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Land Use changes and the Impact of Urbanization During Recent Decades in Sikkim, Eastern Himalaya, India

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ABSTRACT: In recent decades, various forms of developmental activities have made significant impact on the land use types of Sikkim Himalaya which necessitates the need of monitoring and mapping of land use land cover (LULC) changes for assessing various ecosystems, environmental processes and natural resource management for sustainable development. Based on secondary sources including GLAD Global Land Cover and Land Use Change dataset, the study attempts to monitor the changes in LULC patterns of Sikkim Himalaya for the periods 2000–2020. The analysis of built-up areas unveils significant transformations in urban landscapes across the districts. There has been dwindling of snow and ice cover in this ecologically fragile region. The reduction in vegetation cover, growth of built-up areas, and decline in snow/ice extent underscore the significant challenges facing biodiversity conservation and ecosystem resilience. The findings of the current study highlight some of the important policy implications for the sustainable management of LULC in Sikkim Himalaya. By application of remote sensing & GIS techniques, field surveys, data analysis and review of existing literature, this study identifies key patterns in land use transformation, highlights the driving forces behind these changes, and assesses their ecological, social and economic impacts. An integrated approach to formulating future development plans is imperative for maintaining sustainability in the region.

Keywords: GLAD, Impact of urbanization, sustainable land management, Sikkim Himalaya, Land Use Land Cover.

INTRODUCTION

Land-use and land-cover changes refer to the quantitative variations in the aerial extent (increases or decreases) of specific land use or land cover types. These changes can result from land conversion (a shift from one cover type to another), land modification (alterations in structure or function without a complete change from one type to another), or the maintenance of land in its current state against agents of change (Briassoulis, 2009). Land use promotes sustainability and livelihood security by contributing food, fodder and firewood in the society while the extent of forest cover on the land surface governs many crucial ecological processes and is a key factor in characterizing sustainable forest management (Gupta, 2007; Das *et al.*, 2023). Understanding the LULC dynamics has been an impactful tool to assess the change in ecosystem structure and its land use with climate change (Hussain *et al.*, 2024). With the process of urbanization natural ecosystems and landscapes have led to change in land-use leading to significant social and environmental challenges (Vitousek *et al.*, 1997; Naab *et al.*, 2013; Dar *et al*., 2017; Liu *et al.*, 2019). Since 1950's the pace, degree and extent of land use and land cover changes have increased as a result of modernized human activities and therefore modifications caused by urbanization are apparent everywhere at unprecedented rates, magnitudes, and spatial scales which could have crossed the self-repair capacity of the natural ecosystem and directly affected and are reported to be the major threat to biodiversity around the globe (Turner *et al.*, 1994; Sala *et al.*, 2000; Lambin and Geist 2001; Hansen *et al.*, 2013; IPBES, 2019; Kalfas *et al.*, 2023). Previous studies have indicated that with the projected global rise in urbanization, conversions of land cover for urban development will increase, thereby altering considerable ecosystem patterns and processes (Seto *et al.*, 2012). It has been estimated that land-use changes and their associated impacts have resulted in a global decline of local species richness by 13.6% and total abundance by 10.7% (Newbold *et al.*, 2016, Kaur, 2017, Rai, 2017). Inevitably, urbanization has become a defining factor and one of the major driving forces shaping contemporary land use systems (Berry, 2008; Nuissl and Siedentop 2021; Zhang *et al.*, 2024). However, there is limited knowledge about how sensitive species extinction projections are to the quality of forest cover data (Pandit *et al.*, 2007).

Land-use change has led to the fragmentation of natural ecosystems, with major consequences for biodiversity (Liu *et al.*, 2019). Inevitably, understanding the dynamics of land use change is critical for efficient natural resource management, biodiversity conservation, and planning for sustainable development. In tropical regions of the world, large-scale deforestation for agriculture, forestry, wildfires, and urbanization have severely impacted biodiversity, leading to habitat loss and species decline (Mittermeier *et al.,* 1999; Myers *et al.,* 2000; Laurance, 2000; 2015; Sodhi and Brook 2006; Pandit *et al.,* 2007; Miranda *et al.,* 2024). In India, urbanization led land use change has led to ecosystem degradation, habitat destruction, resource depletion and biodiversity loss and cities in India are facing challenges in terms of availability of green space with implications for biodiversity conservation and climate change adaptation (Uttara *et al.,* 2012; Nagendra *et al.,* 2014).

Mountain areas differ from plains in various aspects, including topography, physiographic features, elevation, habitat types, diversity of flora and fauna, ethnic diversity, land use systems, and socio-economic conditions. Tiwari (2000) discussed the extensive land-use changes in the Himalayas due to population growth, leading to deforestation and expansion of cultivation, which have significant impacts on the plains' ecosystems. Rao and Pant (2001) asserted that while most studies recognize the loss of vegetal cover as a regional as well as global problem, very little was understood on a local scale about complex relationships between environmental, economic, social and natural resource policy factors that induce changes in land use. Tiwari (2008) argued that the traditional patterns of resource use in the Himalayas have undergone significant changes in recent years, primarily due to population growth and the consequent rise in demand for natural resources in the area.

Over the past few decades, the Himalayas have experienced unprecedented land-use changes driven by rapid population growth and intensifying human activities, such as agriculture and expanding settlements (Pandit *et al.,* 2007). In this regard, remote sensing has emerged as one of the useful tool to monitor land cover features over a period of time. The temporal dataset can provide the changes brought in by prevailing land-use practices in the region. According to Briassoulis (2009), the multiple factors of land use change operates on more than one spatial and temporal level and acts not in isolation but in intricate webs of place and time-specific relationships. Chakraborty *et al.* (2016) concluded that there is lack of comprehensive detailed assessments of spatial distribution of land use/land cover (LULC) change in the Indian Himalayan Region over an extended period of time. Tiwari *et al.,* (2018) emphasized the need for integrated urban-rural land use planning in the Himalayas to steer urbanization sustainably, advocating for effective urban land use policies for the conservation of forests, biodiversity, water resources and agricultural land. Prakasam *et al.* (2018) found out that forest cover reduced from 81.58% in 1980 to 60.77% in 2017. Same way built-up land has increased from 3.59% to nearly 13.64% in the year 2017 and Agriculture land also increased from 1.91% to 16.51% in the year 2017 at Shimla Tehsil, Himachal Pradesh, Western Himalaya, India. Qadir and Singh (2019) investigated land use/cover changes in the Dal Lake catchment, Srinagar, Western Himalaya, India revealing that urban expansion and solid waste accumulation have adversely affected water quality, underscoring the environmental challenges posed by urbanization. Mishra *et al,* (2020) utilized remote sensing and GIS techniques to monitor LULC changes in the *Rani Khola* watershed of Sikkim Himalaya from 1988 to 2017 and revealed that open forest showed increasing trend during 1988–1996 whereas decreasing trend has been observed during 1996–2017. Gurung and Hannan (2021) explored the dynamics of land use change in Sikkim in relation to agricultural practices, noting transitions from traditional through conventional(green revolution) to organic farming and the associated land use implications. Digra and Kaushal (2021) have reported that the combined use of Remote Sensing (RS) with Geographic Information System (GIS) have proved as an important tool which can provide accurate data and information on LU/LC changes. Anees *et al.* (2022) examined how urbanization has impacted the Himalayas through two main pathways: directly, by transforming land use and land cover to accommodate growing needs, and indirectly, through infrastructure development to support communication, transportation, and energy demands. Behera *et al.* (2022) emphasized that in mountainous regions, classifying land use and forest cover (LUFC) using satellite data is challenging due to the varied topography and complexities caused by differing illumination conditions. No single factor can be solely attributed to land use change. Instead, it is typically the result of a complex interplay of multiple factors including economic, social, environmental, technological and policy-related influences. Sohail and Kaushal (2023) reported that monitoring land use and land cover changes enables the implementation of appropriate control strategies for safeguarding the environment and preserving our natural resources. Haokip *et al.* (2023) observed that the North Eastern Region (NER) of India is equally affected by land degradation, experiencing diverse forms and intensities of environmental damage with different anthropogenic activities such as natural resource extraction, stone quarrying, oil exploration, and various industrial operations have significantly contributed to the degradation of this fragile ecosystem. Phartiyal and Sharma (2024) monitored the LULC changes (1999–2021) in the Himalayan region of Pithoragarh district, Uttarakhand, Western Himalaya and showed that vegetation and built-up have increased whereas cultivation, barren land, and snow cover have decreased. This study provided insights into the shifts in spatial and temporal patterns of landscape of Pithoragarh district. Singh *et al.* (2024) suggested that if the current trends of urbanization persists, the urban areas will expand by 63% and forest cover likely to decline by around 9% by 2055 in the Western Himalayan Region. Parida *et al.* (2024) conducted study from 1990 to 2022 in the Behali Reserve Forest (BRF), Arunachal Pradesh, Eastern Himalaya and have revealed that upper part of Behali Reserve Forest (BRF) have become degraded due to deforestation and e encroachment of the Arunachali people.

There is a lack of comprehensive studies that integrate socio-economic data with ecological assessments to understand the full impact of urbanization on Sikkim's environment and communities. Few studies provide long-term analyses of urbanization trends and their cumulative environmental impacts in Sikkim Himalaya, which are essential for sustainable planning. While policy recommendations exist, there is limited research evaluating the effectiveness of implemented land use and urbanization policies in Sikkim Himalaya. The interplay between urbanization-induced land use changes and climate change effects in Sikkim Himalaya remains underexplored, necessitating focused research in this area.

