Biodiversity Persistence and Climate Change in Bhutan

1. Introduction

Biological diversity is vitally important for every sphere of human existence and provides us with a vast range of products and services ranging from the food we eat, clean water, fuel and construction materials to fertile soils, and healing plants for medicines and not least, the clean air we breathe (Kus et al, 2010, MEA, 2005). Biodiversity also plays a significant role in mitigating and adapting the impacts of climate change. Intact ecosystems such as forests and peat lands sequester carbon in their vegetation and soil thus supporting climate-regulating functions worldwide (Carlson *et al*, 2010).

Loss of biodiversity is caused by several factors such as changes in land use, over exploitation of natural resources, destruction of natural habitats, urbanization, human wildlife conflict, forest fires, hydropower development, industrial development, invasive species, etc. Climate change will further exacerbate the effects of other stressors (CBD, 2009; MEA, 2005) and is likely to become the dominant direct driver of biodiversity loss by the end of this century. Biodiversity and climate change are closely linked and each impacts upon the other. Human-induced climate change threatens biodiversity and biodiversity loss heightens the impacts of climate change on population and ecosystems (Gitay *et al*, 2002, MEA, 2005). In addition, the impacts of climate change on natural ecosystems exerts significant feedbacks to the climate system, mainly through increase in soil respiration under increased temperature and reduced capacity to act as carbon sink (Campbell et al, 2009).

Biodiversity in Bhutan

Bhutan straddles two major biogeographic realms, the Indo-Malayan and Palearctic and is part of the Himalayan biodiversity hotspot with a diverse array of flora and fauna including 5603 species of vascular plants, 400 lichens, 200 mammals and about 700 birds. It has an extensive network of rivers due to the high level of precipitation, numerous glaciers and glacial lakes and well-preserved forests resulting in upstream and downstream benefits such as water and other ecosystem services (BAP, 2009).

The total area under forests is 72.5 percent and 51.32 percent of the country is secured as protected areas and biological corridors. These are not only rich reservoirs of biodiversity but have indirectly served as long-term stores of carbon which mitigate the adverse impacts of climate change. The protected areas system of Bhutan is regarded as one of the most comprehensive in the world. It encompasses a continuum of representational samples of all major ecosystems found in the country, ranging from the tropical/sub-tropical grasslands and forests in the southern foothills through temperate forests in the central mountains and valleys to alpine meadows in the northern mountains (NEC, 2009).

Proportion of other land uses are much smaller, with agriculture, including horticulture, covering 7.8%, pasture 3.9%, settlements 0.1% and others 15.7%, mainly consisting of uninhabitable and inaccessible terrain, including glaciers as per the Land Cover figures of the LUSS-LUPP project of 1995, based on satellite imagery (SPOT) of 1989 and 1990 and considerable ground-truthing (Noord, 2010).

Bhutan is fortunate to have emerged virtually unscathed in the twenty first century in terms of its biological wealth. This is due to the far-sighted vision and leadership of our Kings and our rich tradition of living in harmony with nature throughout the centuries. The Constitution of the Kingdom of Bhutan also mandates the maintenance of a minimum forest cover of 60 percent for perpetuity. In an era where economic goals and developmental needs far outweigh conservation needs, Bhutan firmly perseveres on the development philosophy of Gross National Happiness which categorically states environmental conservation as one of the four pillars of Gross National Happiness. This effectively ensures that development is never achieved at the cost of the environment. Many policy documents and action plans have already been developed and are being implemented.

Most recently, Bhutan committed to remain carbon neutral during the United Nations Climate Change Conference, COP 15 at Copenhagen. Bhutan emits approximately 1.5 million tonnes of carbon annually, and its forests absorb approximately 6.3 million tonnes, leaving it with a carbon emission of -4.7 million tonnes, distinguishing it as one of the few countries in the world with negative carbon emissions. Ironically Bhutan's status as a negative carbon emitter does not make it immune to the impacts of climate change. In fact, its location in the Himalayas renders it more vulnerable to the impacts of climate change because warming trends are higher and the impacts are magnified by the extreme changes in altitude over small distances (Shrestha & Eriksson, 2009). In addition, it has become increasingly evident that those likely to bear the greatest brunt of climate change are the world's poorest countries and in particular the poor and marginalised communities and people who depend almost exclusively on natural resources and have reduced capacity to adapt due to their vulnerable situation (Tse-ring et al, 2010). These raise concerns for the persistence of our biodiversity and the livelihood of 69 percent of our rural population who depend directly on agriculture and natural resources.

Mindful of the reality and the gravity of the impacts of climate change, the national paper on "Persistence of Biodiversity and Climate Change" was developed. This is a pro-active step taken by the country to act nationally to understand, avert and adapt to the impacts of climate change and also strengthen the global movement and contribution to minimizing the impacts of climate change on biodiversity. The national paper discusses the current understanding and observations/trends of climate change and biodiversity, possible impacts of climate change at the ecosystem and species level, current gaps and needs and outlines strategies and actions to minimize biodiversity loss and promote sustainable socio-economic development in the country.

