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Change in Bhutan's Land Use and Land Cover from 1930 - 2020

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ABSTRACT

The land is a fundamental component of Bhutan's geographical makeup, characterized by natural features and human activities. Bhutan's land can be divided into land use and land cover (LULC), where human activities contribute to land use, and natural elements define land cover. This paper analyzes Bhutan's LULC patterns, emphasizing the evolving trends in major LULC types, strengths and challenges of sustainable land use management, and envisioning its future trajectory. In recent years, Bhutan's land-use pattern has displayed a predominant forest cover, encompassing a significant portion of the total land area. Similarly, the built-up area in Bhutan is gradually increasing, reflecting the country's ongoing urbanization and development activities. A long-term analysis reveals dynamic shifts in agricultural land in Bhutan. While there has been a historical expansion of agricultural areas, recent trends may suggest a potential slowdown or decline, influenced by factors such as urban growth and changing economic landscapes. Like community forestry practices in Bhutan, successful conservation efforts may also influence land-use changes. In the eastern Himalayas, Bhutan faces challenges related to snow/glacial cover impacted by climate change. Increasing temperatures in the region contribute to alterations in snow/glacial patterns, necessitating a focus on environmental conservation and sustainable practices to preserve these vital resources. The land tenure system and land use policies in Bhutan have evolved and been shaped by socioeconomic and political dynamics. Bhutan needs to adapt and formulate effective policies to address contemporary challenges and promote sustainable LULC management. Implementing specific LULC zones, as outlined in Bhutan's land use policies, is crucial for ensuring sustainable land management practices.

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1. INTRODUCTION

Bhutan is situated in the eastern Himalayas, spanning approximately between latitudes 26° 41' 52" N to 28° 14' 52" N and longitudes 88° 44' 54" E to 92° 41' 7" E, and has a total surface area of 38,394 sq km and is the only country where the constitution mandates it to keep 60% of land under forest cover for all times to come [1]. The country is home to 11,248 species, of which 1.20% (136) are globally threatened [2]. Land is vital in Bhutan

because it represents livelihoods, dignity, and emotional connections. In an era where farming is the norm, land is a safe asset, a source of financial capital, and an object of emotional reverence [3]. The land has become an increasingly valuable asset due to urbanization, especially in the capital [4]. The government of Bhutan is adamant that every household own at least five acres, following the notion that land is essential for survival. There are two sorts of land: government and private. The King is the only person with the authority to transfer government land into private ownership. *Kidu*, a royal gesture, involves land awards, emphasizing the monarch's central role in shaping land ownership [5].

The land is one of the necessary components to continue human life. The land can be changed by natural and anthropogenic factors, broadly called land use and land cover change [6], [7]. The pattern of land use and land cover (LULC) change can be attributed, direct and indirect, to the interaction between human activities and environmental factors [8], [9]. While land use relates to how people utilize and interact with the land, land cover refers to the land types on Earth's surface [10]. The LULC at a global, regional, and local label is changing on a different scale for the long term [9]. The land cover change assessment provides information related to the past and present situation, and it can also help predict future trends necessary for policy interventions and plans for proper management of natural resources [3].

Table 1. Land Use and Land Cover of Bhutan from 1930 to 2020

LULC Type	1930	1977	1987	1995	2005	2010	2016	2020
	Total area (Km sq.)	Total area (Km sq.)	Total area (Km sq.)	Total area (Km sq.)	Total area (Km sq.)	Total area (Km sq.)	Total area (Km sq.)	Total area (Km sq.)
Forest	26,895.9	26,269.4	26,313.1	26,140.6	26,136.5	27,052.9	27,171.6	26,414.3
Shrubs	-	-	-	-	-	4,005.26	3,740.32	1,576.40
Snow cover	-	4,023.80	4,652.60	4,094.30	4,728.70	2,854.79	2,053.43	1,852.95
Meadows	-	1,631.50	1,424.20	1,823.50	1,505.00	1,575.69	962.73	1,685.34
Bare areas	-	2,262.30	1,698.00	1,702.20	1,694.30	1,229.74	1,594.55	1,948.79
Agricultural land	-	1,433.60	1708.80	1756.80	1756.80	1125.55	1056.82	1137.92
Water bodies	-	120.80	108.10	116.10	116.10	275.69	251.75	233.54
Degraded areas	-	-	-	-	-	206.36	181.24	26.42
Built-up	-	66.80	69.60	70.50	70.50	61.51	74.57	96.83
Non-built up	-	-	-	-	-	3.30	5.95	9.68
Marshy land	-	-	-	-	-	3.19	-	-
Alpine scrubs	-	2,585.70	2,419.70	2,690.00	2,386.00	-	1,300.97	3,411.81
Others	11,498.1	-	-	-	-	-	-	-
Total	**38,394**	**38,393.9**	**38,394.1**	**38,394**	**38,393.9**	**38,393.9**	**38,393.9**	**38,394**

