

## **An Overview of Biodiversity in Bhutan**

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### **Author's contribution**

*The sole author designed, analyzed, interpreted and prepared the manuscript.*

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## **ABSTRACT**

Bhutan is included in the Eastern Himalayan biodiversity hotspot. Because the country's total forest cover surpasses 70%, the exclusive hotspot is a paradise for rich biological diversity. Some of the world's most endangered species can be found in Bhutan's five national parks, four wildlife sanctuaries, one strict nature reserve, a network of biological corridors, and even outside the Protected Areas. The country's documentation of its rich flora and fauna is in the early stage, and to document the biological diversity in Bhutan, more research needs to be carried out. Bhutan's biodiversity faces a major threat from anthropogenic activities and climate change.

*Keywords: Agriculture; agro-ecological; biodiversity; fauna; flora.*

## **1. INTRODUCTION**

Bhutan is a small landlocked country with a population of 735,553 [1] people and an area of 38,394 km<sup>2</sup> [2]. Bhutan is a mountainous country in the eastern Himalayas, with the Himalayan mountain range encompassing the whole country's landmass. It offers a unique collection of extremely varied habitats and considerable biodiversity within a small geographical area and

mountains, steep gorges, river valleys, and flatlands. Bhutan's 38,394 square kilometers make up less than 0.0075 percent of the world's surface, but it is home to a disproportionately diverse range of plants and animals. Over 3.02 % of pteridophytes and 1.47 % of bryophytes are found in forests. Similarly, the country is home to 1.99 % of mammals, 7.07 % of birds, and 4.29 % of the world's butterfly fauna (Table 1). Bhutan's diverse biodiversity results from the country's

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unusual geographic location, climate, and conservation effort of the Royal Government of Bhutan, as the constitution has mandated 60 percent of land under forest cover for all times to come. Bhutan's arable land resource is limited due to rough and steep mountain terrain, wide areas of snow and barren rocks, and enormous forestland [3]. Currently, forests cover 71 % of the country's land area [4,5]. This forest region, which comprises several types of vegetation, must cover at least 60 % of the national territory in all times to come, as mandated by the constitution of the Kingdom of Bhutan [6,7]. Most of Bhutan's arable land is in the central valleys and southern foothills, where agriculture competes with other development activities for a population rising at 1.3 % each year [1]. On average, each household has 3.48 acres of arable land, while more than 60 % of all families have less than 3 acres. As a result, most farmers are small-scale subsistence farmers who produce for their survival. The majority of these arable lands (up to 70 %) are on steep slopes and are cultivated without soil conservation measures. As a result, these fertile areas are susceptible to various types of land degradation, jeopardizing the livelihoods of around 57 % [3] of the people who rely on agriculture.

Bhutan is one of the top ten countries globally for species diversity (species richness per unit area) and one of the top ten worldwide hotspots [8]. Compared to any other Asian country, it has the highest percentage of land covered by protected areas and the highest proportion of forest cover [9]. Many ecologists conclude that Bhutan is the last best hope for biodiversity protection in the Eastern Himalayas, a region of essential importance to world biodiversity [10,11]. Bhutan stands out among developing countries because it has set aside 51.4 percent of its land area for national parks, wildlife sanctuaries, strict nature reserves, and a network of biological corridors, although it is relying on loans to supplement its financial resources for development [12,13]. Bhutan's incredibly diverse flora comprises various components: In tropical and sub-tropical evergreen and semi-evergreen forests, Southeast Asian-Malesian components are common. Himalayan-Chinese elements make up the majority of temperate and sub-alpine vegetation, including western Himalayan, eastern

Himalayan, and pan-Himalayan species. Traditional Tibetan species grow in the northwest of Bhutan, but certain plant species in the alpine zone have Euro-Siberian and Arctic-alpine affinities [14]. Bhutan's high regional biodiversity is partly attributed to the Himalayas' evolutionary history, which resulted from the Deccan Plateau's upward migration into the Eurasian continent during the early Tertiary period [15]. As a result, both Indian and Malesian sources have left a rich legacy of floristic and faunal features [16]. The Indo-Malayan, Indo-Chinese, Sino-Malayan, East Asiatic floras, and many Gondwanan relics can all be found in the eastern Himalayas [17].