2. Observed changes and trends in climatic parameters.

Surface air temperature

Observational evidence from Intergovernmental Panel on Climate Change (IPCC) reports demonstrates that the earth's climate is changing. The global mean surface temperature has increased by 0.6°C (0.4-0.8°C) over the last 100 years (Gitay et al, 2002). The analyses of climate parameters of the Eastern Himalayas, wherein Bhutan is a part, do not present drastic deviations from the IPCC results. Studies have shown that the Eastern Himalayan region's mean annual temperature is increasing at the rate of 0.01°C/year or more (Chettri et al, 2010). Further, warming is observed and predicted to be more rapid in the high mountain areas than at lower elevations, with areas greater than 4000 m experiencing the highest warming rates (Shrestra & Devkota, 2010).

The analysis of surface air temperature data in Bhutan from 1985 to 2002 has shown a warming trend of about 0.5°C, mainly during the non-monsoon season (Tse-ring et al, 2010). Analysis of data from 2000 to 2009 from meteorological stations of the four representative eco-floristic zones of Bhutan also shows trend of rising mean summer and winter temperature (Fig. 1). However, due to the short time-series data on temperature, it is difficult to quantify the annual rise in temperature.

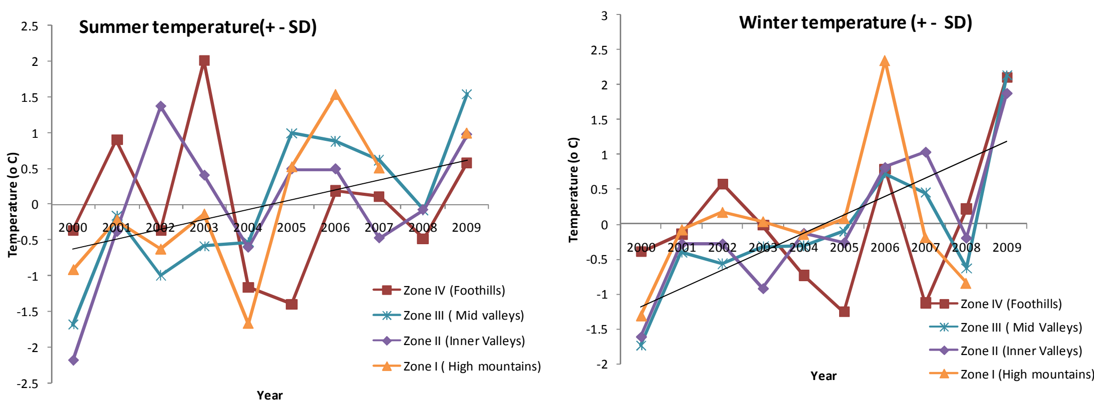

Fig. 1: Observed mean winter and summer temperature

Rainfall

Unlike temperature, no consistent spatial trends have been observed in precipitation throughout the Eastern Himalayan region. The changes in annual precipitation are quite variable, decreasing at one site and increasing at a nearby site (Tse-ring et al, 2010). In Bhutan, no comprehensive precipitation observations are available to conclude any trends. However, rainfall fluctuations are largely random with no systematic change detectable on either annual or monthly scale (Tse-ring 2003). A recent analysis of rainfall data from 2000 to 2009 across four eco-floristic zones of Bhutan shows annual fluctuations within regions without any detectable trend (Fig. 2).

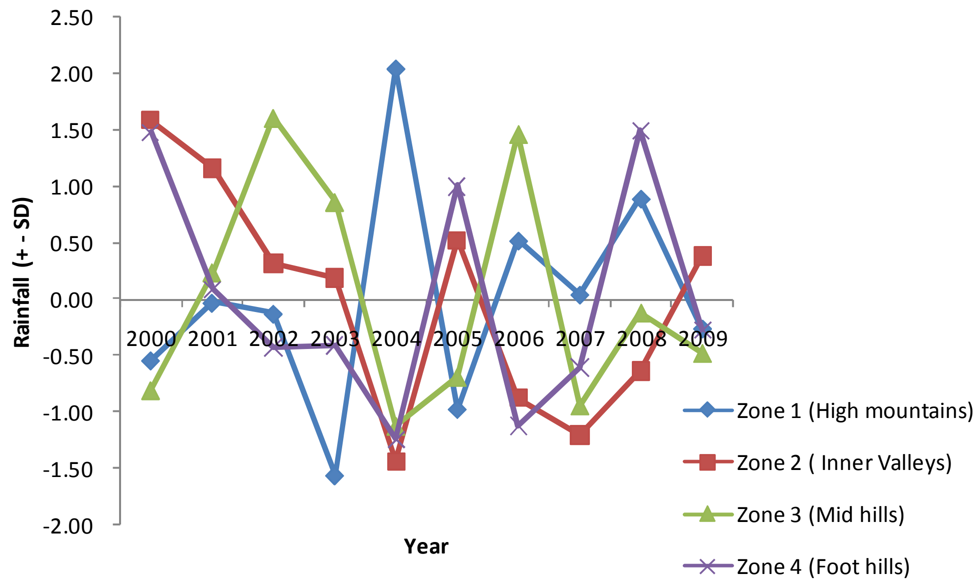

Figure 2: Rainfall trends from 2000 to 2009

Snow cover, Snow Fall pattern and Frost.