Land Use and Land Cover Pattern

1.1 Forest

The study carried out by the Department of Forest and Park Services (DoFPS), Ministry of Energy and Natural Resources, Royal Government of Bhutan reported that forest cover made up 69.71% area of the total land area in Bhutan in 2022 [11], which is a decrease from 70.77 % in 2016 [12]. The analysis indicates that Zhemgang Dzongkhag has the highest proportion of forest cover, amounting to 94.5% of its entire area. Conversely, Gasa Dzongkhag exhibits very little forest coverage. Thimphu

Dzongkhag witnessed a decline in forest cover, from 40.0% in the previous 2016 assessment to 36.2%. This decrease can be ascribed to the developmental endeavors occurring in the nation [12].

Table 2. The Conversion Statistics of Major Land Use Between 1930 and 2020

LULC Type	1930 Total area (Km sq.)	1977 Total area (Km sq.)	1987 Total area (Km sq.)	Conversion between 1977 and 1987	1995 Total area (Km sq.)	Conversion between 1987 and 1995	2005 Total area (Km sq.)	Conversion between 1995 and 2005	2010 Total area (Km sq.)	Conversion between 2005 and 2010	2016 Total area (Km sq.)	Conversion between 2010 and 2016	2020 Total area (Km sq.)	Conversion between 2016 and 2020
Forest	26895.9	26269.4	26313.1	+ 43.7	26140.6	- 172.5	26136.5	- 4.1	27052.91	+ 916.41	27171.61	+ 118.7	26414.32	- 757.29
Shrubs				0		0		0	4005.26	+ 4005.26	3740.32	- 264.94	1576.4	- 2163.92
Snow cover		4023.8	4652.6	+ 628.8	4094.3	- 558.3	4728.7	+ 634.4	2854.79	- 1873.91	2053.43	- 801.36	1852.95	- 200.48
Meadows		1631.5	1424.2	- 207.3	1823.5	+ 399.3	1505	- 318.5	1575.69	+ 70.69	962.73	- 612.96	1685.34	+ 722.61
Bare areas		2262.3	1698	- 564.3	1702.2	+ 4.2	1694.3	- 7.9	1229.74	- 464.56	1594.55	+ 364.81	1948.79	+ 354.24
Agricultural land		1433.6	1708.8	+ 275.2	1756.8	+ 48	1756.8	0	1125.55	- 631.25	1056.82	- 68.73	1137.92	+ 81.1
Water bodies		120.8	108.1	- 12.7	116.1	+ 8	116.1	0	275.69	+ 159.59	251.75	- 23.94	233.54	- 18.21
Degraded areas				0		0		0	206.36	+ 206.36	181.24	- 25.12	26.42	- 154.82
Built-up		66.8	69.6	+ 2.8	70.5	+ 0.9	70.5	0	61.51	- 8.99	74.57	+ 13.06	96.83	+ 22.26
Non-built up				0		0		0	3.3	+ 3.3	5.95	+ 2.65	9.68	+ 3.73
Marshy land				0		0		0	3.19	+ 3.19		- 3.19		0
Alpine scrubs		2585.7	2419.7	- 166	2690	+ 270.3	2386	- 304		- 2386	1300.97	+ 1300.97	3411.81	+ 2110.84
Others	11498.1			0		0		0		0		0		0
Total	**38394**	**38393.9**	**38394.1**		**38394**		**38393.9**		**38393.99**		**38393.94**		**38394**	

2. METHODS

The research design adopts a retrospective approach to analyze changes in land use and cover in Bhutan from 1930 to 2020, employing a combined methodology integrating both quantitative and qualitative methods. Data sources are obtained through secondary data collection from historical maps, government documents, scientific literature, and previous surveys. Data analysis encompasses spatial analysis using geographic information systems (GIS) to map land use and land cover (LULC) changes spatially. Statistical analysis is conducted to identify trends, correlations, and comparisons among different types of LULC. Furthermore, predictive modeling and scenario planning are employed to anticipate future trends based on historical analysis and factors influencing LULC changes. Scenarios are constructed considering variables such as economic development, environmental policies, and urbanization to forecast potential future changes in land use and cover.

