conclusion, the significant LULC modifications that occurred in 2015 had a profound impact on the local community and environment. To protect this fragile ecosystem, continuous monitoring of these changes and the application of sustainable development

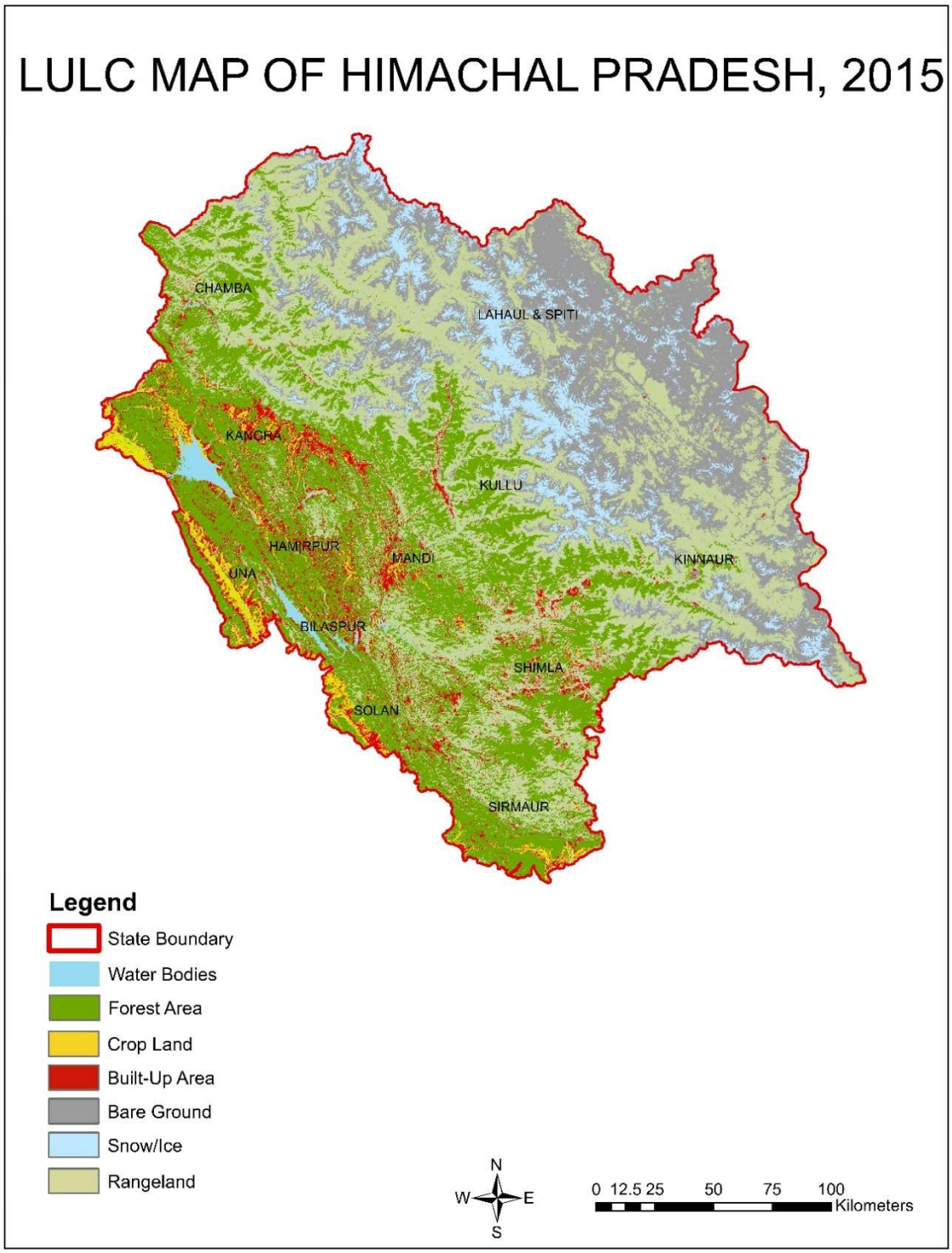


Figure 3: LULC of Himachal Pradesh in 2015

practices are imperative. Further research is necessary to fully comprehend the long-term implications of these changes and to devise effective management and mitigation strategies.