The extent of snow cover has decreased by about 10% on average in the Northern Hemisphere since the late 1960s (Gitay et al, 2002). Analysis of snow cover from Landsat MSS images taken from 1973 to 1979 and Landsat ETM+ images from 1999 to 2000 indicates a decrease in snow cover in the eastern Himalayas by 24.6 percent (Chettri et al, 2010).

There is no systematic record of data and observation on snow cover and snow fall to analyse and conclude any trends in Bhutan. However, people's observations on snow fall are discussed under community observation and perception on climate change.

3. Community Observation and Perception.

In order to record community observation and understand their perspectives on climate change and its impacts on biodiversity, a pre-structured questionnaire survey was conducted from October to November 2010 (hereafter referred to as survey 2010). The survey covered 16 Dzongkhags, 31 Geogs, 154 villages and 417 households across the country representing four broad eco-floristic zones of the country; Zone I- High mountains/Alpine (above 4000 masl), Zone II- Inner valleys (2000-4000 masl), Zone III- Mid hills (1000-2000 masl), and Zone IV- Foothills (150-1000 masl). A total of 417 respondents participated in the survey. The survey results were analysed using SPSS version 16.

The survey 2010 showed that people's understanding on climate change and its impacts on biodiversity was poor in general. The survey also highlighted the poor preparedness of the communities on any potential impacts of climate change. However, change in physical environment such as rising temperature, changing rainfall pattern, change in frost occurrence, change in snowfall pattern, etc. were observed by a majority of the respondents (Fig. 3)

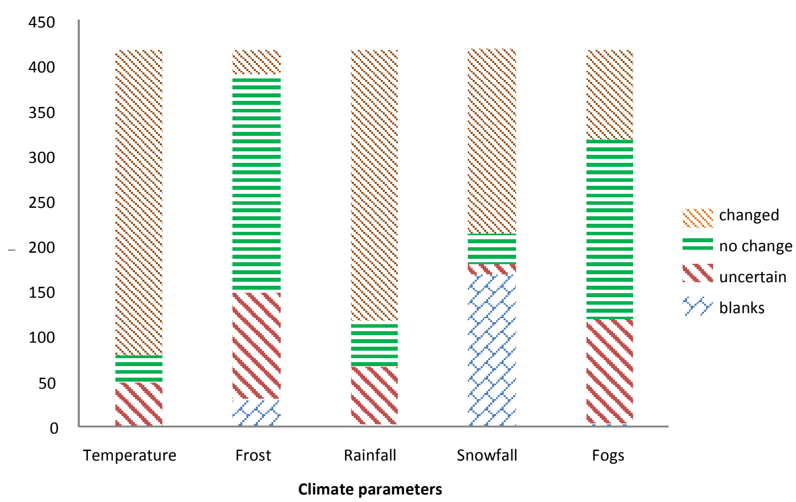

Figure 3: People's perception on change in climate parameters

Irrespective of their residency in different eco-floristic zones, 81.1 percent of the survey respondents reported increase in temperature over the last ten years. The people's observation supplements the results of the observed surface air temperature data (cf. Fig. 1 & 4). For instance, a farmer Rinchen from Thimphu, who has never heard of global warming is "adamant that climate in Thimphu has become warmer over the years" (Kuensel, 7th July, 2007).

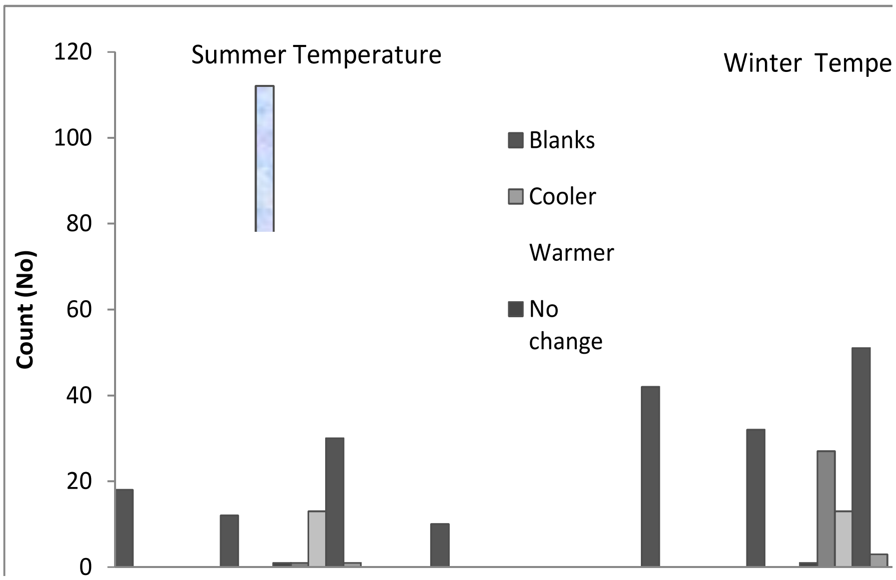

Fig.4. Community perception on winter and summer temperature change.

As observed globally, 72 percent of the survey 2010 respondents across all four eco-floristic zones had the opinion that the rainfall pattern had become more erratic and unreliable. The national newspaper, Kuensel also carried various news articles reporting on the changing weather patterns. An unusually long spell of dry weather in 2007 scorched farmlands across central and eastern Bhutan with farmers delaying the preparation of the field for paddy transplantation due to the extremely dry weather (Kuensel 2nd June, 2007). Low potato yields in 2007 were also blamed on a long dry-spell in June accompanied by unceasing rains just before harvest time (Kuensel 4th August, 2007) highlighting the vulnerability of farming communities to erratic weather conditions.