Sikkim Himalaya as a part of the Eastern Himalayas (EH), India is one of the 36 global biodiversity hotspots (Pullaiah, 2024). The EH region is also regarded as a part of crisis ecoregions (Hoekstra *et al.,* 2005). Ever since, its merger with the Indian Union in 1975 the Sikkim state has experienced rapid socio-economic transformation. The forests clearing was extensive, practice of cattle grazing in reserve forests depleted the vegetation cover and most of the *khas* (village forests) was without trees and eroded (Karan, 1987). The scope for industrialisation increased in Sikkim especially after 2007 as Sikkim was incorporated into North East Council and due to the enactment of New Industrial Policy, 2006 by the Government of Sikkim. This transformation has been characterized by shifts in land use patterns, including the expansion of settlements, infrastructure development, agricultural intensification, and changes in forest cover. In recent decades, rapid urbanization, industrialization and population growth have led to profound land use changes, raising concerns about ecological integrity, biodiversity conservation, and socio-economic sustainability in Sikkim Himalaya. While several studies have examined land use changes in the region mainly at the watershed level (Rai and Sharma 1995; Sharma *et al.,* 2007; Mishra *et al.,* 2020; Mishra *et al.,* 2021; Parida *et al.,* 2022; Behera *et al.,* 2022; Roy *et al.,* 2024), there remains a need for comprehensive analyses that capture the spatial and temporal trends, drivers, and impacts of these changes over the past two decades. Such analyses can provide valuable insights into the underlying processes driving land use change, identify vulnerable areas, and inform evidence-based policy interventions to promote ecosystem resilience and sustainable land use practices. Therefore, the current study aims to investigate the patterns and drivers of land use change in Sikkim over the recent last two decades (2000-2020) using RS and GIS techniques. Specifically, the objectives of this study are:

1. To analyze the spatial and temporal dynamics of land use changes in Sikkim during the last two decades (2000-2020).
2. To provide recommendations for sustainable land use planning and management to promote socio-economic and environmental resilience in Sikkim

By addressing these objectives, this study seeks to contribute to the existing body of knowledge on land use change dynamics in Sikkim and provide valuable insights to policymakers, land managers and researchers to support informed decision-making and sustainable development initiatives in the region.

MATERIALS AND METHODS

A. Study Area

Sikkim, a part of eastern Himalayas, India is griddled between 27°04'46" and 28°07'48" North latitude and 88' 58" and 88°55'25" East longitude with a total geographical area of 7,096 sq. km with four districts East Sikkim, West Sikkim, North Sikkim and South Sikkim. The third highest mountain peak Khangchendzonga forms a major part of Sikkim. The *Teesta Khangse* glacier & *Chho Lhamo* in North Sikkim and Mt. Kabru in the southern Kangchendzonga region are the main sources of water, which flows through river *Teesta* and *Rangit* respectively. The state of Sikkim is bounded by Nepal in the west, parts of Bhutan and Tibetan Autonomous Region (China) in the East, West Bengal in the South and the Tibetan Plateau of the Tibetan Autonomous Region (China), in the North. It extends 114 km from north to south and nearly 64 km from east to west with the altitude ranging from 300 m to 8598 m. The state is inhabited by a number of ethnic groups including its aboriginal people, the *Lepchas*, *Bhutias* and *Nepalese*. The people of Sikkim have been engaged in different economic activities like tourism, forest related jobs, horticulture, floriculture, mining, power units, pharmaceuticals and other industries besides the government jobs.

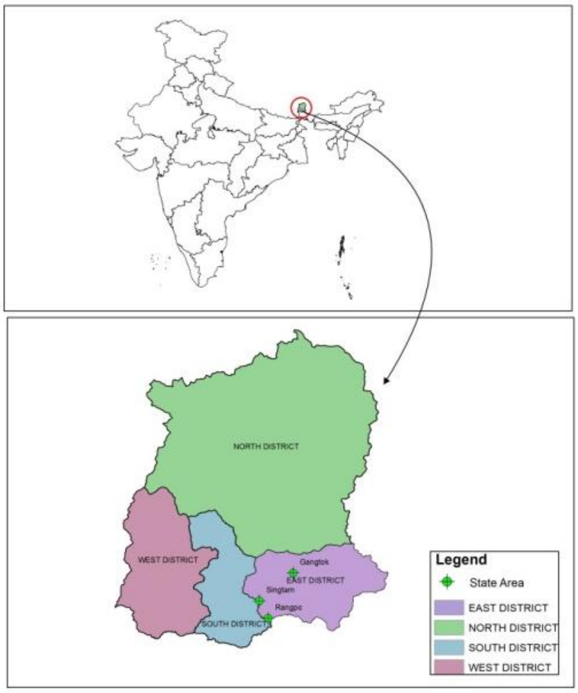

Fig. 1. Location of study area in India and urban towns in East District.

B. Methodology

We collected data from secondary sources, including the GLAD Global Land Cover and Land Use Change dataset, which quantifies changes in forest extent and height, cropland, built-up areas, surface water, and perennial snow and ice from 2000 to 2020 at a 30-meter spatial resolution (Potapov *et al.*, 2022). The datasets contain wide range of data under extensive number of parameters and for very large area. As the area under study was restricted to state of Sikkim therefore the data was clipped for Sikkim only. Further to evaluate the variations within the state, the data was further clipped into four districts *i.e.*, East, West, North and South (Fig. 1). We obtained the full disaggregated data along with legend for the original map and the mapping from the disaggregated classes was downloaded from run through a systematic review process. After completing the primary data extraction and analysis, we conducted an extensive review of published journal articles and books concerning the effects of urbanization on biodiversity in Sikkim. This was complemented by systematic web-based searches. Using "Google Scholar," we specifically searched for literature employing terms such as "urbanization," "impacts," "biodiversity," and "Sikkim." Our review covered publications available up to 2024, and additional searches included technical reports, student theses, government publications, agency reports, and databases of ongoing projects. This literature served to validate our analytical findings and to provide broader context on the implications of land use changes in Sikkim.

RESULTS AND DISCUSSION

The historical background of urbanization in Sikkim, reflects a trajectory influenced by various socio-political and economic factors. Prior to its merger with India, Sikkim was a kingdom ruled by the Chogyal monarchy (Gupta, 1975). Following Sikkim's accession to India in 1975, urbanization gained momentum with the establishment of government institutions, educational facilities, and infrastructure projects. The construction of roads, bridges, and utilities accelerated urban growth, attracting migrants from neighboring states and countries.

Over the past two decades, substantial shifts in land use and vegetation cover have been observed across various regions, reflecting both anthropogenic influences and environmental processes. The data under study captured a comprehensive assessment of land cover transformations in Sikkim for the year 2000 and 2020 (Fig. 2, Table 1).

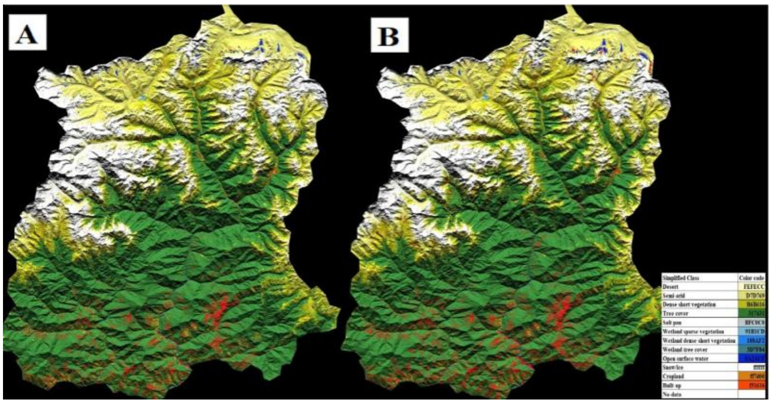

Fig. 2. Land Use Changes in Sikkim between (A) 2000 and (B) 2020.

Table 1: Land Use and Land Cover Changes in Sikkim for 2000 and 2020.

	East		South		North		West		Sikkim	
	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020
Dense short vegetation >79% vegetation cover	13149.64	12068.67	6630.51	5679.8	70726.22	70606.94	16761.73	15540.43	107376.3	103993.7
Tree cover 3-15m trees	21659.55	17961.06	21280.99	18342.74	50744.05	50651.01	30832.3	27669.55	124581.5	114692.1
Tree cover 16-25m trees	38548.27	41244.59	31805.45	34092.17	64831.62	65487.45	41650.98	46025.54	177000.6	187015.2
Tree cover >25m trees	14056.4	13903.98	5137.35	4930.12	20186.39	18999.41	7149.25	5548.81	46578.34	43428.14
Open surface water 90-100% of year	121.75	65.25	66.31	47.22	1010.21	926.49	39.45	29.51	1240.49	1068.06
Snow/ice	0.24	0	898.2	579.41	82061.04	76424.71	6098.12	6089.93	89431.38	83482.31
Cropland	142.98	75.06	337.29	164.44	2.14	24.09	526.39	335.5	1003.57	593.56
Built-up	5916.36	8232.07	5776.84	7897.43	2871.31	5602.62	5077.72	6945.75	19601.96	28638.43

B. Vegetation Cover Changes

The structure and development of vegetation in a region is affected by both the anthropogenic and environmental factors (Sharma *et al.*, 2010). Over the span of two decades from 2000 to 2020, the dynamics of vegetation cover have undergone notable shifts across the diverse landscapes of the East, South, North, West and Sikkim regions. A primary focus lies on the alterations observed in dense short vegetation cover, defined as areas with over 79% vegetation cover, which serves as a crucial indicator of ecosystem health and vitality (Styers *et al.,* 2010). The data reveals intriguing trends in dense short vegetation cover, showcasing both gains and losses in different regions. For instance, between 2000 and 2020, the East region experienced a reduction from 13,149.64 hectares to 12,068.67 hectares, indicating a decline in dense vegetation cover (Fig. 2). Similarly, in the North region, there was a decrease from 16,761.73 hectares to 15,540.43 hectares over the same period, reflecting a diminishing extent of dense short vegetation. Conversely, certain regions witnessed a contrasting trajectory. Notably, in Sikkim there was a marginal increase from 107,376.26 hectares to 103,993.66 hectares, suggesting a modest expansion of dense vegetation cover despite potential anthropogenic pressures. Studies show that vegetation changes in response to factors like land use, climate change, and disturbance regimes (Atherden and Hal 1999; Chen *et al.,* 2024). For instance, vegetation alterations due to land use changes can lead to shifts in plant communities and a decrease in species diversity (Erich *et al.,* 2002; Tan *et al.,* 2024). Moreover, vegetation cover plays a key role in controlling erosion rates, with areas of high vegetation density exhibiting lower erosion rates, emphasizing the protective role of vegetation against soil erosion in mountain environments (Sun *et al.,* 2021; Ashraf and Ahmad 2024). Therefore, decrease in short dense vegetation can disrupt ecosystem dynamics, biodiversity, and erosion control mechanisms in mountainous regions. Moreover, alongside the assessment of dense short vegetation, it is imperative to delve into the intricacies of tree cover density, which comprises varying height categories ranging from 3-15 meters, 16-25 meters, to greater than 25 meters.