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The study highlighted an increase in dense forest (25%) and settlement (~300%) near agricultural areas (19%), at the expense of open forest and waste/combined grazing land. This shift resulted in reduced permeable surfaces, diminished rainfall, decreased groundwater recharge, and a lowered static water level (SWL) in the basin. The rise in water nitrate concentrations since 1994 aligns with alterations in agricultural practices as depicted in the LULC maps of 2015.

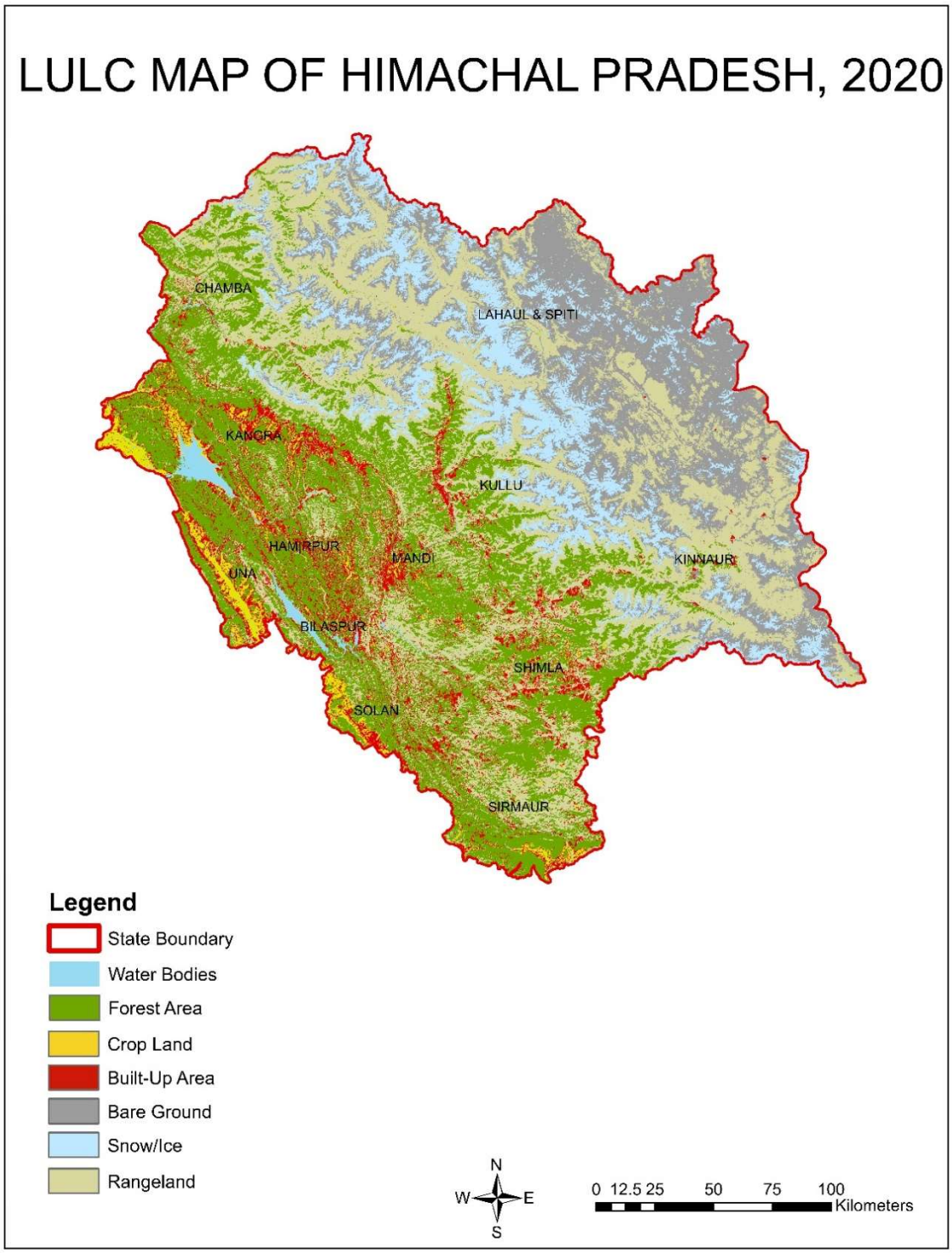


Figure 4: LULC map of Himachal Pradesh in 2020

Figure 4 depicts the land use land cover dynamics of Himachal Pradesh in 2020. The present investigation employs geographic information systems (GIS) to scrutinize the shifts in land use

and cover (LULC) in Himachal Pradesh in 2015. The unplanned nature of LULC modifications has presented significant challenges in the state.

The unplanned nature of LULC modifications has presented significant challenges, including ecological issues like deforestation, soil erosion, landslides, loss of biodiversity, changes in hydrological processes, land degradation, and heightened food insecurity. The land use and land cover dynamics are shaped by the intricate interplay between natural land capabilities and cultural contexts. In the Western Himalaya, within the Kullu district of Himachal Pradesh, the Sainj River Valley stands out as a focal point of biodiversity. The area has witnessed notable Land Use/Land Cover (LULC) transformations over time, particularly evident in the adjustments observed in 2020. In 2020, Kullu district shows remarkable expansion in build up area from the level of 2010 and 2015, however reduction in forest area also significantly appear in 2020 in Kullu district. It clears that the population growth in the district led to the expansion of built-up area and that directly resulted into the reduction of forest area. Human-induced alterations to the natural landscape, known as LULC changes, play a crucial role in shaping strategies for resource management and environmental monitoring. By evaluating the utilization and exploitation of resources like land, soil, forests, and water in regions such as the vulnerable Himalayan basin of Sainj, steps towards sustainable resource development can be identified and implemented.