80 percent of the survey 2010 respondents living in snow fall area had observed changes in snowfall pattern and frequency. Further, respondents had the opinion that the current snowfall depth had decreased by about 61 percent compared to the last ten years.

Despite the lack of systematic records of frost occurrence, there is no dearth of casual observations to support the change in frost occurrence and its impacts on biodiversity. A newspaper article in 2007 reported that farmers in the apple growing region of Paro in western Bhutan blamed the fruitless season on the late frost that coincided with the flowering season in March (Kuensel 4th August, 2007). This substantiates the role that frost plays in determining the growth and reproduction of plants on a seasonal scale (Inouye, 2000).

Community observations and perceptions on the impacts of climate change on biodiversity are discussed under climate change impacts on ecosystems and species

4. Impacts of climate change on Biodiversity

Change in climate is already adversely impacting biological diversity at the **ecosystem level** through changes in distribution, composition, function, successional process and community dynamics, and values and services, (Campbell et al, 2009) and at the **species** level, and further changes in biodiversity are inevitable with further changes in climate.

Figure 5 reflects local communities' observations and perceptions on biodiversity change in four eco-floristics zones of Bhutan (Survey 2010).

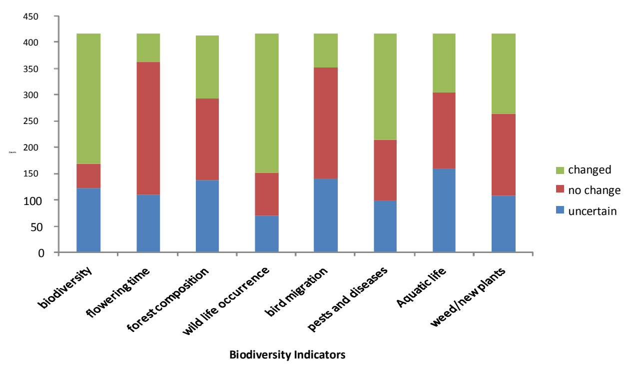

Fig.5: People perception on biodiversity change

In this paper we discuss the impacts of climate change on biodiversity at ecosystem and species level.

4.1 Climate change impact on Ecosystems.

The resilience of many ecosystems could be threatened by an unprecedented combination of climate change, associated disturbances (e.g. flooding, drought, wildfire, insects, etc) and other global change drivers (e.g. land use change, pollution, fragmentation of natural systems, and overexploitation of resources (IPCC 2007, CBD, 2009). Modelling studies combined with experimental evidence of species tolerance indicate significant changes in the state of some ecosystems, mainly due to rising temperature and altered precipitation regimes. It is predicted that such changes will first happen at the present boundaries between different ecosystems, such as shift in tree line. In addition to shifting the location of ecosystems and their boundaries, climate change will alter the **composition** of many ecosystems. Observation studies have already documented changes in species turnover and richness within both terrestrial and aquatic ecosystems, especially at temperate latitude, as some species less tolerant to new conditions get replaced by those with greater tolerance for warmer and drier conditions. There is growing concern regarding the role of climate change in facilitating the spread and establishment of invasive species, which can have major impacts on ecosystem composition. Studies have shown that climate change in combination with changes in ecosystems composition and structure would lead to changes in ecosystem **function.** In addition, changing climatic variables can have a profound influence on **succession process and community dynamic.** A final, key property of ecosystems that may be affected by climate change is the **values and services** they provide (Campbell et al, 2009, Rosenzweig, et al., 2007).

It is important to understand that changes in biodiversity and ecosystem functioning could lead to changes in critical goods and services upon which human societies rely. These are provisioning services, such as food, water, timber, fibre, genetic resources, and medicines; regulating services such as regulation of climate and, water and soil quality, and pollination; cultural services such as recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation and nutrient cycling. Intact ecosystems are more resilient and better able to buffer the impacts of climate change in comparison to ecosystems which are already weakened due to other stressors such as pollution or overuse (Amend & Eiβing, 2010).

The impacts of climate change at ecosystem level are discussed by broadly dividing it into the following key ecosystems: Alpine Ecosystem, Forest Ecosystem, Wetlands and Freshwater Ecosystem, and Agriculture Ecosystem (Annexure I).

4.1.1. Alpine Ecosystem

Alpine areas of the Himalayas are rich in native and endemic biodiversity and are home to many specialized and range-restricted biota (Dhar, 2002; Chettri et al, 2010), with the Eastern Himalayan region supporting one of the world's richest alpine flora (Chettri et al, 2010). The alpine meadows of Bhutan is rich in many species of grasses and herbs, and is the habitat of the famous Chinese caterpillar fungus (*Ophiocordyceps sinensis*), and a haven for wild fauna, such as the snow leopard, blue sheep, takin, with recorded sightings of the Royal Bengal Tiger at elevations not reported elsewhere (4100 m). Further, over 200 medicinal plants used for traditional medicine are also found in this region.