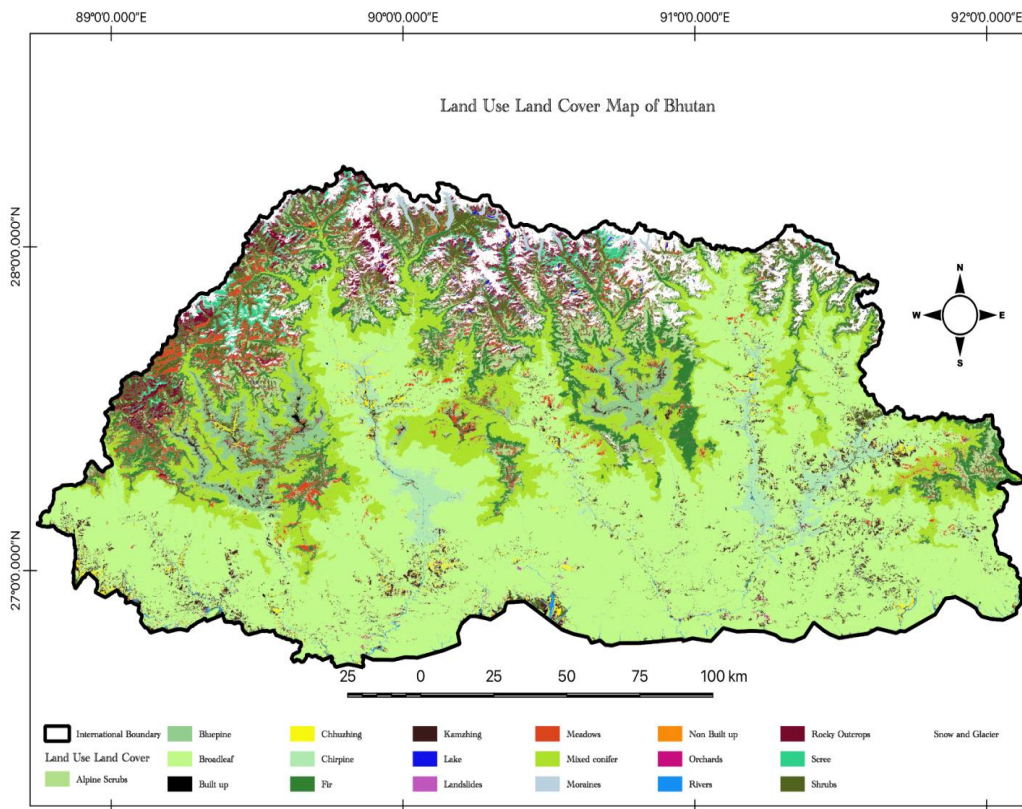
In the alpine zone of Bhutan, more than 300 species are used in Chinese and Tibetan traditional medicine for therapeutic purposes, resulting in almost 200 different traditional medicines [26,27,28,29]. Many of these drugs have been standardized by the National Institute of Traditional Medicine Services and are now available in traditional medicine clinics around the country. In addition, a variety of herbal items are marketed and exported. The country has made it into the twenty-first century with much of its biodiversity and natural environment intact, thanks to the wise leadership of kings, nature-reverent religious principles, rough terrain, low population pressure, gradual modernization, and environmentally sound development plans [30,31,32,33]. However, recent modifications in the road and hydroelectric infrastructure highlight the urgent need for a more comprehensive baseline evaluation of the country's biodiversity [34,35]. According to forest surveys conducted by the Ministry of Agriculture and Forests in 2017, 71 % of the country was covered in forests [36].

The vegetation types found in Bhutan are Dry Alpine Scrub (4,000 - 4,600 masl), Juniper / Rhododendron Scrub (3,700 to 4,200 masl), Fir Forest (2,800 - 3,300/3,800 masl), Hemlock Forest (2,800 - 3,100/3,300 masl), Spruce Forest (2,700 - 3,100/3,200 masl), Blue Pine Forest (2,100 - 3,000 masl), Evergreen / Oak Forest (1,800 - 2,000 masl), Cool Broadleaf Forest (2,000 - 2,900 masl), Chir Pine Forest (900 - 1,800 masl), Warm Broadleaf Forest (1,000 - 2,000 masl), and Sub-tropical Forest (200 - 1,000 masl) [4].