All categories of land use land cover experienced significant LULC variations in 2020. Findings from this research revealed a substantial decrease in snow cover (60%) and forest land (14.18%), alongside notable increases in agriculture (34.19%), settlements (89.42%), barren land (33.54%), and range land (19.01%) in the state. The unanticipated nature of LULC changes has presented considerable challenges, including ecological concerns like deforestation, soil erosion, landslides, loss of biodiversity, altered hydrological processes, land degradation, and heightened food insecurity. The interplay between natural land capacities and cultural contexts determines the land use and cover status of a region. In conclusion, the significant LULC transformations observed in the Himachal Pradesh in 2020 had considerable impacts on the local community and environment. Vigilance and application of sustainable development methodologies are imperative to safeguard this fragile ecosystem. Further research is essential to fully comprehend the long-term repercussions of these changes and devise effective management and mitigation strategies. Environmental factors also plays a crucial role in driving LULC transformations. The Himalayan states, being a biodiversity hotspot, reflects the conservation efforts of the park administration through changes in land use practices. Nonetheless, these alterations have led to environmental issues such as land degradation, landslides, soil erosion, and deforestation.

Human desires serve as the catalyst for altering the human-nature relationship, consequently triggering further modifications in land uses and covers. The evolving human dynamics shed light on how wealth and population growth manifest in distinct ways, thereby unveiling significant regional disparities. Due to alterations in land use and land cover (LULC), the river valley in the Kullu district of Himachal Pradesh, India, is encountering significant environmental challenges. These alterations, stemming from human interactions with the environment, have led to various

environmental issues including deforestation, soil erosion, a reduction in biodiversity, adjustments to hydrological processes, and land degradation. The river valley of the state also has experienced a visible 14.18% decrease in forest area due to LULC alterations, primarily driven by the expansion of agricultural activities and human settlements, which have risen by 34.19% and 89.42%, respectively, causing deforestation that contributes to global climate change. Soil erosion is a pressing environmental concern in the state with an average rate of 11.15 tons/ha/year and an annual predicted soil loss ranging from 0 to 541.52 tons/ha/year, exacerbated by near-saturation antecedent moisture content and heavy rainfall. The biodiversity in the state has dwindled due to LULC modifications, with numerous species losing their habitats to agricultural land and settlements. Despite this loss, efforts are underway to conserve biodiversity by converting arid land into pasture and forest areas.