Though there is an increase in the area under tree cover of 16-25 meters however across the height categories, discernible trends emerge, elucidating the nuances of tree cover density changes. In particular, the data indicates fluctuations in tree cover density across different height categories, with notable variations observed between 2000 and 2020. For instance, there was a significantly higher decrease in tree cover density for trees ranging between 3-15 meters in East, West and South districts as compared to the decrease in density of taller trees (>25 meters). It is important to emphasise that large trees are much more important for the forest ecosystems than the smaller trees. Large trees play a decisive role in forest ecosystems due to their disproportionate contribution to aboveground carbon storage (David *et al.,* 2023; Romero *et al.,* 2024). They regulate forest diversity, structure, function and aboveground biomass, especially in early successional forests, influencing the total vegetation's biomass significantly (Melinda *et al.,* 2022; Lee *et al.,* 2022; Ralhan *et al.,* 2024). Such insights underscore the multifaceted nature of vegetation dynamics and its intricate interplay with factors such as land use changes, climate variability, and anthropogenic pressures. By juxtaposing these trends with other parameters such as water bodies, snow/ice cover, and land use patterns, a holistic understanding of landscape transformations emerges, offering invaluable insights for ecosystem management and biodiversity conservation efforts.

Although comprehensive biodiversity studies have not yet been conducted in Sikkim, a significant number of species have been recorded in its forest areas and wetlands (SBFP, 2012). The significant decrease observed in tree cover, particularly in the categories of "Tree cover 3-15m trees" and "Tree cover >25m trees," between 2000 and 2020, raises several pertinent questions regarding the underlying drivers and implications of such changes. Firstly, the decline in tree cover within the 3-15 meter height category suggests potential disturbances or alterations in forest ecosystems. This range often represents younger or secondary growth forests, which are susceptible to changes in land use such as deforestation, agricultural expansion, or urbanization. The reduction in this category may signify the habitat loss for various species, disruption of ecological processes, and a decline in biodiversity. Land-use modifications have been shown to increase understorey species composition, affecting the overall functioning and stability of ecosystem (Sandra *et al.,* 2006; Tonleu *et al.,* 2024). Additionally, the enlargement of woodlands due to factors like fire suppression can lead to the establishment of invasive pathogens, impacting the inoculum load and disease prevalence in certain tree species within the forest ecosystem (Singh and Chaturvedi 2017). Invasive Alien Species *Titebati* (*Artemesia milagirica*) and *Banmara* (*Eupatorium adenophorum*) have spread uncontrollably in different parts of Sikkim (SoER, 2016). During the last decade, forest fire has emerged as a potential environmental threat (Sharma *et al.,* 2014; Dahal, 2024). In Sikkim, studies have shown that forest fires are predominantly ground fires, which significantly damage the biodiversity of the forests (Sharma and Thapa 2021; Dahal, 2024; Singh and Singha 2024). Forest cover in Sikkim has shown no significant improvement since 2011 and natural hazards have had a significantly negative impact on Sikkim's verdant forests and the Hindu Kush Himalayan region (Banerjee *et al.,* 2019; Adhikari *et al.,* 2024).

Despite the ecological significance, Sikkim Himalaya faces numerous threats to biodiversity. Increase in population, infrastructure development, urbanization, and climate change, unplanned and mass tourism, loss of rich traditional knowledge (Chettri and Lama 2014; SoER; 2016; Pandey and Priya 2021; Chandra *et al.,* 2024) are among the key threats to biodiversity in the region. The construction of the mega four-lane road in Sikkim has had profound negative impacts on local flora and fauna (Banerjee *et al.,* 2019). Furthermore, the ongoing Sevok-Rangpo railway project (45 kms approx), linking West Bengal and Sikkim will fragment the forests habitat and change the vegetation structure and composition along this Sevok-Rangpo route. The implications of these decreases in tree cover are far-reaching and multifaceted. The hill ecosystem is always under the transition due to the change in frequency, density, abundance, structure and composition of vegetation along forest to urban gradient due to land use change accelerated by various developmental activities including tourism. Previous vegetation studies conducted along a Deorali-Gangtok Ridge in East Sikkim showed high frequency, rich density and abundance of *Alnus nepalensis, Saurauia napaulensis, Prunus cerasoides, Schima wallichi, Macaranga pustulata* etc (Sharma *et al.,* 2010). However, with the establishment of tourist resorts and urbanization, there has been change in the structure, composition, density, abundance of forest cover during from the last decade along this gradient. With the prospering of tourism industry and rapid urbanization, the changed in structure, composition, density, abundance of vegetation has occurred at rapid pace in Sikkim Himalaya. Ecologically, the loss of tree cover threatens the stability and functioning of ecosystems, leading to altered hydrological cycles, soil erosion, and reduced carbon storage capacity (Kumar *et al.,* 2022). Moreover, the decline in habitat availability can exacerbate biodiversity loss, contributing to species extinctions (Sandor *et al.,* 2022; Premlata *et al.,* 2024) and disrupting trophic cascades. Socioeconomically, the degradation of forest ecosystems can impact local communities dependent on forest resources for livelihoods (Oldekop *et al.,* 2020; Mae *et al.*, 2024), as well as affect global climate regulation (Tian *et al.,* 2022; Rabbi & Kovács 2024) and resilience to natural disasters (Kumar *et al.*, 2022; Xu, 2024). Addressing the drivers behind the decrease in tree cover requires comprehensive strategies that prioritize sustainable land management practices, conservation efforts, and policy interventions (Pandit *et al.,* 2020). This includes promoting reforestation and afforestation initiatives, implementing effective land-use planning and zoning regulations, incentivizing sustainable forestry practices, and raising awareness about the importance of preserving forest ecosystems for present and future generations. In essence, the drastic decrease in tree cover, particularly in critical height categories, underscores the urgent need for rigorous action to reduce further loss and maintain the invaluable ecological, social, and economic benefits and ecosystem services provided by forests.

B. Land Use Changes

The analysis of land use changes between 2000 and 2020 reveals notable shifts in cropland areas and built-up (urbanized) areas across the North, South, East, and West districts. These changes have multifaceted implications for agricultural practices, urban development, and habitat fragmentation, reflecting the complicated interaction between anthropogenic activities and natural landscapes. The analysis of built-up areas unveils significant transformations in urban landscapes across the districts. Notably, the South district witnessed a substantial increase from 5776.84 hectares to 7897.43 hectares, indicative of infrastructure development due to rapid urbanization (Table 1). Similarly, the West district exhibited a notable increase in built-up areas, reflecting urban sprawl and population growth trends. The west district has the major towns including the state capital Gangtok. Conversely, the North and East districts displayed relatively modest changes in built-up areas, suggesting varying degrees of urbanization pressures and land use planning policies. However, it is essential to note that even incremental changes in built-up areas can have profound implications for land cover, ecosystem services, and habitat fragmentation. In Sikkim, majority of the population subsists in the urban areas of East district (80 %) followed by South district (13%) followed by west (4%) and North (3%) (Paul *et al.,* 2016). The population of Gangtok has surged in recent decades (Rai and Singh 2022), fuelled by in-migration and tourism (Chakraborty and Ghosal 2024). This influx of people has led to the increase of built-up areas, the proliferation of informal settlements, and the intensification of land-use activities. The impacts of population growth and migration on urban expansion in Gangtok are multifaceted. On one hand, they contribute to economic dynamism, cultural diversity, and social vibrancy, enhancing the city's livability and attractiveness. On the other hand, they exert pressure on natural resources, strain infrastructure systems, and exacerbate environmental degradation.

In addition to Gangtok, other towns of Sikkim Namchi - the capital town of South Sikkim has also transformed rapidly due to urbanization (McDui and Chettri 2018). Likewise, Chungthang - in North Sikkim has also been on the path to urbanization due to state induced development (Chettri, 2017). Similarly, other towns of Sikkim for instance, Jorethang, Rangpo, Singtam, Rhenock, Rongli, Mangan, Pakyong etc are also have taken rapid strides in urbanization. The urban town of Gangtok reflects the impact of urbanization on the environment as urban development has led to changes such as alterations in land use, slope modification, and fragmentation of natural habitats, thereby modifying the habitat's character and introducing man-made habitats (Das *et al.*, 2013; Kumar *et al.,* 2024). During the decade of 1991 and 2001, the population growth rate of this town was only 17.30 % which increased to 1,00,286 in 2011 from 29,354 in 2001 which was around 241 % increase (Paul *et al.,* 2016). Post-2011, Gangtok has witnessed a noticeable suburban sprawl, with rapid expansion of built-up areas beyond the traditional city limits into surrounding rural and semi-urban zones such as *Burtuk, Bojoghari, Pangthang, Tadong, Ranipool, and 5th Mile*. The trends and patterns of urbanization in Sikkim Himalaya, particularly in Gangtok, are characterized by rapid population growth, spatial expansion, and vertical development (Kumar, 2017). A shift from vertical growth within Gangtok to horizontal expansion outside city boundaries reflects the limited carrying capacity of the urban core, driving sprawl into previously undisturbed slopes contributing to strain on infrastructure, waste management systems, and local ecosystems in the adjoining areas.