3. RESULTS AND DISCUSSION

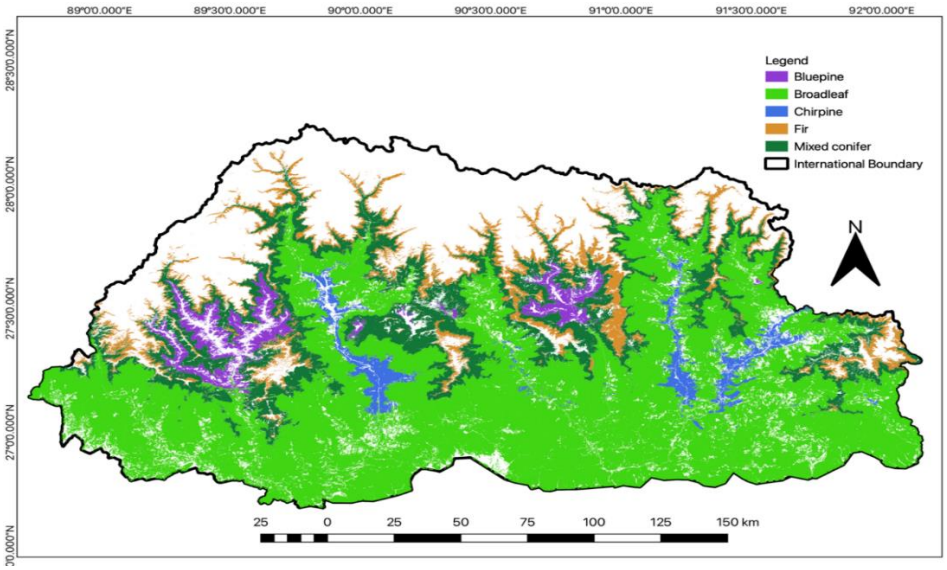

Figure 1. Forest Cover Map 2016

In Bhutan, the subtropical broad-leaved hill forest is the most common form, covering 34.1% of the total forest area. It is followed by the dry temperate forest, which covers 20.9% of the land; montane wet temperate forest, which covers 18.9%; moist temperate forest, which covers 10%; and moist Sal Forest, which covers 8.1% in 2014. The forest types that have experienced significant decline in the past forty years are the subtropical broad-leaved hill forest, which has decreased by 64.5 km^2, and the moist Sal Forest, which has decreased by 9.9 km^2. Increased forest growth and decreased forest destruction rates caused the changes in forest cover in Bhutan (Refer to Table 1 and 2 and Figure 1). These changes were especially significant in the broadleaf forest ecosystem of the low-elevation districts in the southern region of Bhutan in the years 1990, 2002, and 2011 [13], [14].

3.1 Agricultural Land

The land-use pattern of Bhutan shows that the total agricultural land was 1137.92 sq. km. (2.96%) in 2020 [15], which is a decrease from 1756.8 sq. km. (4.58%) in 2005 [14].

Bhutan has a limited cultivated area of 2.96% (Table 1), characterized by rugged mountainous terrain. Farming is primarily confined to river valleys, represented by small slope parcels (refer figure 2). The main land use categories are *Kamzhing* (dryland) (61.90%), *Chhuzhing* (terraced rice fields) (27.86%), and horticulture (10.24%).

Bhutanese farmers, typically smallholders with an average landholding of 1.4 ha, practice sustainable integrated and subsistence agricultural systems [16]. They engage in diverse crops, including rice, maize, and potatoes, using multiple farming practices such as agroforestry and livestock integration. This approach supports food and nutritional security but also aids in transitioning from subsistence to intensive farming. The farmers benefit from collecting and selling non-wood forest products, contributing to their livelihoods. The Department of Forests and Park Services also supports private and community forests, with farmers managing 600 and 627 private forests. These practices contribute to sustainable forestry resource management, offering income and employment opportunities to rural communities [16].