**Table 1. Faunal diversity: number of species in Bhutan as a % of global numbers (data until 2017)**

Faunal group	Global numbers	No. of species	Bhutan
			Bhutan/global * 100 (%)
Spiders	40,462 <sup>a</sup>	155 <sup>b</sup>	0.38
Moths	160,000 <sup>c</sup>	1,115 <sup>b</sup>	0.70
Fish	33,230 <sup>d</sup>	125 <sup>b</sup>	0.38
Butterflies	17,500 <sup>c</sup>	750 <sup>b</sup>	4.29
Amphibians and Reptiles	11,750 <sup>e</sup>	158 <sup>b</sup>	1.34
Birds	10,625 <sup>f</sup>	752 <sup>b</sup>	7.07
Mammals	6,495 <sup>h</sup>	129 <sup>b,g</sup>	1.99

Source: <sup>a</sup>Sharma [18]; <sup>b</sup>NBC [19]; <sup>c</sup>Smithsonian Institution [20]; <sup>d</sup>FishBase [21]; <sup>e</sup>Halliday [22]; <sup>f</sup>[23]; <sup>g</sup>Manita & Nepal [24]; <sup>h</sup>Burgin et al. [25]



**Fig. 1. Land use and land cover map of Bhutan**

## 2. AGRO-ECOLOGICAL ZONES OF BHUTAN

The country is divided into three climate zones: alpine in the northern mountains, temperate in the central valleys and inner hills, and sub-tropical in the southern foothills [37,38]. Summers in the southern foothills are hot and humid and have cool winters. Summers are hot, and winter is cold in the middle and inner hills,

although spring and autumn are nice. The alpine highlands are chilly all year, with lengthy, severe winters that make crop cultivation extremely difficult. Climate, geography, and altitude all play a role in determining land use, farming systems, crops grown, opportunities, and obstacles in agriculture. The country is organized into six major agro-ecological zones for agricultural planning, each with its altitudinal range and climatic circumstances (Table 2).

**Table 2. Major Agro-ecological zones of Bhutan**

Agro-ecological Zones	Elevation (meter above sea level)	Temperature (degree Celcius)			Rainfall (mm/yr)
		Monthly Min.	Monthly Max.	Annual Mean	
Wet Sub-tropical	150 - 600	11.6	34.6	23.6	2,500 - 5,500
Humid Sub-tropical	600 - 1,200	4.6	33	19.5	1,200 - 2,500
Dry Sub-tropical	1,200 - 1800	3	28.7	17.2	850 - 1,200
Warm Temperate	1,800 - 2,600	0.1	26.3	12.5	650 - 850
Cool Temperate	2,600 - 3,600	0.1	22.3	9.9	650 - 850
Alpine	3,600 - 4,600	-0.9	12	5.5	<650

Sources: Ministry of Agriculture and Forests [39]; Pulami [40]; Katwal & Bazile [41]



**Fig. 2. *Abies densa* forest in Trongsa, Bhutan. (Photo: Author)**

The northern region's alpine zone is characterized by alpine meadows and is too high to grow food crops. Livestock farming is the most typical mode of life in the cool temperate zone, with some dryland farming thrown in for good measure. Wheat, potato, buckwheat, mustard, and barley are farmed. Agriculture is frequently conducted in terraced irrigated wetlands and drylands in the warm temperate zone, with moderately warm temperatures until winter, when frost occurs. Rice is the principal crop in wetland agricultural areas, and it is rotated with wheat,

potato, seasonal fodder, and a variety of vegetables [42]. The dry subtropical zone is warm, with moderate rainfall, allowing a larger range of crops to be grown. Rice, maize, mustard, barley, legumes, and vegetables are all grown. The humid subtropical zone has a higher rainfall and temperature than the dry subtropical zone. Rice is the most common crop is grown in terraced irrigated wetland agricultural areas, followed by wheat and mustard. The main revenue crops are citrus (mandarin orange) farms at lower elevations and cardamom at



higher elevations. Maize, millet, mustard, many types of legumes, ginger, and vegetables are the most common crops in the sloppy dryland agricultural areas. The agroecological parameters in the wet subtropical zone support intensive subsistence agriculture through various forms of multiple cropping. Summer rice is the principal crop, cycled with wheat and maize in the winter, depending on irrigation [43]. Most irrigation supplies are rain-fed, and they dry up throughout the winter months. Although large-scale winter cropping is technically viable, it is rarely done due to water scarcity. Maize and various millets are the principal crops in dryland agricultural areas, and they are rotated with a variety of legumes, mustard, niger, millet, tuber crops, and vegetables [43].