The observed shifts in built-up areas have far-reaching implications for urban development and habitat fragmentation (Dai *et al.*, 2018; Mansingh *et al.*, 2025). The proliferation of built-up areas can fragment natural habitats, disrupting ecological connectivity and species migration patterns (Jaeger *et al.*, 2016; Wang *et al.*, 2020; Ding *et al.*, 2024). This fragmentation poses challenges for biodiversity conservation, as it isolates populations, reduces genetic diversity, and increases the vulnerability of ecosystems to environmental stressors (Liu *et al.*, 2019; Faye *et al.*, 2024). Correlating these land use changes with other parameters such as tree cover dynamics reveals complex relationships between human activities and ecosystem integrity (Yang, 2021). For instance, the expansion of built-up areas often correlates with declines in tree cover, highlighting the trade-offs between green spaces and urban development (Han *et al.*, 2022; He *et al.*, 2023). Such correlations underscore the need for integrated land use planning approaches that balance economic development with environmental conservation objectives. The analysis of land use changes underscores the dynamic nature of human-environment interactions and the imperative of sustainable land management practices.

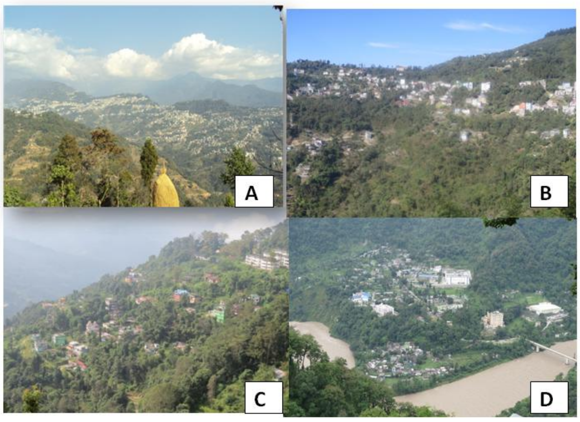

Plate 1: Some of the plates of urban, suburban, rural and riverine ecosystem in Sikkim with urbanization at various stages (A: 17.06.2012; B: 11.12.2016; C: 10.11.2015 D: 13.06.2015).

C. Water Bodies and Snow/Ice Cover

The pristine mountain landscapes of Sikkim, nestled in the Himalayas, have long been characterized by their shimmering snow-capped peaks and glistening glaciers (Starkel and Sarkar 2014). However, the data spanning from 2000 to 2020 of present study paints a concerning picture of dwindling snow and ice cover in this ecologically fragile region. Over this two-decade period, a noticeable reduction in snow/ice cover across Sikkim's mountainous terrain was observed. In 2000, the snow/ice cover in Sikkim's mountains stood at 89,431.38 ha. By 2020, this figure had diminished to 83,482.31ha, reflecting a substantial reduction over the study period. Such a decline in snow and ice cover raises significant concerns regarding the implications for aquatic ecosystems, regional climates, and hydrological cycles (Stewart, 2009; Huss *et al.*, 2017). The implications of this decrease in snow/ice cover are manifold and far-reaching. Aquatic ecosystems, including rivers and streams fed by snowmelt, are particularly vulnerable to alterations in freshwater input (Slemmons *et al.*, 2013; Yan *et al.*, 2021; Leathers *et al.*, 2024). The decline in snow cover can disrupt river flows, exacerbate water scarcity during dry seasons, and heighten the risk of water-related conflicts and socio-economic challenges (Beniston and Stoffel 2014). Reduced snow accumulation alters surface albedo, or reflectivity, leading to increase in absorption of solar radiation and localized warming effects (Skiles *et al.*, 2018).

The snow cover in North Sikkim, a region renowned for its rugged terrain and high-altitude landscapes (Basnett *et al.*, 2012), has witnessed significant fluctuations over the past two decades. In 2000, the snow cover in North Sikkim encompassed approximately 82061.04 Hectare. However, by 2020, this figure had experienced a noticeable decline, diminishing to 76424.71 Hectares (Table 1). This decrease in snow cover highlights the vulnerability of North Sikkim's mountain ecosystems to changing climatic conditions and underscores the challenges posed by climate change in high-altitude regions (Krishna, 2005; Notarnicola, 2022). The implications of reduced snow cover in North Sikkim are multifaceted and far-reaching (Bawa and Ingty 2012). Moreover, the loss of snow cover in North Sikkim's mountains has implications for regional climates and weather patterns. Snow acts as an insulating blanket, regulating surface temperatures and influencing local microclimates (Roberts *et al.*, 2017). Reduced snow accumulation can exacerbate warming trends, leading to changes in precipitation patterns, cloud cover and atmospheric circulation in North Sikkim and surrounding areas. The rapid melting of snow and ice, along with heavy rainfall, has led to the formation and expansion of moraine-dammed lakes. This has caused glacial lake outburst floods (GLOFs) in the Teesta River in North Sikkim, altering the landscape in many areas of the upper reaches of Sikkim (Dahal *et al.*, 2024).

D. Ecological and Biodiversity Implications

The period from 2000 to 2020 has witnessed profound land cover changes, with significant implications for biodiversity conservation and ecosystem functioning. These changes, including habitat loss, fragmentation, and alterations in ecosystem services, pose considerable challenges to maintaining biodiversity hotspots and key ecological processes (Hasan *et al.*, 2020). The data from table 1 reveals shifts in land cover, such as the reduction in dense short vegetation cover (>79% vegetation) in certain regions. For instance, the East district experienced a decline from 13,149.64 square kilometers to 12,068.67 square kilometers. This loss of dense vegetation indicates habitat degradation and potential fragmentation, which can exacerbate the vulnerability of species and contribute to biodiversity decline (Zambrano *et al.*, 2019; Liu *et al.*, 2019; Tulloch *et al.*, 2016; Faye *et al.*, 2024; Alshayeb, 2025). In addition, , the decrease in tree cover density results in the fragmentation of habitats and the loss of essential wildlife corridors (Laurance, 2004; Theobald *et al.*, 2011; Hendling *et al.*, 2023). Changes in land cover, including the increase of built-up areas and croplands, can disrupt the provision of ecosystem services critical for human well-being (Mathewos and Aga 2023; Simeon and Wana 2024). The increase in built-up areas, as seen in the South district from 5776.84 square kilometers to 7897.43 square kilometers, results in habitat loss and degradation, compromising ecosystem functions such as water purification and carbon sequestration (Ekka *et al.*, 2023; Assennato *et al.*, 2022; Simeon and Wana 2024). Given the significant ecological and biodiversity implications of land cover changes, continuous monitoring and mitigation efforts are essential (Schirpke *et al.*, 2017; Li *et al.*, 2022). By tracking changes in vegetation cover, land use, and species populations, conservationists can identify areas at risk and prioritize conservation actions. Moreover, implementing mitigation measures such as habitat restoration, reforestation, and sustainable land management practices can help mitigate the adverse effects of habitat loss and fragmentation, promoting ecosystem resilience and biodiversity conservation.

Biodiversity is essential for sustaining health of ecosystem and achieving Sustainable Development Goals (SDGs) (Lu *et al.*, 2020; Reyers *et al.*, 2020; Saleh *et al.*, 2024). On the contrary, urbanization leads to changes in species composition, diversity and community structure and is a major driver of the rapid decline and extinction of many native species due to habitat loss and degradation (Boivin *et al.*, 2016; Li *et al.*, 2022; Hessen, 2024). Understanding the dynamics of urbanization is crucial for addressing its impacts on the environment and ensuring sustainable development (Bai *et al.*, 2017; James, 2024). Anthropogenic disturbances are generally harmful to species richness, population structure, and the regeneration of tree species. However, moderate disturbances can sometimes benefit the regeneration of certain selected species (Gautam *et al.*, 2016). While numerous studies have explored how urbanization affects ecological patterns and processes, there is still limited understanding of the spatial and temporal distribution of biodiversity (Chen, 2007; Seto *et al.*, 2012; Sun *et al.*, 2022; Ruas *et al.*, 2024). Our understanding of the relationships between urbanization and biodiversity remains inadequate, particularly in the Global South (Batty, 2008; Güeneralp and Seto 2013; McDonald *et al.*, 2020; Sun *et al.*, 2022). As the total urban area is expected to more than double by 2050, understanding the impact of urbanization on species communities becomes increasingly crucial for biodiversity conservation (Zhou *et al.*, 2019; Sidemo *et al.*, 2022).

Sustainable Land Use Planning and Management in Sikkim: Promoting Socio-Economic and Environmental Resilience

In order to ensure long-term socio-economic, environmental resilience and sustainable land management in Sikkim, a comprehensive and integrated approach to land use planning is essential (Table 2).

Table 2: Strategy and Mechanism for ensure sustainable land management in Sikkim.