Future Repercussions of Himachal Pradesh's LULC Shifts

The ecosystem of Himachal Pradesh is undergoing significant changes, particularly in central parts of the state with far-reaching implications for the state's future across various sectors including infrastructure, agriculture, energy, and biodiversity. With a target to become a "Green Energy State" by 2026, Himachal Pradesh aims to rely on renewable energy sources such as wind, solar, biomass, and small- and micro-hydropower, though their effectiveness and availability may be influenced by environmental shifts, potentially affecting hydropower production due to alterations in hydrological processes. The state's infrastructure is at risk due to the increased occurrence of landslides resulting from environmental changes, impacting projects like highway construction and other development endeavours, leading to casualties and property damage that could hamper the state's advancement and economic growth. Variations in precipitation patterns can lead to soil erosion and reduced agricultural output, affecting a large portion of the state's population in Himachal Pradesh who depend on agriculture for their livelihoods. Environmental changes may disrupt local flora and fauna, leading to a decline in biodiversity that could have consequences for the state's ecosystems and the essential services they provide, including pollination and pest control, crucial for agriculture. The potential exacerbation of these environmental challenges is foreseen with the projected general warming of the climate in Himachal Pradesh, likely resulting in increased frequency and intensity of extreme weather events like floods and landslides.

In summary, the evolving environmental landscape in Himachal Pradesh will significantly impact the state in the future, necessitating immediate attention and resolution. It is imperative for the government to invest in resilient and eco-friendly infrastructure, adopt sustainable land management practices, promote renewable energy sources, enact policies safeguarding biodiversity, and mitigate the impacts of climate change. Analysis of Land Use and Land Cover (LULC) changes in Himachal Pradesh from 2010 to 2020 reveals substantial alterations attributed to various human activities. The expansion of agricultural land and urban centres indicates a growing human population and its associated socioeconomic needs. However, these transformations have posed challenges for the ecosystem, such as deforestation, soil erosion, loss of biodiversity, changes in hydrological systems, and land degradation, underscoring the urgency

of implementing sustainable development strategies and effective natural resource management in the region.

Himachal Pradesh's Environmental Shifts: A Thorough Examination

The northern Indian state of Himachal Pradesh, situated in the Himalayas, is renowned for its rich cultural heritage, diverse flora and fauna, and breath-taking landscapes. However, significant environmental transformations are on the horizon for this picturesque region, potentially leading to profound implications in the future. This essay aims to delve deeper into these evolving environmental dynamics, their potential repercussions, and the necessary societal and policy responses.

Climate Change and Its Impacts: While climate change is a global phenomenon, Himachal Pradesh stands out as being particularly vulnerable due to its unique topography and geographical positioning. The state is experiencing rising temperatures, erratic rainfall, and an increase in extreme weather events, affecting various aspects of daily life such as tourism, agriculture, and water resources.

Agriculture: The majority of the population in Himachal Pradesh depends on agriculture as their primary livelihood, making it the economic backbone of the region. Changes in temperature and precipitation patterns are affecting crop yields and leading to a surge in pest attacks. The apple industry, a key economic driver, is especially at risk, with orchards being pushed to higher altitudes due to warming temperatures, jeopardizing the livelihoods of farmers in lower regions.

Tourism: Himachal Pradesh attracts numerous tourists from around the globe due to its stunning natural beauty. Nevertheless, the state's tourism sector could face challenges from environmental shifts. Declines in winter activities like skiing and snowboarding may occur due to glacier retreat, while changes in the region's unique biodiversity could impact ecotourism.

Water Resources: Environmental changes have the potential to disrupt the state's water supply. Melting glaciers and altered precipitation patterns could lead to water scarcity, affecting both agriculture and the local populace.