### **3. PROTECTED AREAS AND BIOLOGICAL CORRIDORS**

A severe loss of biodiversity habitats worldwide has heightened interest in measures to improve conservation methods [44]. While reserve selection techniques and algorithms are already well developed, the lack of good habitat networks and baseline data is the most significant constraint. This is sometimes exacerbated by widely scattered and disjointed remaining habitat fragments where biota movement is severely restricted, culminating in the irreversible disintegration of sustainable plant and animal populations [17]. In light of this, the Royal Government of Bhutan (RGoB) has chosen a forward-thinking approach to ensure an adequate network of environmental ('biological') corridors that allow the free movement of wild animals between protected areas around the country. Given the likelihood of climate change, such a move is significant. The Forest and Nature Conservation Act of 1995 [45] and other pertinent legislation give these protected regions legal protection. The goal of these sites is to conserve flora and wildlife in their natural habitats, including wild relatives of crops. Over 2.7 million ha of forest land [4] and ten protected areas encompassing alpine to dry deciduous ecosystems are well scattered in Bhutan's 20 dzongkhags (districts). The protected areas and biological corridors cover 51.4 % of the country (Table 3, Fig 3). The protected area management plan includes zoning of the parks to accommodate the rights and needs of local communities for timber and fuelwood. Special laws apply in conservation areas to safeguard

the protection of local species vital for conservation. It is largely aided by the character of the RGoB's tough and well-established policies, which originate from a deep and long-standing ethical commitment to safeguarding species and the ecosystem that supports them.

Villagers that live within or on the outskirts of the protected areas collect forest produce. The possible uses are for construction and fuelwood, while vegetables, mushrooms, and other food crops are collected mostly for home use. Traditional knowledge about utilizing plant resources is dwindling due to changing attitudes toward a more westernized lifestyle and a waning desire to continue the tradition among younger generations [46]. However, people of Bhutan has to seek permit if they want to use timber from the forest, and for every tree they use, they have to plant double the number [45]. This helps in sustainable management of forest resources.

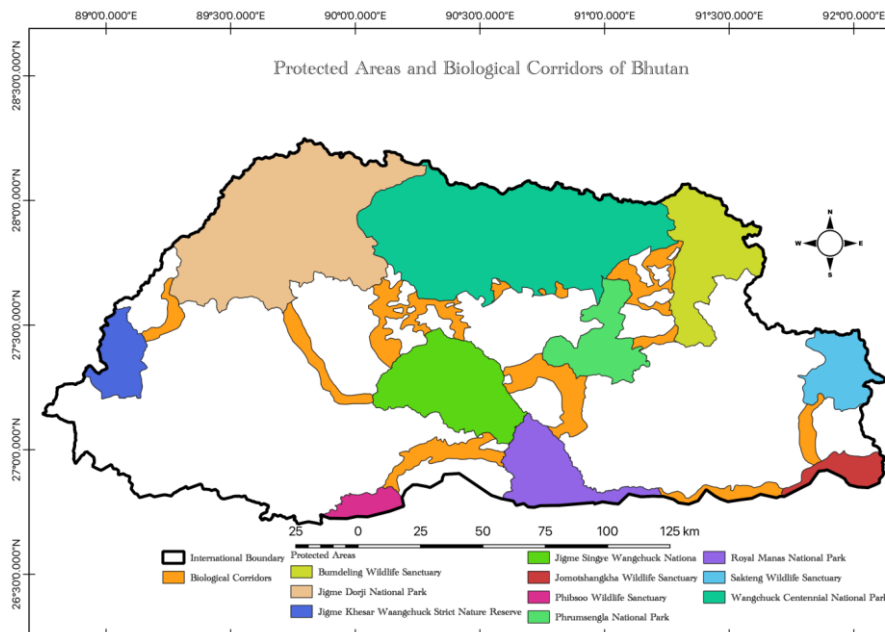
Bhutan's conservation policy is centered on a system of national parks that cover 42.82 percent of the country's land, with an additional 8.61 percent designated as 'biological corridors' or 'wildlife highways' that connect protected areas to facilitate the free passage of animals [57]. All protected areas have huge forest cover and are rich in biodiversity; farming and shifting cultivation raise some worries about their long-term viability [58].