Sr. No.	Strategy	Mechanism
1.	Promote Agroecological and Organic Farming Practices	Sikkim is already a fully organic state, so the focus should now be on: • Diversifying crops to prevent monoculture vulnerabilities. • Agroforestry systems to integrate trees with crops/livestock for better soil, water retention, and biodiversity. • Local seed banks and indigenous crop varieties to preserve genetic diversity and reduce dependency on external inputs.
2.	Zoning and Land Suitability Mapping	• Conduct GIS-based land capability assessments to determine optimal land use (agriculture, forestry, tourism, habitation). • Implement eco-sensitive zoning to restrict development in fragile ecosystems like riverine ecosystems, lakes, high altitudes etc.
3.	Sustainable Urban and Rural Development	• Encourage compact and vertical urban growth in towns to limit sprawl into natural habitats. • Use low-impact, climate-resilient construction materials for infrastructure. • Develop eco-villages that blend traditional knowledge with modern sustainability practices.
4.	Forest and Biodiversity Conservation	• Strengthen community forest management (like Joint Forest Management Committees). • Promote incentives schemes where locals are compensated for conserving biodiversity and watersheds. • Rehabilitate degraded lands using native species afforestation
5.	Watershed Management and Climate Adaptation	• Integrate watershed-based planning to manage water resources, prevent landslides, and improve agricultural productivity. • Build check dams, rainwater harvesting structures, and terraces to reduce runoff and erosion. • Promote climate-resilient agriculture tailored to different altitudes and rainfall patterns.
		• Involve local communities, especially women and indigenous groups, in land use planning decisions.

6.	Community Participation and Capacity Building	• Offer training in sustainable land management, GIS, eco-tourism, and green technologies. • Encourage eco-entrepreneurship in sectors like organic food, sustainable crafts, and nature-based tourism.
7.	Policy Integration and Institutional Strengthening	• Align state policies with SDGs, National Action Plan on Climate Change (NAPCC), and regional conservation strategies. • Establish a land use monitoring and evaluation system using satellite imagery and ground verification. • Multi-sectoral representation in State Land Use Board to guide policy and coordination.

Source: Compiled by authors, 2024

CONCLUSIONS

The analysis of land cover changes, hydrological dynamics, and ecological implications between 2000 and 2020 reveals a complex relationship between human activities and natural ecosystems. The reduction in vegetation cover, expansion of built-up areas and decline in snow/ice extent underscored the significant challenges facing biodiversity conservation and ecosystem resilience. The decrease in the snow area in north and increase in the built up in south, east and west district of Sikkim Himalaya is a matter of concern for an area which is known for its biodiversity and is a part of Eastern Himalaya which is one of the 36 biodiversity hotspots of the world. The land use changes highlight the urgent need for data-driven monitoring, mitigation, and conservation efforts to safeguard habitat integrity, preserve ecosystem services, and enhance resilience to environmental change. An integrated approach to formulating future development plans is imperative for maintaining sustainability in the region. By prioritizing sustainable land management practices and embracing integrated approaches, the delicate balance between human development and ecological health can be achieved for sustainable future for generations to come in Sikkim Himalaya.

FUTURE SCOPE

With the creation of two more districts in Sikkim (Soreng and Pakyong) few yrs ago (2021), the pace of urbanization and land use change is going to impact biodiversity, ecosystem services in Sikkim. Therefore, future research on Land Use Land Cover (LULC) changes in the Sikkim Himalaya should focus on high-resolution and real-time monitoring, integrating climate change variables to better understand environmental transformations. Predictive modeling tools can help simulate future scenarios, while assessments of biodiversity, ecosystem services, and socio-economic impacts will support holistic planning. There's a need to examine disaster risks linked to land degradation and evaluate existing governance frameworks for adaptive and inclusive management. Community-based monitoring and participatory GIS can enhance local engagement and data accuracy. Additionally, focused research on the impacts of infrastructure and tourism development in Sikkim can offer valuable insights for sustainable land use planning and policy-making.

REFERENCES

Adhikari, B. R., Gautam, S., Sharma, T. P. P. and Devkota, S. (2024). Land cover, land use change and its implication to disasters in the Hindu Kush Himalayan region. In *Surface Environments and Human Interactions: Reflections from Asia* (pp. 7-27). Singapore: Springer Nature Singapore.

Alshayeb, M. J. (2025). Evaluating Ecosystem Service Trade-Offs and Recovery Dynamics in Response to Urban Expansion: Implications for Sustainable Management Strategies. *Sustainability*, *17*(5), 2194.

Anees, M. M., Sharma, R. and Joshi, P. K. (2022). Urbanization in Himalaya—An interregional perspective to land use and urban growth dynamics. *Mountain Landscapes in Transition: Effects of Land Use and Climate Change*, 517-538.

Ashraf, A. and Ahmad, I. (2024). Evaluation of soil loss severity and ecological restoration approach for sustainable agriculture in the Hindu Kush, Karakoram and Himalaya region. *Journal of Mountain Science*, *21*(5), 1509-1521.

Assennato, F., Smiraglia, D., Cavalli, A., Congedo, L., Giuliani, C., Riitano, N., Strollo, A. and Munafò, M. (2022). The impact of urbanization on land: a biophysical-based assessment of ecosystem services loss supported by remote sensed indicators. *Land*, *11*(2), p.236.

Atherden., M., A. and Hall, J. A. (1999). Human impact on vegetation in the White Mountains of Crete since AD 500. *The Holocene*.

Bawa, K. S. and Ingty, T. (2012). Climate change in Sikkim: A synthesis. In: *Climate Change in Sikkim, Patterns, Impacts and Initiatives*, 19-48.

Bai, X., McPhearson, T., Cleugh, H., Nagendra, H., Tong, X., Zhu, T. and Zhu, Y. G. (2017). Linking urbanization and the environment: Conceptual and empirical advances. *Annual review of environment and resources*, *42*, 215-240.

Banerjee, A., Chakraborty, P. and Bandopadhyay, R. (2019). Urgent conservation needs in the Sikkim Himalaya biodiversity hotspot. *Biodiversity*, *20*(2-3), 88-97.

Behera, M. D., Sharma, N., Neeti, Chowdhary, V. M. and Shrestha, D. G. (2022). Hybrid approach for land use and forest cover classification in Sikkim Himalaya. *Geospatial Technologies for Land and Water Resources Management*, 17-35.

Beniston, M. and Stoffel, M. (2014). Assessing the impacts of climatic change on mountain water resources. *Science of the Total Environment*, *493*, pp.1129-1137.

Basnett, S., Kulkarni, A. V. and Tambe, S. (2012). Monitoring of seasonal snow cover in Sikkim Himalaya using remote sensing techniques. *Climate change in Sikkim: patterns, impacts and initiatives. Information and Public Relations Department, Government of Sikkim, Gangtok*, pp. 69-80.

Batty, M. (2008). The size, scale, and shape of cities. Science *319*, 769–771.

Berry, B. J. (2008). Urbanization. an international perspective on the interaction between humans and nature, Urban ecology: 25-48.

Briassoulis, H. (2009). Factors influencing land-use and land-cover change. *Land cover, land use and the global change, encyclopaedia of life support systems (EOLSS)*, *1*, 126-146.

Boivin, N. L., M. A. Zeder, D. Q. Fuller, A. Crowther, G. Larson, J. M. Erlandson, T. Denham, Petraglia, M. D. (2016). Ecological consequences of human niche construction: Examining longterm anthropogenic shaping of global species distributions. *Proc. Natl. Acad. Sci. U.S.A. 113*, 6388–6396.

Chakraborty, A., Sachdeva, K. and Joshi, P. K. (2016). Mapping long-term land use and land cover change in the central Himalayan region using a tree-based ensemble classification approach. *Applied Geography*, *74*, 136-150.

Chakraborty, P. and Ghosal, S. (2024). An eco-social exploration of tourism area evolution in mountains through stakeholders' perspective. *Environmental Development*, 100963.

Chettri, A. and Lama, S. (2014). Trends of urbanization and its impacts on environmental resources: A case study of Gangtok town of Sikkim Himalayas. *Geo-Analyst*, ISSN, 2249, 2909.

Chen, J. (2007). Rapid urbanization in China: A real challenge to soil protection and food security. *Catena*, *69*, 1–15.

Chandra, A., Gupta, Y., Dinakaran, J., Raina, N., Hanif, M., Meena, A. and Rao, K. S. (2024). Climate Change and Biodiversity in the Himalaya: Trends and Perception. In: *Biodiversity Hotspot of the Himalaya* (pp. 439-458). Apple Academic Press.

Chen, M., Xue, Y., Xue, Y., Peng, J., Guo, J. and Liang, H. (2024). Assessing the effects of climate and human activity on vegetation change in Northern China. *Environmental Research*, *247*, 118233.

Chettri, M. (2017). Chungthang: an emerging urban landscape in Sikkim. International Institute for Asian Studies, The Newsletter 77.
https://www.iias.asia/the-newsletter/article/chungthang-emerging-urban-landscape-sikkim

Das, N., Chatterjee, S. and Roy, U. (2013). Habitat-based ecological analysis of urban space in mountain environment: An appraisal for Gangtok town, Sikkim, India. *Ecol. Environ. Conserv.*, *19*(3), 707-715.

Dahal, D. R., Mehta, M., Bhatt, C. M. and Luirei, K. (2024). Flash floods and their cascading tumults: an example from Teesta River valley, Eastern Himalaya, Sikkim, India. *Current Science*, *126*(10), 1280-1283.

Dahal, D. R. (2024). Increasing incidences of forest fire in Sikkim, India. In: *Geo-information for Disaster Monitoring and Management*. Cham: Springer International Publishing pp. 373-388.

Dar, Shahnawaz Ahmad, Shaban, Tauseef, Dar, Mohd Sajad and Bharadwaj, Ramesh (2017). Impacts of Urbanization on Quality of Environment in Jammu Region. *International Journal of Theoretical & Applied Sciences, Special Issue 9*(2), 54-60.

Das, A., Mishra, G., Lakra, P. C., Kumar, S. and Mishra, S. N. (2023). Impact of Land Uses on Soil Organic Carbon Dynamics in the Indian Himalayan Region. In: *Soil Carbon Dynamics in Indian Himalayan Region* (pp. 55-75). Singapore: Springer Nature Singapore.