Species already occupying high altitude/alpine areas are most at risk as they have little scope for upward migration. The warmer climate will cause lower-elevation habitats to move into higher zones encroaching on alpine and sub-alpine habitats (Beniston, 2003). This could result in drastic area losses or even extinction of cryophilous plants, a disintegration of current species composition, and destabilization of high mountain ecosystems (Pauli et al, 2003). It is also predicted that high-altitude rangelands would be the most sensitive agro-ecosystem in terms of the effects of erratic shifts in rainfall patterns, greater variability, and frequent extreme events of both precipitation and temperature (Tse-ring et al, 2010).

The results of the survey 2010 indicate that Juniper scrub forest is increasing in area while the availability of alpine plants (eg: *Picorihiza kuroo, Gentiana urnula and Fritillaria spp.*) are decreasing in the high mountains. While changes in management practices like fire suppression and forestry rules have led to increase in scrub forest coverage, climate change could further accelerate this process. It is likely that with the climate becoming warmer in future, the increasing upward movement of conifer scrub forest could result in habitat encroachment of medicinal plants such as *Picorhiza sp., Fritillaria sp and Rhodiola sp.* Climate warming has also been implicated in increasing the role of inter specific competition in determining alpine plant community structure and diversity

(Campbell et al, 2009) and creation of new assemblage of species with novel interactions and unknown ecosystem functions (CBD, 2009).

A rapidly warming climate and changes in land use practices such as suppression of fire as a management tool have been indicated to have led to upward advancement of alpine treeline through encroachment of woody vegetation into alpine meadows in Yunnan, China thus threatening both biodiversity and livelihood in high altitude areas (Baker & Moseley, 2007). This spells the need to study the change in grazing land management regimes in the alpine regions in the country where locals report that the discontinuation of the use of fire as a grazing management tool has led to the acceleration of the incursion by woody species of the alpine region.

The average rate of glacial retreat in Bhutan from 1963 to 1993 is estimated to be about 2 m/year vertically and about 7 m/year horizontally, with 8.1 percent area shrinkage in 66 selected glaciers in 30 years (Karma et al, 2003). Reports state that in the coming decades, many Himalayan glaciers will retreat, with some smaller glaciers disappearing altogether (Eriksson et al, 2009). Many alpine species are able to start their growth with the supply of snow melt water, well before the commencement of monsoon. Hence, the growth and life cycle of alpine plants can be disrupted because of the lack of snow melt water, once the glaciers disappear (Singh, Year missing). This could lead to change in species composition, structure and functioning of alpine meadows leading to habitat alteration and disappearance of ecologically sensitive and economically important species such as *Ophiocordyceps sinensis* and plants (*Picrorhiza, Fritillaria* and *Rhodiola, etc).*

4.1.2. Forest Ecosystems.

Forest ecosystems are ecologically distinct from other ecosystems due to their high rates of primary productivity and biodiversity (Thompson et al, 2009). Forests play a critical role in delivering a wide range of ecosystem services, including the provision of timber, fuel and other non-timber forest products, regulation of hydrological processes, flows and retention of biodiversity, and carbon sequestration (Campbell, et al, 2009, Nasi et al, 2002; Krierger, 2001).

Global assessments have shown that future climate change will have a significant impact on forest ecosystems (Ravindranath et al, 2006). As the global climate changes, forest ecosystems will change because species' physiological tolerance may be exceeded and the rates of biophysical forests processes will be altered (Thompson et al, 2009). Ecosystems dominated by long-lived species such as long-lived trees, will often be slow to show evidence of change and slow to recover from climate-related stresses. In cases where increased mortality of long-lived species is caused by stressors related to climate change such as pests and diseases, the recovery to a state similar to the previous stand may not be possible or might take decades to centuries, if it is achieved at all (Gitay et al, 2002). A very important advancement since IPCC AR4 was the recognition that old-growth forests continue to stock carbon rather than being carbon neutral and that they therefore play a vital role in offsetting carbon emissions (Campbell et al, 2009). This is important in our context where most of our forests are believed to be old-growth/primary forests spelling the need for a comprehensive study of our forests and the development of a long-term research and monitoring plan to maintain them.

Change in forest boundary, species diversity and composition

Although, detecting changes in forest ecosystems take a longer time - frame (Campbell et al, 2009), researchers estimate that in the eastern Himalayas, the tree-line has moved by about 110 m over the past century; and in the western Himalayas an upward shift of treeline by 19 and 14 m over the last ten years on the south and north slopes, respectively has been reported (Xu et al, 2009). In the Uttarkashi forest division of Uttaranchal state of India, it is reported that areas at lower elevation previously dominated by Oak (*Quercus leucotricophora*) has currently become dominated by Chir Pine (*Pinus roxburghii).* The local elders attribute this change in vegetation composition to gradual increase in temperature and the consequent drying up of soil (Lekkar & Bhadwal, 2007).

There are no studies with systematic records of treeline shifts in the country, however, Bluepine (*Pinus wallichiana*) encroachment into spruce/maple/birch forests and rhododendron and juniper scrubs into alpine meadows are observed (*pers.com*). The strong correlation between the upper limit of evergreen broad-leaved species and the winter temperature was also reported (Wangda & Ohsawa 2006a & b). Along the slopes of dry valley mid hills, the distribution of evergreen broad-leaved species along the altitudinal slope was limited by winter temperature (coldest month's mean temperature) of minus one degree celsius which coincided at 2900 masl (Wangda & Ohsawa 2006a). Now with the increasing trend of winter temperature over the past ten years, according to unpublished meteorological data of Research and Development Centre (RDC), Yusipang, there is a probability of increasing the upper limit of evergreen broad-leaved species from 2900 m (current) to higher altitudes in the near future. Similarly, upper limit of conifer species like *Abies, Tsuga* and *Juniperus* may shift higher or may get extinct in the process.