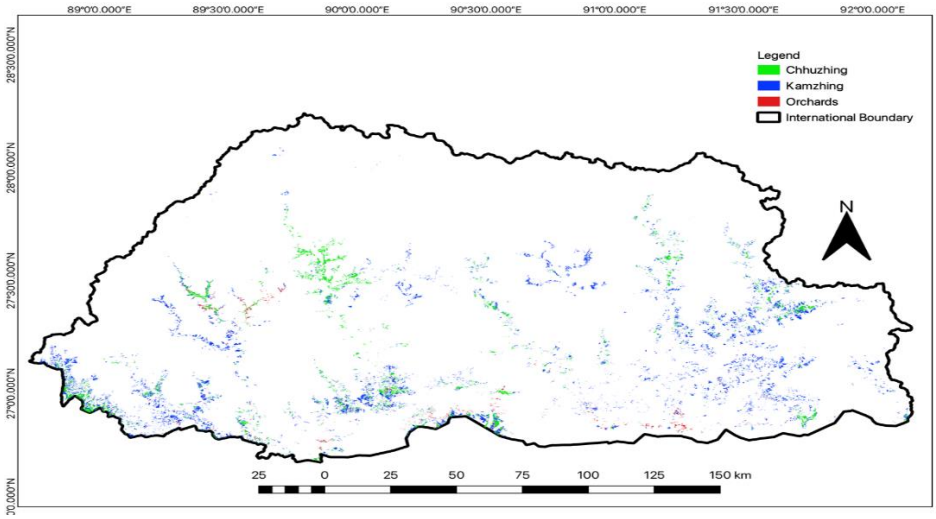

Figure 2. Agriculture Land Cover Map 2016

The data about agricultural land indicates a dynamic pattern of changes over the decades. From 1433.60 Km sq. in 1977 to peaks of 1756.80 Km sq. in 1995 and 2005, followed by a decline to 1056.82 Km sq. in 2016 and a slight rebound to 1137.92 Km sq. in 2020, the trends in agricultural land exhibit fluctuations (Refer table 1 and 2). This decline, particularly between 2005 and 2016, suggests potential challenges for agricultural activities, possibly influenced by urbanization or land-use policy shifts. The inverse relationship between the decrease in agricultural land and the simultaneous increase in built-up areas underscores the impact of urbanization on agricultural spaces. Policymakers must consider these trends when formulating strategies to balance urban development with the preservation of agricultural resources, ensuring sustainable land-use practices for long-term economic and environmental stability.

3.2 Snow/Water Bodies

Snow and water bodies covered 5.43% (2086.49 sq. km.) of Bhutan's total land in 2020; out of this area, 0.61% was covered by water bodies, and snow and glaciers covered 4.83% of the land area [3] (refer table 1). However, in 1977, the snow and water bodies covered 12.4% (4760.70 sq. km.) of Bhutan's total land [14]. The difference in 2020 and 1977 could be because of the change in boundaries, the use of improved land cover assessment methods in LCMP 2010, the difference in land cover due to snowfall, and the under-classification of land cover [11]. The snow-covered land is primarily found in the northern part of the country and feeds the river system in Bhutan (see Figure 3).