There is a traditional reliance on a number of these protected locations [58]. However, as people migrate from rural places to towns and cities, the human resources for normal subsistence have decreased. To address these issues, the RGoB has created participatory Integrated Conservation Development Programmes (ICDPs) that provide direct material support, such as a monetary compensation scheme for livestock depredation that has reduced human-wildlife conflicts. There were almost no retaliatory killings of wild animals, especially tigers and snow leopards, by residents due to this. Similarly, the ark administration distributed corrugated galvanized sheets to residents of the protected area, which has reduced tree harvesting. The campaign has saved thousands of trees. The park management gave residents new stoves under the ICDP, which reduced their use by around 30%. The ICDP has significantly impacted protected areas and ecological corridors [17].

**Table 3. Protected Areas of Bhutan with its total area, percent cover, and the districts it touches**

Protected Area	Total Area (sq. km.)	% covered	Dzongkhags
Bumdeling Wildlife Sanctuary	1,521	3.96	Lhuntse, Mongar, Trashiyangtse <sup>a,g</sup>
Jigme Dorji National Park	4,316	11.24	Gasa, Paro, Punakha, Thimphu, Wangdue Phodrang <sup>b,g</sup>
Jigme Singye Wangchuck National Park	1,730	4.51	Sarpang, Tsirang, Trongsa, Wangdue Phodrang, Zhemgang <sup>c,e</sup>
Jomotsangkha Wildlife Sanctuary	334.73	0.87	Samdrup Jongkhar <sup>d,e</sup>
Phibsoo Wildlife Sanctuary	268.93	0.70	Dagana, Sarpang <sup>h</sup>
Royal Manas National Park	1,057	2.75	Pemagatshel, Sarpang, Zhemgang <sup>e,i</sup>
Sakteng Wildlife Sanctuary	740.6	1.93	Trashigang, Samdrup Jongkhar <sup>e,j</sup>
Phrumsengla National Park	905.05	2.36	Bumthang, Lhuntse, Mongar, Zhemgang <sup>k</sup>
Jigme Khesar Strict Nature Reserve	609.51	1.59	Haa, Samtse <sup>g</sup>
Wangchuck Centennial National Park	4,914	12.80	Bumthang, Gasa, Lhuentse, Trongsa, Wangdue Phodrang <sup>g</sup>
Biological Corridors	3,307.14	8.61	Haa, Paro, Thimphu, Punakha, Wangdue Phodrang, Sarpang, Tsirang, Zhemgang, Trongsa, Mongar, Bumthang, Trashigang, Lhuntse, Samdrup Jongkhar <sup>e</sup>
Royal Botanical Park, Lamperi	47	0.12	Punakha <sup>l</sup>
	19,751	51.44	

Source: <sup>a</sup>Thinley et al. [47]; <sup>b</sup>Sharma et al. [48]; <sup>c</sup>Tshewang & Letro [49]; <sup>d</sup>Choden et al. [50]; <sup>e</sup>Tshewang et al. [51]; <sup>f</sup>National Environment Commission (n.d.) [52]; <sup>g</sup>Wangchuk & Tharchen [53]; <sup>h</sup>Mallick [54]; <sup>i</sup>Wangmo et al. [55]; <sup>j</sup>Karst & Nepal [44]; <sup>k</sup>Tshering & Wangmo [56]