In cool temperate forests, *Tetracentron sinensis*, a vessel-less angiosperm is likely to become threatened with increase in winter temperature and prolonged dry spell (Oshawa, 1987). In the cold temperate forest, *Abies densa* forests on the mountain tops had declined in 1980s due to moisture stress (Gratzer et al, 1997).

The montane cloud forests of Bhutan occurs around 2500 m in the inner deep dry valley slopes of Dochula-Bajo series (Wangda & Ohsawa, 2010) and around 2000 m along the mid hills of Gedu-Darla series (Wangda et al, in press). These two cloud forests eco-regions are important forest resources for the communities and act as watersheds. The cloud forests ecosystem is vulnerable to change in temperature and human disturbances. This might lead to habitat loss for some important relict plant species like *Taxus, Magnolia, Tetracentron* and endangered bird species such as hornbills.

The sub-tropical forests of Bhutan are home to important wildlife species such as elephant, tiger, rhinoceros, leopard, pygmy hog, golden langur, golden mashers, pangolin and a host of birds and insects endemic to Bhutan. However, the composition of this ecosystem is already undergoing some degree of change. Survey 2010 results show an increase in population of wild animals such as rabbit, wild boar, sambar, macaque, barking deer, porcupine, gaur and bear, and a decline in the population of elephant, wild dog and tiger. Birds such as hornbill, common crow, vulture and ring dove are also on the decline as shown by the survey results (Table 1). This ecosystem and its assemblage of species could be further impacted by rising temperature and fluctuation in rainfall patterns.

Table 1: Observed changes in population of animal species (Survey 2010)

Eco-floristic zones	**Observed increase in species population**	**Observed decrease in species population**
Alpine – above 4000 masl Altitude -4000m + Mean Temp-5.5^0 C/y Rainfall <550 mm/year	Tibetan fox, blue sheep, wild boar, takin and snow leopard, blood pheasant and monal pheasant	musk deer and barking deer
Inner Valleys Altitude -(2000-4000 m) Mean Temp-9.9^{0}C-12.5^{0}C /y Rainfall -650-850 mm/year	bear, wild boar and sambar, black necked crane, mynah, yellow billed blue magpie.	barking deer, wild fox, leopard and tiger, eagle
Mid valleys Altitude -(1000-2000 m) Mean Temp-17.2^{0}C-18.5^{0}C /y Rainfall -850-2500 mm/year	macaque, wild boar, deer, laughing thrush and common crow.	jackal, tiger, bear, musk deer, leopard, jungle fowl, hornbill, pheasant, cuckoo and vulture
Foothills – 150 – 1500 masl Altitude -(150-1000 m) Mean temp- 23.6^{0}C- Rainfall-2500-5500 mm/year	rabbit, wild boar, sambar, macaque, barking deer, porcupine, gaur, bear	Asian elephant, wild dog, tigers hornbill, common crow, vulture and ring dove

The flora in the sub-tropical region comprises tropical and sub-tropical elements of *Shorea, Phoebe, Pterosperum, Tetrameles* and *Duabanga.* Major areas of the southern foothills have been replanted with indigenous economic species of *Terminalia, Shorea, Arborea* and *Michelia* spp. after timber harvesting from the region was stopped in the 1960s. A few areas have been planted with *Tectona grandis* introduced from India. The survey 2010 result revealed a decrease in the wild population of *Terminalia tomentosa, Aquilaria spp, Ficus* spp, *Daubanga grandiflora, Michelia champaca, Bombax ceiba* with increase in weedy species such as *Mikania* spp., *Eupatorium odoratum, Ageratum* spp. and *Lantana* spp. This substantiates research findings that forest compositional change will occur due to selective advantage of different species dealing with the physiological demands of climate change (Campbell et al, 2009).

Occurrences of pests, diseases, and fire

Recent moderate warming have been linked to improved forests productivity, but these gains are expected to be offset by the effects of increasing drought, fire and insect outbreak as a result of further warming (Campbell et al, 2009). It is evident from survey 2010 results that the productivity of *Abies densa*, *Pinus wallichiana, Quercus glauca and Quercus griffithii* forests suffered set-backs due to periodic diebacks and insect attacks. Further the survey indicated that pests and diseases in forests and agriculture had increased over the years in general. There were outbreaks of bark beetle in spruce forests, increased mistletoe infestation incidence, and moisture–stress related problems in blue pine forests. It is likely that with rising temperature and erratic dry and moist periods, intensity and incidences of diseases and pests will increase. The chir pine die-back observed in 2007 and 2009 showed a strong correlation between die-back incidences and the high temperature with low precipitation making chir pine stands susceptible to pine looper attack (REF). Similarly, along the shallow valley of Wangchu (Thimphu-Paro) the impact of climatic factors on blue pine die-back was observed. In less than 16 years (1992-2008), five incidences of pine die-backs were observed (1994, 1999, 2001, 2003 & 2008) along the Paachu-Wangchu valley (Wangda et al. 2009). The study found that pine die-back was strongly correlated with higher temperature and lower rainfall during the die-back incidences in the area.