David, J., Mildrexler, Logan, T., Berner, Beverly, E., Law, Richard, A., Birdsey, William, R., Moomaw (2023). Protect large trees for climate mitigation, biodiversity, and forest resilience. *Conservation science and practice*.

Dai, E., Wang, Y., Ma, L., Yin, L. and Wu, Z. (2018). 'Urban-Rural'gradient analysis of landscape changes around cities in mountainous regions: a case study of the Hengduan Mountain region in southwest China. *Sustainability*, *10*(4), 1019.

Ding, G., Guo, J., Ou, M. and Prishchepov, A. V. (2024). Understanding habitat isolation in the context of construction land expansion using an ecological network approach. *Landscape Ecology*, *39*(3), 56.

Digra, A. and Kaushal, A. (2021). Land Use and Land Cover Change Analysis using Remote Sensing and GIS Techniques. *Biological Forum – An International Journal*, *13*(3b), 134-138

Erich, Tasser, Ulrike, Tappeiner (2002). Impact of land use changes on mountain vegetation. *Applied Vegetation Science*,

Ekka, P., Patra, S., Upreti, M., Kumar, G., Kumar, A. and Saikia, P. (2023). Land Degradation and its impacts on Biodiversity and Ecosystem services. *Land and Environmental Management through Forestry*, pp.77-101.

Faye, B., Du, G., Li, Q., Faye, H. V. M. T., Diéne, J. C., Mbaye, E. and Seck, H. M. (2024). Lessons learnt from the influencing factors of forested areas' vulnerability under climatic change and human pressure in arid areas: a case study of the Thiès Region, Senegal. *Applied Sciences*, *14*(6), 2427.

Gautam, M. K., Manhas, R. K. and Tripathi, A. K. (2016). Patterns of diversity and regeneration in unmanaged moist deciduous forests in response to disturbance in Shiwalik Himalayas, *India. Journal of Asia-Pacific Biodiversity*, *9(*2), 144-151.

Güeneralp, B. and Seto, K. C. (2013). Futures of global urban expansion: Uncertainties and implications for biodiversity conservation. *Environ. Res. Lett. 8*, 014025.

Gupta, R. (1975). Sikkim: the merger with India. *Asian Survey*, *15*(9), 786-798.

Gupta, H. K. (2007). Deforestation and forest cover changes in the Himachal Himalaya, India. *International Journal of Ecology and Environmental Sciences*, *33*(2-3), 207-218.

Gurung, A. and Hannan, A. (2021). Dynamics of Land Use and Trends of Agriculture in Sikkim. *Journal of North East India Studies*, *11*(1).

Haokip, I. C., Devi, M. H., Sunil, B. H. Mahima, D. Tasung, A. and Yabi Gadi, Y. (2023). Land Degradation in the North Eastern Region of India and its Mitigation. *Biological Forum – An International Journal*, *15*(12), 473-479

Hending, D., Randrianarison, H., Andriamavosoloarisoa, N. N. M., Ranohatra-Hending, C., Holderied, M., McCabe, G. and Cotton, S. (2023). Forest fragmentation and its associated edge-effects reduce tree species diversity, size, and structural diversity in Madagascar's transitional forests. *Biodiversity and Conservation*, *32*(10), 3329-3353.

Huss, M., Bookhagen, B., Huggel, C., Jacobsen, D., Bradley, R.S., Clague, J. J., Vuille, M., Buytaert, W., Cayan, D. R., Greenwood, G. and Mark, B. G. (2017). Toward mountains without permanent snow and ice. *Earth's Future*, *5*(5), pp.418-435.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A. and Townshend, J. R. (2013). High-resolution global maps of 21st-century forest cover change. *science*, *342*(6160), 850-853.

Hoekstra, J. M., Boucher, T. M., Ricketts, T. H. and Roberts, C. (2005). Confronting a biome crisis: global disparities of habitat loss and protection. *Ecol. Lett.*, *8*, 23–29.

Han, H., Zhang, Y., Liu, Y., Yu, X. and Wang, J. (2022). Spatiotemporal changes of the habitat quality and the human activity intensity and their correlation in mountainous cities. *Journal of Environmental Engineering and Landscape Management*, *30*(4), 472-483.

He, X., Ziegler, A. D., Elsen, P. R., Feng, Y., Baker, J. C., Liang, S., Holden, J., Spracklen, D. V. and Zeng, Z. (2023). Accelerating global mountain forest loss threatens biodiversity hotspots. *One Earth*, *6*(3), pp. 303-315.

Hasan, S. S., Zhen, L., Miah, M. G., Ahamed, T. and Samie, A. (2020). Impact of land use change on ecosystem services: A review. *Environmental Development*, *34*, p.100527.

Hessen, D. O. (2024). Biotic Deterioration and Homogenization: Why It Matters. *International Journal of Politics, Culture, and Society*, 1-23.

Hussain, S., Sharma, S., Bhatti, R. C. and Singh, A. N. (2024). Sustainability in the Indian Himalayan Region: Understandings the Ecosystem Services, Climate Change Impacts, Land Use Shifts and Their Threats. In: *The Himalayas in the Anthropocene: Environment and Development* (pp. 33-57). Cham: Springer Nature Switzerland.

IPBES (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. *Popl Dev Rev*., *45*, 680–681.

Jaeger, J. A., Soukup, T., Schwick, C., Madriñán, L. F. and Kienast, F. (2016). Landscape fragmentation in Europe. In*: European landscape dynamics* (pp. 187-228). CRC Press.

James, N. (2024). Urbanization and its impact on environmental sustainability. *J. Appl. Geogr. Stud*, *3*, 54-66.

Krishna, A. P. (2005). Snow and glacier cover assessment in the high mountains of Sikkim Himalaya. *Hydrological Processes: An International Journal*, *19*(12), 2375-2383.

Kumar, R., Kumar, A. and Saikia, P. (2022). Deforestation and forests degradation impacts on the environment. In: *Environmental Degradation: Challenges and Strategies for Mitigation* (pp. 19-46). Cham: Springer International Publishing.

Kumar, A. (2017). Analysing urban sprawl and land consumption patterns in major capital cities in the Himalayan region using geoinformatics. *Applied Geography*, *89*, 112-123.

Kalfas, D., Kalogiannidis, S., Chatzitheodoridis, F. and Toska, E. (2023). Urbanization and land use planning for achieving the sustainable development goals (SDGs): A case study of Greece. *Urban Science*, *7*(2), 43.

Karan, P. P. (1987). Development issues in Sikkim and Bhutan. *Mountain Research and Development*, 275-278.

Kaur, Sandeep (2017). The Effect of Urbanization on Environment in India. *International Journal on Emerging Technologies*, *8*(1), 122-126.

Kumar, A., Saikia, P. and Srivastava, P. (2024). Human-induced impacts on ecological infrastructure in the Himalayan urban agglomerations. *Ecological Frontiers*, *44*(1), 84-95.

Liu, J., Coomes, D. A., Gibson, L., Hu, G., Liu, J., Luo, Y., Wu, C. and Yu, M. (2019). Forest fragmentation in China and its effect on biodiversity. *Biological Reviews*, *94*(5), 1636-1657.

Laurance, S. G. (2004). Landscape connectivity and biological corridors. *Agroforestry and biodiversity conservation in tropical landscapes*, *1*, 50-63.

Laurance, W. F. (2000). Mega-development trends in the Amazon: implications for global change. *Environ Monit Assess*, *61*, 113–122.

Laurance, W. F. (2015). Emerging threats to tropical forests. *Ann Mo Bot Gard.*, *100*(3), 159–169.

Liu, W., Zhan, J., Zhao, F., Yan, H., Zhang, F. and Wei, X. (2019). Impacts of urbanization-induced land-use changes on ecosystem services: A case study of the Pearl River Delta Metropolitan Region, China. *Ecological Indicators*, *98*, 228-238.

Li. G., C. Fang, Y. Li, Z. Wang, S. Sun, S. He, W. Qi, C. Bao, H. Ma, Y. Fan, Y. Feng, X. Liu (2022). Global impacts of future urban expansion on terrestrial vertebrate diversity. *Nat. Commun*., *13*, 1628.

Lu, Y., Y. Yang, B. Sun, J. Yuan, M. Yu, N. C. Stenseth, J. M. Bullock, M. Obersteiner (2020). Spatial variation in biodiversity loss across China under multiple environmental stressors. *Sci. Adv.*, *6*, eabd0952.

Lambin, E. F. and Geist, H. J. (2001). Global land-use/land-cover changes: What have we learned so far? *IGBP Global Change Newsletter*, *46*, 27–30.

Leathers, K., Herbst, D., de Mendoza, G., Doerschlag, G. and Ruhi, A. (2024). Climate change is poised to alter mountain stream ecosystem processes via organismal phenological shifts. *Proceedings of the National Academy of Sciences*, *121*(14), e2310513121.

Lee, C. B., Ali, A., Yuan, Z., Lutz, J. A., Svenning, J. C. and Lee, M. K. (2022). Large-diameter trees control forest structure and function in successional temperate forests. *Biogeosciences Discussions*, *2022*, 1-20.

McDuie-Ra, D. and Chettri, M. (2018). Himalayan boom town: rural–urban transformations in Namchi, Sikkim. *Development and Change*, *49*(6), 1471-1494.

McDonald, R. I., Mansur, A. V., Ascensão, F., Colbert, M. L., Crossman, K., Elmqvist, T. and Ziter, C. (2020). Research gaps in knowledge of the impact of urban growth on biodiversity. *Nature Sustainability*, *3*(1), 16-24.