**Fig. 3. A network of protected areas and biological corridors**

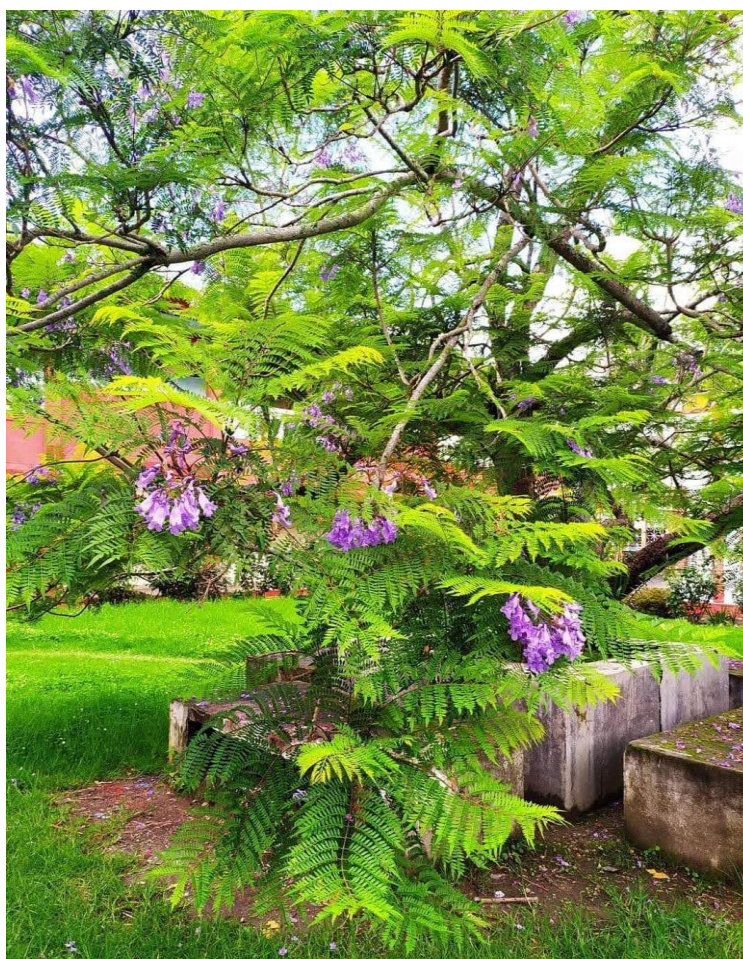
Much of Bhutan's biological treasure remains undiscovered by scientists. There are very basic baseline data available to aid scientists in documenting and monitoring changes in flora, wildlife, or forests. Most of the research work in Bhutan is done on mammals, birds, and plants. Very few researchers are working on insects, spiders, and other small members of Animalia Kingdom.

#### 4. FAUNA AND FLORA

Bhutan has one of the world's most comprehensive conservation policies. Bhutan is home to some of the world's rarest plants and animals due to its policies and conservation efforts. Bhutan records 11,248 species in all taxa of biodiversity until 2017, of which 136 (1.20 %) are globally threatened [24]. Out of 11,248 species, 2 (0.02 %) is categorized under Kingdom Protista, 18 (0.16 %) under Kingdom Eubacteria, 55 (0.49 %) under Kingdom

Chromista, 690 (6.13 %) under Kingdom Fungi, 5,114 (45.47 %) under Kingdom Animalia, and 5,369 (47.73 %) under Kingdom Plantae [19,24].

Bhutan's biological diversity documentation is still in its infancy. Bhutan recorded 3 fishes [59], 1 dragonfly [60], 4 snails [61], 16 plants [62], 2 aphids, 4 moths, 1 stonefly, and 2 beetles that were all new to science between 2009 and 2017 [19]. Bhutan also recorded 566 new species in the same years 2 bryophytes, 5 cicadas, 119 moths, 4 butterflies, 14 crabs, 4 beetles, 108 fishes, 101 plants, 44 amphibians and reptiles, 1 true flies, 65 bees and wasps, 59 dragonflies, and damselflies, 35 snails and slugs, and 5 birds [19,21]. At a rate of 62 species every year (62.88 percent), Bhutan has set a new species record. Many species have yet to be discovered and documented in Bhutan necessitating extensive research to document the undiscovered species (to science and Bhutan) and understand the number and diversity of species [63].