Forest fires are considered to be one of the key threats to coniferous forests in the country with 526 incidents of forest fire, affecting over 70,000 ha of forest between 1999/2000 to 2007/2008 (BAP, 2009). The most recent case was in the Punakha-Wangdi valley where fires raged for XX days and burnt XXX hectares of forests. While most fires in Bhutan are caused by human activity, the rising temperature and long spells of drought due to climate change are likely to increase the risk of forest fires resulting in further reduction and degradation of forest resources. Such examples include the fires in the winter of 1998/99 which was characterised by a prolonged spell of dry (snow-less) weather with forest fire incidents even in places without a known history of forest fires (BAP, 2009). However, forest fires are also an essential part of the natural process in the functioning of many ecosystems. Fire suppression in fire-adapted ecosystems or ecosystems that depend on fire often results in reduced biodiversity and increased vegetation and fuel density, often amplifying risks of catastrophic fire over time. Furthermore, the fire-ecosystem relationship is also being altered by climate change, with significant consequences for ecological processes and biodiversity. Effective biodiversity conservation therefore requires allowing fire to play their role in maintaining ecosystem functioning, without posing a threat to biodiversity or human well-being through excessive occurrence (CBD, 2009). Forest fire cannot be considered only as a threat for timber production, but its role as a conservation tool for Bhutan's forests needs to be understood and applied under both present and future climatic conditions.

Other drivers of change in forest ecosystem

As per the most recent scoping study on the feasibility of REDD+ in Bhutan, many drivers of forest change and degradation are discussed such as slash-and –burn agriculture, livestock and grazing areas, leaf litter collection, fallowing of agricultural land, infrastructure development, firewood collection, timber extraction and other drivers of forest cover change, including mining. The general trend for the drivers of forest degradation seems to be decreasing, except for timber and firewood extraction. An imbalance in increasing market demand and the limited growth potential in the supply side could have a negative impact on forest cover and quality if left unchecked (Noord, 2010)

4.1.3 Wetland and Fresh water ecosystems.

The four major river basins of Bhutan comprise Amo Chhu (Toorsa), Wang Chhu, Puna Tsangchhu (Sunkosh) and Drangme Chu (Manas). In addition, there are several small river basins occupying largely the southern part of the country. These include Samtse Area multi-river basin, Gelephu area multi-river, Samdrup Jongkhar area multi-river and Shingkhar Lauri area multi-river (BAP, 2009). The most recent inventory of high altitude wetlands in the country carried out by Ugyen Wangchuck Institute for Conservation and Environment (UWICE) and WWF- Bhutan Program recorded a total of 3,027 wetlands inclusive of lakes and marshes. These high altitude wetlands cover about 102 square kilometers, contributing 0.61 percent of the high altitude land area and 0.26 percent of the country's total land area. They are composed of supra-snow lakes, supra-glacial lakes, glacial lakes, and lakes in alpine meadows, sub-alpine habitats and marshes. The high altitude wetlands are located in the northern fringes of the country and are integral components of the river basin system they feed and contribute to water storage and the hydrological cycle (UWICE/WWF, 2010). The continuous flow of water from these reservoirs is of paramount importance as "water towers" for the region. Culturally too, high altitude wetlands bear great significance as sacred sites and are interconnected strongly with the beliefs and lifestyles of local communities (UWICE/WWF, 2010).

The wetlands and freshwater ecosystems are important lifelines for migratory birds and other animals and support high biological diversity. It is understood that 20 percent of all the known fresh water vertebrate species and 25 percent of the known aquatic plants are found in South and South East Asia, making the region one of the most speciose on the planet (Allen et al, 2010). In Bhutan, about 104 bird species including the critically endangered White Bellied Heron are listed to be dependent on wetlands and freshwater ecosystems (UWICE/WWF, 2010). In addition, existing records list 50 fresh water fish species, including eight introduced species (BAP, 2009). The main indigenous fish species include Himalayan trout *Barillius spp.* and mahseer *Tor tor,* which is listed as a totally protected species in Forests and Nature Conservation Act 1995. Amongst introduced species, brown trout, *Salmo trutta trutta* is the most common. However, further field investigation and authentication on the use and habitation of fresh water ecosystems by floral and faunal diversity is considered important for validation of conservation significance (UWICE/WWF, 2010).

Wetlands are physiographically limited systems with inability to migrate, and hence are particularly vulnerable to climate change through alterations in hydrological regimes, nutrient inputs, among others (CRM, 2007). There is growing concern that climate change may accelerate the damage to wetlands and fresh water ecosystems, such as lakes, marshes and rivers. Studies from elsewhere show that increasing temperature will cause water quality to deteriorate and have negative impacts on micro-organisms and benthic invertebrates. Plankton communities and their associated food webs are likely to change in composition, including change in distribution of fish and other aquatic organisms, with possibility of some species becoming extinct (Campbell, 2009).