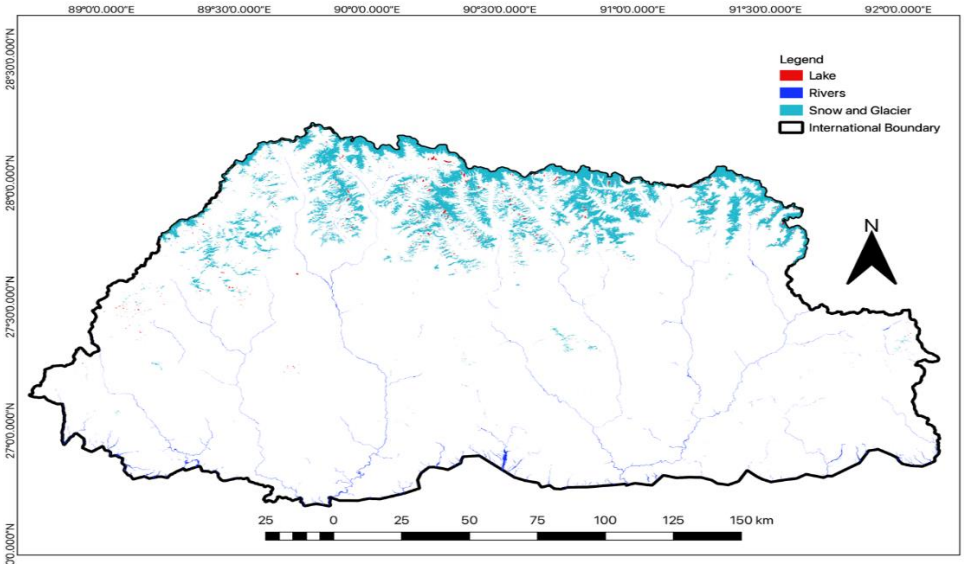

Figure 3. Snow/Water Bodies Cover Map 2016

The data on water bodies and snow cover reveals distinctive patterns in land cover dynamics. Water bodies, represented by an increase from 120.80 Km sq. in 1930 to 233.54 Km sq. in 2020, suggest changes in hydrological features over the years (refer table 2). The fluctuations in water bodies might be influenced by factors such as climate variations, land-use changes, or water management practices [18]. On the other hand, snow cover shows a fluctuating trend, with peaks at 4728.70 Km sq. in 2005 and a subsequent decline to 1852.95 Km sq. in 2020. This dynamic pattern reflects the sensitivity of snow cover to climate conditions and underscores potential implications for water resources and regional climate [17]. Both water bodies and snow cover data are essential for understanding the broader environmental context, influencing ecological processes, and informing water resource management strategies. These insights are crucial for sustainable land-use planning, climate adaptation, and preserving vital water resources [18].

3.3 Built-up Areas

The dataset consistently increased built-up areas from 66.80 Km sq. in 1930 to 96.83 Km sq. in 2020. The substantial rise observed between 2005 and 2010 indicates a rapid urbanization phase (see Table 1 and Figure 4). The incremental growth in built-up areas across these decades reflects a persistent trend of urban development. Additionally, it's crucial to observe this trend in conjunction with changes in other land-use categories. The decrease in meadows and shrubs coincides with the ascent in built-up areas, suggesting a possible conversion of natural landscapes to urban spaces. This spatial transformation highlights the trade-offs between urban expansion and ecological preservation. The data showcases the dynamic nature of land use, with built-up areas increasing over time, possibly driven by population growth and economic activities [19]. This detailed data analysis provides insights into the evolving landscape, serving as a foundation for informed decision-making in urban planning and environmental management (refer to Table 2).