Maes, L., Lambert, M. and Lefevre, O. (2024). The Socioeconomic Impact of Forest Degradation on Rural Communities. *Journal of Selvicoltura Asean*, *1*(6), 304-315.

Mansingh, A., Pradhan, A., Rath, L. P., Kujur, A. J., Ekka, N. J. and Panda, B. P. (2025). Spatio-temporal analysis of fragmentation and rapid land use changes in an expanding urban region of eastern India. *Discover Sustainability*, *6*(1), 131.

Mathewos, M. and Aga, A. O. (2023). Evaluation of the Linkages between Ecosystem Services and Land Use/Land Cover Changes in Matenchose Watershed, Rift Valley Basin, Ethiopia. *Quaternary*, *6*, 13.

Mishra, P. K., Rai, A., Abdelrahman, K., Rai, S. C. and Tiwari, A. (2021). Analysing challenges and strategies in land productivity in Sikkim Himalaya, India. *Sustainability*, *13*(19), 111-12.

Mittermeier, R. A., Myers, N., Mittermeier, C. G. and Robles Gil, P. (1999). *Hotspots: Earth's biologically richest and most endangered terrestrial ecoregions*. CEMEX, SA, Agrupación Sierra Madre, SC.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772), 853-858.

Miranda, J., Britz, W. and Börner, J. (2024). Impacts of commodity prices and governance on the expansion of tropical agricultural frontiers. *Scientific Reports*, *14*(1), 9209.

Melinda, Gilhen-Baker, Valentina, Roviello, Diana, Beresford-Kroeger, Giovanni, N., Roviello (2022). Old growth forests and large old trees as critical organisms connecting ecosystems and human health. A review. *Environmental Chemistry Letters*.

Mishra, P. K., Rai, A. and Rai, S. C. (2020). Land use and land cover change detection using geospatial techniques in the Sikkim Himalaya, India. *The Egyptian Journal of Remote Sensing and Space Science*, *23*(2), 133-143.

Mishra, P. K., Rai, A., Abdelrahman, K., Rai, S. C. and Tiwari, A. (2021). Analysing challenges and strategies in land productivity in Sikkim Himalaya, India. *Sustainability*, *13*(19), 11112.

Naab, F. Z., Dinye, R. D. and Kasanga, R. K. (2013). Urbanisation and its impact on agricultural lands in growing cities in developing countries: a case study of Tamale in Ghana. *Modern Social Science Journal*, 2(2), 256-287.

Nagendra, H., Sudhira, H. S., Katti, M., Tengö, M. and Schewenius, M. (2014). Urbanization and its impacts on land use, biodiversity and ecosystems in India. *INTERdisciplina 2*(2).

Nuissl, H. and Siedentop, S. (2021). Urbanisation and land use change. *Sustainable land management in a European context: a co-design approach*, 75-99.

Newbold, T., Hudson, L. N., Hill, S. L., Contu, S., Gray, C. L., Scharlemann, J. P. and Purvis, A. (2016). Global patterns of terrestrial assemblage turnover within and among land uses. *Ecography*, *39*(12), 1151-1163.

Notarnicola, C. (2022). Overall negative trends for snow cover extent and duration in global mountain regions over 1982–2020. *Scientific reports*, *12*(1), p.13731.

Oldekop, J. A., Rasmussen, L. V., Agrawal, A., Bebbington, A. J., Meyfroidt, P., Bengston, D. N., and Wilson, S. J. 2020. Forest-linked livelihoods in a globalized world. *Nature Plants, 6*(12), 1400-1407.

Paul, K., Sharma, D., Mumkherjee, R., Sengupta, R. and Tamang, K. L. 2016. Demographic characteristics and changing land use pattern in Gangtok, Sikkim (1975–2011). *International Journal of Geomatics and Geosciences*, *6*(4), 1769-1781.

Parida, B. R., Kumar, P., Chakraborty, J. S., Bag, N. and Kumar, N. (2022). Dynamics of land use/land cover over Indian Himalayan region (IHR) using satellite data from 1985 to 2015 coupled with local perceptions. In *Handbook of Himalayan Ecosystems and Sustainability, Volume 1* (pp. 3-22). CRC Press.

Pandit, M. K., Sodhi, N. S., Koh, L. P., Bhaskar, A. and Brook, B. W. (2007). Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalaya. *Biodiversity and Conservation*, *16*, 153-163.

Pandit, R., Parrotta, J. A., Chaudhary, A. K., Karlen, D. L., Vieira, D. L. M., Anker, Y., Chen, R., Morris, J., Harris, J. and Ntshotsho, P. (2020). A framework to evaluate land degradation and restoration responses for improved planning and decision-making. *Ecosystems and People, 16*(1), 1-18.

Prakasam, C., Aravinth, R. and Kanwar, V. S. (2018). Land Use Land Cover Change Detection & Urban Sprawl Study: A Case Study on Shimla Tehsil, Himachal Pradesh, India. *Journal of Geography, Environment and Earth Science International*, *16*(1), 1-13.

Premlata, Kumar, R., Hajam, Y. A. and Giri, A. (2024). Threats, challenges, and conservation strategies of Himalayan Faunal Biodiversity. In *Role of Science and Technology for sustainable future: volume 1: Sustainable Development: a primary goal* (pp. 321-344). Singapore: Springer Nature Singapore.

Pandey, R. and Priya, M. A. (2021). Biodiversity Strategy and Action Plan (BSAP) of Sikkim and the Resource Mobilisation Strategy for implementing the BSAP with the focus on Khangchendzonga – Upper Teesta Valley. National Institute of Public Finance and Policy, New Delhi, India.

Parida, B. R., Kanu, B. and Dwivedi, C. S. (2024). Deciphering Forest Cover Losses and Recovery (1990–2022) Using Satellite Data in Behali Reserve Forest of Northeastern Himalaya. *Remote Sensing in Earth Systems Sciences*, *7*(1), 1-14.

Phartiyal, M. and Sharma, S. (2024). Comprehending drivers of land use land cover change from 1999 to 2021 in the Pithoragarh District, Kumaon Himalaya, Uttarakhand, India. *Journal of Mountain Science*, *21*(7), 2394-2407.

Potapov P., Hansen M.C., Pickens A., Hernandez-Serna A., Tyukavina A., Turubanova S., Zalles V., Li X., Khan A., Stolle F., Harris N., Song X. P., Baggett A., Kommareddy I. and Kommareddy A. (2022). The global 2000-2020 land cover and land use change dataset derived from the Landsat archive: first results. *Frontiers in Remote Sensing.*

Pullaiah, T. (2024). Biodiversity Hotspots. In *Biodiversity Hotspot of the Western Ghats and Sri Lanka* (pp. 1-4). Apple Academic Press.

Qadir, J. and Singh, P. (2019). Land use/cover mapping and assessing the impact of solid waste on water quality of Dal Lake catchment using remote sensing and GIS (Srinagar, India). *SN Applied Sciences*, *1*(1), 25.

Rabbi, M. F. and Kovács, S. (2024). Quantifying global warming potential variations from greenhouse gas emission sources in forest ecosystems. *Carbon Research*, *3*(1), 70.

Ralhan, D., Rodrigo, R., Keith, H., Stegehuis, A. I., Pavlin, J., Jiang, Y. and Svoboda, M. (2024). Tree structure and diversity shape the biomass of primary temperate mountain forests. *Forest Ecosystems*, *11*, 100215.

Romero, F. M. B., de Nazaré Oliveira Novais, T., Jacovine, L. A. G., Bezerra, E. B., de Castro Lopes, R. B., de Holanda, J. S. and Fearnside, P. M. (2024). *Wood Basic Density in Large Trees: Impacts on Biomass Estimates in the Southwestern Brazilian Amazon. Forests 2024; 15, 734*.

Ruas, R. D. B., de Godoy, S. M., Feliciano, D. C., Ruas, C. D. F. and Bered, F. (2024). A bromeliad living in the city: a case of a native species resilient to urbanization in South Brazil. *Botanical Journal of the Linnean Society*, *205*(2), 161-176.

Reyers, B. and Selig, E. R. (2020). Global targets that reveal the social-ecological interdependencies of sustainable development. *Nat. Ecol. Evol.*, *4*, 1011–1019.

Roberts, J. J., Fausch, K. D., Schmidt, T. S. and Walters, D. M. (2017). Thermal regimes of Rocky Mountain lakes warm with climate change. *PLoS One*, *12*(7), p. e0179498.

Rai, Mohit Singh (2017). Impact of Urbanization on Environment. *International Journal on Emerging Technologies*, *8*(1), 127-129.

Rai, S. C. and Sharma, E. (1995). Land-use change and resource degradation in Sikkim Himalaya: a case study from the Mamlay watershed. Sustainable reconstruction of highland and headwater regions Proceedings *of Third International Symposium on Headwater Control*, New Delhi, India, 265-278

Rai, S. and Singh, E. I. (2022). Urbanization and Solid Waste Management in Gangtok, Sikkim *J. Himalayan Ecol. Sustain. Dev.*, 1-17

Rao, K. S. and Pant, R. (2001). Land use dynamics and landscape change pattern in a typical micro watershed in the mid elevation zone of central Himalaya, India. *Agriculture, ecosystems & environment*, *86*(2), 113-124.

Roy, D., Aithal, B. H., Dhar, A. and Desai, V. R. (2024). Impact of land use/land cover change on future flash flood vulnerability and monsoon runoff in an ungauged Himalayan watershed. *Journal of Hydrologic Engineering*, *29*(3), 05024006.

Saleh, M., Ashqar, H. I., Alary, R., Bouchareb, E. M., Bouchareb, R., Dizge, N. and Balakrishnan, D. (2024). Biodiversity for ecosystem services and sustainable development goals. In *Biodiversity and Bioeconomy* (pp. 81-110). Elsevier.