Health: Environmental changes may also have implications for public health. Fluctuations in temperature and precipitation could facilitate the spread of vector-borne diseases, while extreme weather events could result in fatalities and injuries.

Policy Implications: In light of these environmental shifts, there is a critical need to re-examine both state and federal policies. New policies must be formulated to mitigate the impacts of these changes and adapt to the evolving environmental landscape. Strategies for water resource management, biodiversity conservation, climate change mitigation, and sustainable land use should be prioritized. The societal implications of environmental changes are profound, potentially leading to significant social consequences such as shifts in livelihoods, particularly affecting those reliant on tourism and agriculture. Consequences may include migration, changes in social frameworks, and potential conflicts over resources.

In summary, the evolving environment of Himachal Pradesh will have a notable impact on the state's future. Despite the challenges posed by these transformations, there are also opportunities

for innovation and progression towards a more resilient and sustainable future. Addressing these challenges proactively is crucial to safeguarding the state's future. This comprehensive examination serves as a call to action for experts, governments, and the public to work together in addressing these pressing environmental issues.

Conclusion

The land use and land cover in Himachal Pradesh are constantly changing, influenced by both natural events and human activities. Understanding these changes is important for promoting sustainable development and effective conservation. As the state continues to develop, finding a balance between economic growth and environmental protection is essential to preserving its unique ecology and the well-being of its residents. An analysis of land use and land cover (LULC) changes in Himachal Pradesh from 2010 to 2020 shows significant shifts in the landscape. These changes, largely driven by human activities, have considerable effects on the environment and resource management in the region. In 2010, activities like expanding horticulture, tourism, and infrastructure development led to notable deforestation and the melting of snow cover in the Sarbari Khad watershed in Kullu Valley. These unplanned changes caused ecological issues such as land degradation, increased food insecurity, loss of biodiversity, landslides, soil erosion, and further deforestation. These problems highlight the need for sustainable land-use practices and better resource management to mitigate these adverse effects.

By 2015, the Himachal Pradesh experienced a reduction in open forest and waste/grazing land, while agricultural land increased by 19%, urban areas grew by about 300%, and dense forest expanded by 25%. These changes also impacted the static water level (SWL) and groundwater quality, with a continuous decline in SWL indicating overuse of groundwater resources. This underscores the importance of effective water management strategies to ensure sustainable use of the region's water resources.

In 2020, the state experience remarkable changes in land use land cover especially in the Kullu district saw a 158.2% increase in urban areas and a 15.52% decrease in agricultural land. From 1990 to 2020, the areas classified as water and barren land steadily decreased. These changes reflect the efforts of park administration in managing and conserving biodiversity. This highlights the critical role of conservation efforts in protecting the area's biodiversity and maintaining ecological balance. The LULC changes in Himachal Pradesh from 2010 to 2020 illustrate the dynamic interaction between human activities and the environment. These changes stress the need for sustainable development plans and effective management of natural resources to reduce the negative impacts of LULC alterations. Policymakers, urban planners, and environmentalists can use these findings to develop strategies for resource conservation and sustainable development in the region. The changes in land use and land cover (LULC) underscore the importance of ongoing monitoring and assessment of land use patterns. Such monitoring is crucial for shaping policy decisions and guiding sustainable development efforts. By regularly tracking these patterns, we can identify trends, evaluate the effectiveness of policies, and detect environmental issues early.

Overall, the LULC changes in Himachal Pradesh provide a valuable case study of the challenges and opportunities in managing land resources in a rapidly evolving environment. The insights gained from this case study can be applied to land use planning and management practices in other regions facing similar issues. The changes in land use and land cover (LULC) emphasize the ongoing need to monitor and assess land use patterns to inform policy decisions and guide sustainable development efforts. Regular monitoring helps detect trends and patterns in land use changes, evaluate the effectiveness of policies, and provide early warnings of environmental issues. Overall, the LULC modifications in Himachal Pradesh serve as a valuable case study of the challenges and opportunities in managing land resources in a rapidly changing environment. The lessons learned from this case study can be applied to land use planning and management practices in other regions facing similar challenges.

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