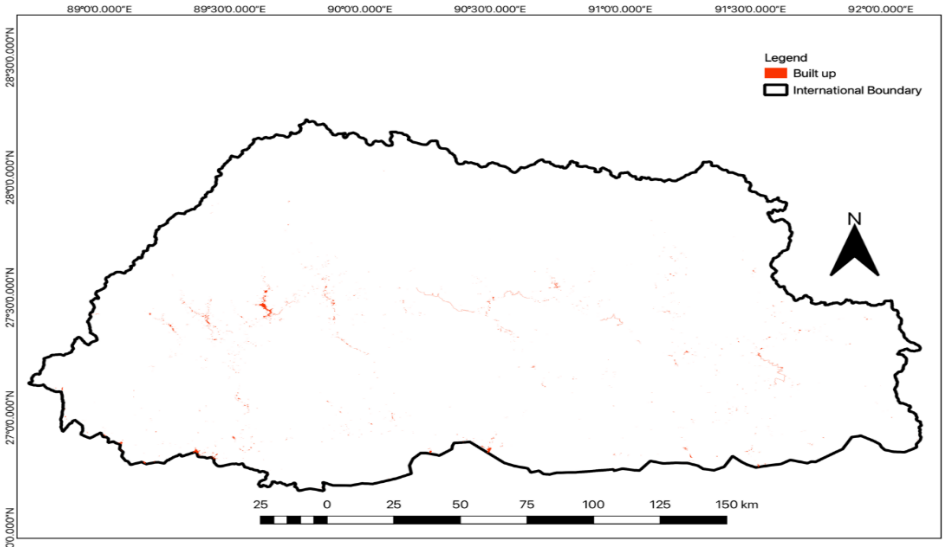

Figure 4. Built-up Areas Map 2016

3.4 Alpine Scrubs

The data regarding Alpine Scrubs unveils notable shifts in land cover, emphasizing the ecological changes in high-altitude regions. From 2585.70 Km sq. in 1977 to 3411.81 Km sq. in 2016, Alpine Scrubs have exhibited variations over the years (refer to Table 1). This increase may indicate changes in vegetation patterns, possibly influenced by climate factors or land-use alterations. The absence of data for 2005 and the subsequent decline in 2020 to 2386.00 Km sq. suggest a certain level of ecological variability in these alpine ecosystems (refer to Table 2 and Figure 5). The fluctuations underscore the vulnerability of high-altitude habitats to environmental changes and warrant attention for conservation efforts. Understanding these dynamics is crucial for preserving biodiversity in alpine regions, which are often sensitive to climatic shifts and human activities [3]. Policymakers and environmentalists can use this data to inform conservation strategies and ensure the sustainable management of these unique and fragile ecosystems.

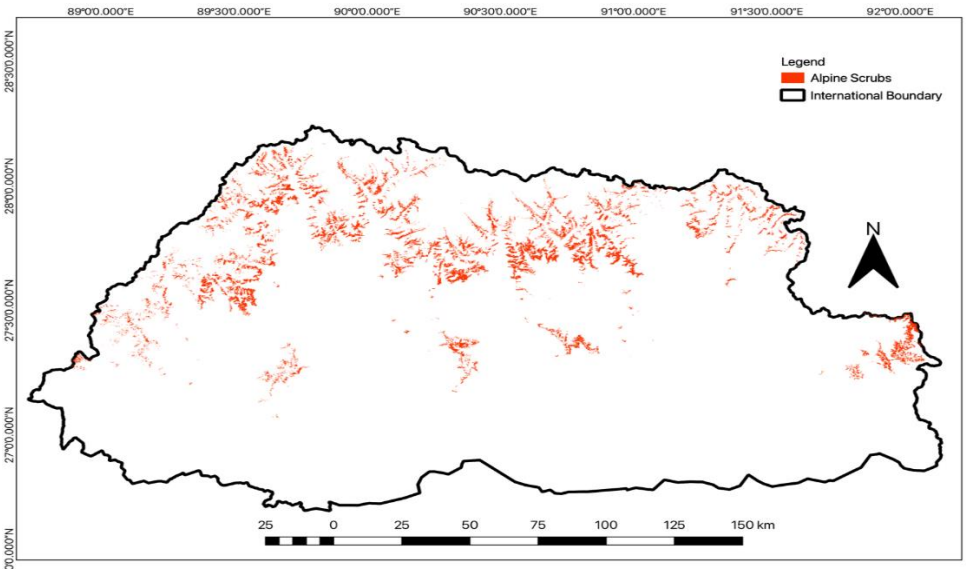

Figure 5. Alpine Scrubs Map 2016

3.5 Others

The data on shrubs, meadows, bare areas, degraded areas, non-built-up land, and marshy land collectively provide insights into diverse land cover categories. Shrubs notably decreased from 4005.26 Km sq. in 1987 to 1576.40 Km sq. in 2010, suggesting potential changes in vegetation patterns (refer to Figure 6 and Table 1). Meadows, conversely, display variations, with a decrease from 1631.50 Km sq. in 1977 to 962.73 Km sq. in 2010, followed by an increase to 1685.34 Km sq. in 2016 (refer to Table 1 and Figure 7).