**Fig. 4.** *Jacaranda mimosifolia* (IUCN Status: Vulnerable), popularly known as the Wisdom tree among Sherubtseans, at Sherubtse College, Royal University of Bhutan (Photo: Author)





**Fig. 5. Man coexisting with nature at Shengor, Bhutan (Photo: Author)**

Bhutan is home to several globally vulnerable species, such as White-bellied Heron *Ardea insignis* Hume, 1878, Rufous-necked Hornbill *Aceros nipalensis* Hodgson, 1829, Black-necked Crane *Grus nigricollis* Przewalsky, 1876, Himalayan Musk Deer *Moschus leucogaster* Hodgson, 1839, Asian Elephant *Elephas maximus* Linnaeus, 1758, Capped Langur *Trachypithecus pileatus* Blyth, 1843, Golden

Langur *Trachypithecus geei* Khajuria, 1956, Bhutan Takin *Budorcas taxicolor whitei* Lydekker, 1907, Red Panda *Ailurus fulgens* F. Cuvier, 1825, Clouded Leopard *Neofelis nebulosa* Griffith, 1821, Golden Mahseer *Tor putitora* F. Hamilton, 1822, Chinese Pangolin *Manis pentadactyla* Linnaeus, 1758, Snow Leopard *Panthera uncia* Schreber, 1775, and the Bengal Tiger *Panthera tigris tigris* Linnaeus, 1758.



**Fig. 6. Druk Wangyal Chorten and mixed coniferous forest at Dochula (Photo: Author)**



Bhutan's avifauna variety is of great international importance. It is a part of the Sino-Himalayan mountain forests, Indo-Burmese forests, Indo-Gangetic grasslands, South Asian dry habitats, and Tibetan plateau wetlands, classified as BirdLife Important Bird Areas [64]. Bhutan is important for migratory birds from the south and north in the summer and winter, respectively (e.g., Bhutan is a major wintering area for the black-necked crane *Grus nigricollis*). The highest levels of avian biodiversity may be found in the tropical and subtropical zones, where around 700 species can be found below 2,000 meters and about 50 species between 2,000 and 4,000 meters [65,15]. In addition, 30 species found in the country have been classified as globally endangered [19].

## 5. CLIMATE

Bhutan's climate is extraordinarily diverse, which may be due to two main factors: the country's significant altitude differences and the effect of the North Indian monsoons [66]. Like most of Asia, Bhutan's climate is as variable as its heights. Bhutan's weather and climate are influenced by its elevation. The weather in the northern sections of the country, where mountains soar to 7,570 meters, is arctic. The temperature is hot and humid in the summer and chilly in the winter as you get closer to India. Rainfall during the monsoon season is typically heavy. Winters are a nice time to visit the lower parts of the country, but the higher elevations are chilly [67]. The climate varies from semi-tropical to alpine depending on altitude (For every 1,000 m height increase, the temperature drops about 7 degrees Celsius). During the monsoon season, the climate of southern Bhutan is tropical, with temperatures ranging from 15 degrees Celsius in winter to 30 degrees Celsius in summer. In addition, the east is warmer than the west. The central section of the country has a subtropical climate with mild winters, while the northern regions of the country have a harsh environment with snowfall two to three times a year. Temperatures in Thimphu range from -2.5°C in January to 25°C in the summer, with 100 mm of rainfall. The average temperature in the high mountain regions ranges from 0°C in the winter to 10°C in the summer, with an average rainfall of 350 mm. Because of the valley's height, it has relatively beautiful weather all year. Except for the southern parts that border India's plains and the northern border with Tibet, the middle valleys, where most people live, and visitors

come, have a pleasant temperate climate with modest seasonal fluctuations [68].

## 6. CONCLUSION

Bhutan's high biodiversity is due to the country's varied geography, climate, and conservation efforts. With a population of 735,553, the country has a total geographical area of 38,394 square kilometers. Only 2.93 percent of the land is cultivated. For 57 percent of the population, agriculture is their primary source of income. Bhutanese farmers are mostly small-scale, with an average farm size of 3 acres and self-sustaining subsistence integrated farming systems. Due to the great fluctuation in altitude, agro-ecology is diverse despite its modest area. From subtropical to alpine, the diversity of flora provides a mosaic of habitats for a wide range of creatures, which are the foundation of the Himalayan ecosystem's interconnectedness. Bhutanese conservation efforts are mostly focused on the preservation of flagship species. The country has a diverse ecosystem preserved by many protected areas and stringent conservation rules. Bhutan still requires an inter-coregional research-based conservation program due to the diversity of habitats and ecosystems and anthropogenic concerns. A program like this will ensure the Himalayan hotspot, of which Bhutan is a part, is preserved for the long future. More intensive research and funding should focus on other small species as these species also play a role in the ecosystem.

## COMPETING INTERESTS

Author has declared that no competing interests exist.

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