Sala, O. E., Chapin, F. S. III., Armesto, J. J., Berlow, E., Bloomfield, J. and Dirzo, R. (2000). Biodiversity: Global biodiversity scenarios for the year 2100. *Science*, *287*, 1770–1774.

Simeon, M. and Wana, D. (2024). Impacts of Land use Land cover dynamics on Ecosystem services in maze national park and its environs, southwestern Ethiopia. *Heliyon*, *10*(9).

Sandor, M. E., Elphick, C. S. and Tingley, M. W. (2022). Extinction of biotic interactions due to habitat loss could accelerate the current biodiversity crisis. *Ecological Applications*, *32*(6), e2608.

Seto, K. C., Güneralp, B. and Hutyra, L. R. (2012).Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences*, *109*(40), 16083-16088.

Singh, E. I. and Singha, A. (2024). Climate Change and Forest Fire in Eastern Himalaya: A Case Study of Sikkim and Darjeeling Himalayas of West Bengal. In *Climate Change, Vulnerabilities and Adaptation: Understanding and Addressing Threats with Insights for Policy and Practice* (pp. 215-230). Cham: Springer Nature Switzerland

Singh, J. S. and Chaturvedi, R. K. (2017). Influence of Biotic Pressure and Land-Use Changes. In: *Tropical Dry Deciduous Forest: Research Trends and Emerging Features* (pp. 149-189). Springer, Singapore.

Singh, P., Kala, R., Bhavsar, D., Roy, A., & Karnatak, H. (2024). Urban explosion and hotspots of forest loss in western Himalaya: Mapping land use/cover change trends since 1975. *Advances in Space Research*, *74*(3), 1238-1252.

Sodhi, N. S. and Brook, B. W. (2006). *Southeast Asian biodiversity in crisis*. Cambridge University Press.

Sandra, Lavorel, Fabien, Quétier, Aurélie, Thébault, Pierre, Liancourt, Sophie, Daigney, Ian, D., Davies, Jacqui, de, Chazal (2006). Vulnerability to land use change of services provided by alpine landscapes. Sapiens Publishing\A5150 - Global Change in Mountain Regions\Makeup\A5150 - Global Change Mountains 1-3

Sohail, J. S. and Kaushal, A. (2023). Analyzing Land Use and Land Cover Changes using Geospatial Techniques, A Review. *Biological Forum – An International Journal*, *15*(10), 164-168

Seto, K. C., Güeneralp, B. and Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proc. Natl. Acad. Sci.* U.S.A. *109,* 16083–16088.

Sharma, S., Joshi, V. and Chhetri, R. K. (2014). Forest fire as a potential environmental threat in recent years in Sikkim, Eastern Himalayas, India. *Climate Change and Environmental Sustainability*, *2*(1), 55-61.

Sharma S., Pradhan, G. and Dahal, D. R. (2010). Observations on vegetations richness over a gradient along the Gangtok-Deorali ridge in Sikkim", *Journal of Hill Research*, Sikkim Science Society, Gangtok. *23*(1 & 2), 28-30.

Sikkim Biodiversity Conservation and Forest Management Project (SBFP) (2012). *Biodiversity – All Creatures Great and Small.* Department of Forest, Environment and Wildlife Management, Government of Sikkim.PP.23.

SoER (2016). State of Environment Report Sikkim – 2016. An ENVIS Sikkim 2017-18 Publication, Forests, Environment & Wildlife Management Department, Government of Sikkim

Sharma, E., Bhuchar, S., Ma, X. and Kothyari, B. P. (2007). Land use change and its impact on hydro-ecological linkages in Himalayan watersheds. *Tropical Ecology*, *48*(2), 151-161.

Sharma, K. and Thapa, G. (2021). Analysis and interpretation of forest fire data of Sikkim. *Forest and Society*, *5*(2), 261-276.

Schirpke, U., Kohler, M., Leitinger, G., Fontana, V., Tasser, E. and Tappeiner, U. (2017). Future impacts of changing land-use and climate on ecosystem services of mountain grassland and their resilience. *Ecosystem services*, *26*, pp.79-94.

Skiles, S. M., Flanner, M., Cook, J. M., Dumont, M. and Painter, T. H. (2018). Radiative forcing by light-absorbing particles in snow. *Nature Climate Change*, *8*(11), 964-971.

Starkel, L. and Sarkar, S. (2014). The Sikkim-Darjeeling Himalaya: landforms, evolutionary history and present-day processes. Landscapes and landforms of India, 157-164.

Stewart, I. T. (2009). Changes in snowpack and snowmelt runoff for key mountain regions. *Hydrological Processes: An International Journal*, *23*(1), 78-94.

Slemmons, K. E., Saros, J. E. and Simon, K. (2013). The influence of glacial meltwater on alpine aquatic ecosystems: a review. *Environmental Science: Processes & Impacts*, *15*(10), pp.1794-1806.

Styers, D. M., Chappelka, A. H., Marzen, L. J. and Somers, G. L. (2010). Developing a land-cover classification to select indicators of forest ecosystem health in a rapidly urbanizing landscape. *Landscape and Urban Planning*, *94*(3-4), 158-165.

Sidemo-Holm, W., Ekroos, J., Reina García, S., Söderström, B. and Hedblom, M. (2022). Urbanization causes biotic homogenization of woodland bird communities at multiple spatial scales. *Global Change Biology*, *28*(21), 6152-6164.

Sun, B., Lu, Y., Yang, Y., Yu, M., Yuan, J., Yu, R. and Li, J. (2022). Urbanization affects spatial variation and species similarity of bird diversity distribution. *Science Advances*, *8*(49), eade3061.

Sun, C., Hou, H. and Chen, W. (2021). Effects of vegetation cover and slope on soil erosion in the Eastern Chinese Loess Plateau under different rainfall regimes. *Peer J.*, *9*, e11226.

Tan, Z., Chen, X., Wang, Y., Wang, S., Wang, R., Yao, B., and Qu, J. (2024). The impact of the Qinghai-Tibet highway on plant community and diversity. *Frontiers in Plant Science*, *15*, 1392924.

Theobald, D. M., Crooks, K. R. and Norman, J. B. (2011). Assessing effects of land use on landscape connectivity: loss and fragmentation of western US forests. *Ecological Applications*, *21*(7), 2445-2458.

Tonleu, J., Tsafack, N., Bobo, K. S., Lhoumeau, S., Lontchi, W. G., Tanebang, C. L. and Mbida, M. (2024). Understorey-nesting bird community responses to land use in the Korup National Park, an Afrotropical rainforest in South-Western Cameroon. *Acta Oecologica*, *125*, 104040.

Tiwari, P. C. (2000). Land-use changes in Himalaya and their impact on the plains ecosystem: need for sustainable land use. *Land use policy*, *17*(2), 101-111.

Tiwari, P. C., Tiwari, A. and Joshi, B. (2018). Urban growth in Himalaya: understanding the process and options for sustainable development. *Journal of Urban and Regional Studies on Contemporary India*, *4*(2), 15-27.

Tiwari, P. (2008). Land use changes in Himalaya and their impacts on environment, society and economy: A study of the Lake Region in Kumaon Himalaya, India. *Advances in Atmospheric Sciences*, *25*, 1029-1042.

Tian, L., Tao, Y., Fu, W., Li, T., Ren, F. and Li, M. (2022). Dynamic simulation of land use/cover change and assessment of forest ecosystem carbon storage under climate change scenarios in Guangdong Province, China. *Remote Sensing*, *14*(10), 2330.

Turner, B., Meyer, W. B. and Skole, D. L. (1994). Global land-use/land-cover change: towards an integrated study. *Ambio. Stockholm*, *23*(1), 91-95.

Tulloch, A. I., Barnes, M. D., Ringma, J., Fuller, R. A. and Watson, J. E. (2016). Understanding the importance of small patches of habitat for conservation. *Journal of applied Ecology*, *53*(2), pp.418-429.

Uttara, S., Bhuvandas, N. and Aggarwal, V. (2012). Impacts of urbanization on environment. *International Journal of Research in Engineering and Applied Sciences*, *2*(2), 1637-1645.

Vitousek, P. M. Mooney, H. A., Lubchenko, J. and Mellilo, J. M. (1997). Human domination of Earth's ecosystems. *Science*, *277*, 494–499.

Wang, K., Li, Z., Zhang, J., Wu, X., Jia, M. and Wu, L. (2020). Built-up land expansion and its impacts on optimizing green infrastructure networks in a resource-dependent city. *Sustainable Cities and Society*, *55*, 102026.

Xu, H. (2024). Sustainable forest ecosystem management. *Open Science Journal*, *9*(1).

Yang, Y. (2021). Evolution of habitat quality and association with land-use changes in mountainous areas: A case study of the Taihang Mountains in Hebei Province, China. *Ecological Indicators, 129,* 107967.

Yan, H., Sun, N., Fullerton, A. and Baerwalde, M. (2021). Greater vulnerability of snowmelt-fed river thermal regimes to a warming climate. *Environmental Research Letters*, *16*(5), p.054006.

Zambrano, J., Garzon-Lopez, C. X., Yeager, L., Fortunel, C., Cordeiro, N. J. and Beckman, N. G. (2019). The effects of habitat loss and fragmentation on plant functional traits and functional diversity: what do we know so far?. *Oecologia*, *191*(3), 505-518.

Zhang, J., Lu, X., Qin, Y., Zhang, Y. and Yang, D. (2024). Can Urbanization-Driven Land-Use and Land-Cover Change Reduce Ecosystem Services? A Case of Coupling Coordination Relationship for Contiguous Poverty Areas in China. *Land*, *13*(1), 82.

Zhou, Y., Varquez, A. C. and Kanda, M. (2019). High-resolution global urban growth projection based on multiple applications of the SLEUTH urban growth model. *Scientific data*, *6*(1), 34.

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