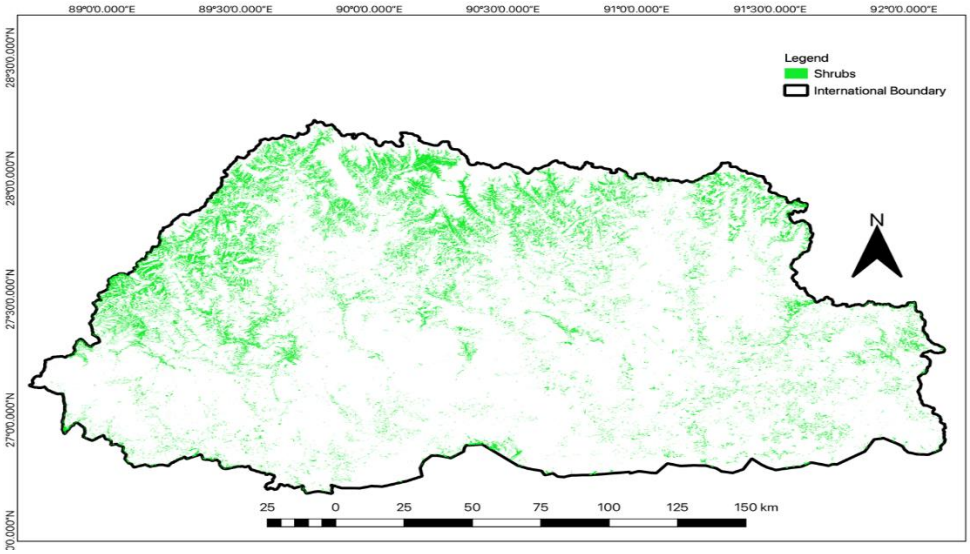

Figure 6. Shrubs Map 2016

Bare areas show a declining trend from 2262.30 Km sq. in 1977 to 1229.74 Km sq. in 2010, followed by a subsequent increase to 1948.79 Km sq. in 2016. Degraded areas show a decline from 206.36 Km sq. in 2005 to 26.42 Km sq. in 2016, indicating potential land restoration efforts. Non-built-up land increased from 3.30 Km sq. in 2005 to 9.68 Km sq. in 2016, suggesting a focus on preserving non-urbanized spaces. Marshy land, while having limited data, points to a presence of 3.19 Km sq (refer to Table 2). The intricate dynamics of these land cover categories highlight the complex interplay between natural and anthropogenic factors, emphasizing the need for nuanced land-use management strategies that consider ecological diversity and sustainability.

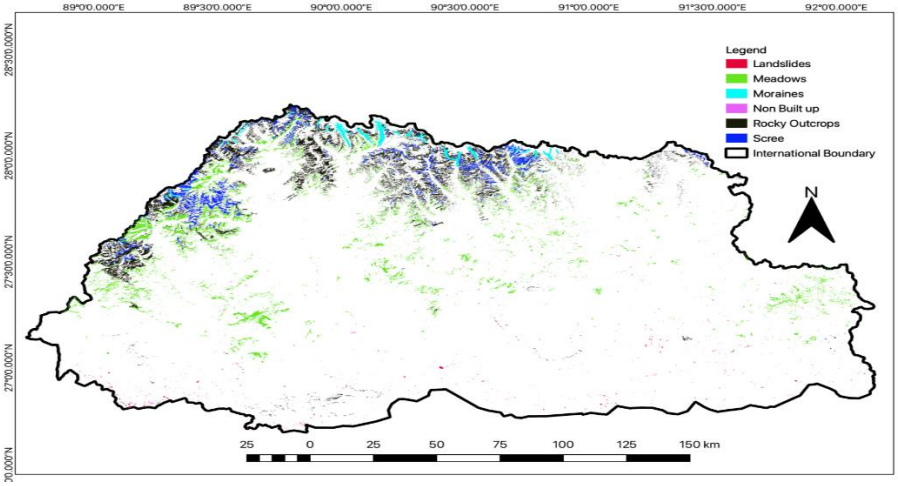

Figure 7. Other Land Cover Map 2016

4. CONCLUSION

Dynamic shifts are revealed in Bhutan's Land Use and Land Cover (LULC) research from 1930 to 2020. Development was a major factor in the forest cover's small decline from 70.77 percent in 2016 to 69.71 percent in 2022, particularly in Thimphu Dzongkhag. The amount of agricultural land varied, falling from 1756.80 square kilometers in 2005 to 1056.82 square kilometers in 2016, suggesting possible problems brought on by urbanization. The increase in built-up areas, particularly from 2005 to 2010, indicates a significant urbanization process that affects shrubs and meadows. The need for protection is shown by changes in Alpine Scrubs, which show ecological heterogeneity at high altitudes. Variations in snow cover and water bodies point to the impact of changing land uses and climate, necessitating adaptive management of water resources. Various types of land cover indicate intricate dynamics, necessitating sophisticated land-use plans. Bhutan prioritizes environmental preservation and sustainability while addressing the effects of climate change on snow and glacial cover. The necessity for adaptable measures is reflected in the evolving land tenure systems. The complex interactions between natural and human effects are highlighted by Bhutan's LULC patterns, underscoring the need for well-informed policies for sustainable land management and preserving the country's distinctive landscapes.

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