Wetlands are already under threat from anthropogenic activities such as infrastructure development, resource extraction, agriculture, mega hydropower projects, urban expansion/encroachment, etc. For example, agriculture, continuous grazing and encroachment by bluepine and scrubs into marshy areas are indicated to be altering the wetlands of Phobjikha, and thereby the habitats of the globally vulnerable black-necked cranes. In future, with increasing effects of climate change, such wetland ecosystems could gradually disappear or become unsuitable for wintering and breeding of these birds. However, apart from a few inventories of the high altitude wetlands, there is a huge paucity of data on wetlands and freshwater ecosystems, as well as studies on impacts of climate change. This severely limits the understanding of climate change impacts on these ecosystems and development of effective management and conservation strategies.

4.1.4 Agriculture Ecosystems

Bhutan is largely an agrarian country with over 69 percent of the population engaged in agriculture. Bhutan's agriculture ecosystems are diverse and fragile, and lie between 150 to 4600 masl. Farming is predominantly at subsistence level and a majority of Bhutanese farmers continue to grow traditional crops and crop varieties. Rice and maize are the major staple crops and other commonly grown crops are wheat, barley, buckwheat, millets, oil seeds, grain legumes, orange, apple, cardamom, etc. Bhutan has over 350 traditional rice varieties grown at different agro-ecological zones starting from 150 to 2800 masl and is home to over 80 species of other agriculture crops (BAP, 2009).

Agricultural biodiversity plays a crucial role for adapting to altered climatic conditions through the genetic variability of agriculture crop plants and livestock species which can be bred to better adapt to climate change impacts. It is widely accepted that genetic diversity is important both in its own right and in determining the resilience of species to the impacts of climate change and other pressures. Therefore, conserving the broadest possible genetic diversity acts as an insurance against risks posed by climate change. We must also protect areas where original wild varieties exist in order to preserve the genepool and foster exchange for selective breeding aimed at adaptation as well as in safeguarding and promoting evolutionary processes and traditional knowledge relating to the use of these plants (Kus et al, 2010).

The principal factors that could lead to reduced agro-biodiversity are the prevailing rise in temperature and changes in precipitation leading to increased incidence of extreme weather events and an increase in greenhouse gases in the atmosphere (Chettri et al, 2010).

This in turn could lead to low yield, higher incidences of pests and diseases, and disappearance of some species, varieties and breeds.

Survey 2010 reported a high incidence of pests such as ants in potatoes, trunk borer (in rice and wheat), and fruit fly and diseases like Citrus greening, Turcicum Leaf Blight (TLB) and Gray Leaf Spot (GLS) in maize, ginger rot, cardamom rot, potato blight, maize root rot in crops and Foot and Mouth Disease in livestock. Even as the correlation between the increase of these pests and diseases to climate change needs to be ascertained, outbreaks of GLS and TLB in eastern Bhutan is already threatening the survival of about 38 traditional maize varieties (Bhutan Observer, 24th July 2010). In recognition of the potential threat to traditional crop and crop varieties due to natural disasters and rising temperature, the National Adaptation Program of Action (NAPA, 2006), Bhutan forewarns the need for immediate and appropriate actions to prevent the loss of this traditional heritage.

4. 2. Impacts of climate change on species.

It is understood that many of the Earth's species are already at risk of extinction due to pressures arising from natural processes and human activities. Climate change will further exacerbate these pressures especially for threatened and vulnerable species (Gitay et al, 2002). According to the IPCC AR4, up to 30 percent of the higher plant and animal species are likely to be at an increased risk of extinction if global average temperature increase exceeds 1.5 to 2.5 degree celsius over present temperature (Campbell et al, 2009).

Climate change will impact species mainly through changes in distribution and population status. The risk of extinction will increase especially for those that are already at risk due to factors such as slower life history trait, limited dispersal abilities, low reproduction rate, small population size and specialist and range-restricted species, limited climatic ranges, or occurrence on low-lying islands or near mountain tops (Campbell et al, 2009, Gitay, 2002). In addition, where no migration was assumed in model projections, endemic species were predicted to be most affected. Climate change will also affect phenology, which in turn could affect the species population, plant-pollinator interactions and prey-predator dynamics (Campbell et al, 2009).

Global scientific reports already cite the loss of species such as the striking colored Harlequin frogs (*Atelopus* sp.) to global warming in the mountain forests of Central America with six to seven percent of 110 endemic species having become extinct in just two decades. Conversely, some species are projected to increase their abundance and expand their range under warming climate (Campbell, et al, 2009). For example, in Canada, warming trends have resulted in a northward expansion of the range of the red fox but with a subsequent retreat of the range of the Arctic fox (Kannan & James, 2009). Such idiosyncratic response to climate change could affect species assemblage and, consequently may have unexpected distribution and abundance of species depending on the novel interactions that occur from the change (Campbell et al, 2009).

These reports raise concerns for Bhutan which has about 105 endemic plants (Annexure 2) and a number of globally threatened species that include 27 mammals (Annexure 3), 17 birds, one reptile, one amphibian, one invertebrate and seven plants. There is further concern for the continued existence of high altitude species which will be at risk due to the higher impacts of climate change in the alpine region and as land areas decrease with increasing elevation (Campbell et al, 2009). This could result in the potential loss of restricted Himalayan endemics such as the pygmy hog, Himalayan field mouse, flying squirrel, including high altitude medicinal/endemic plant species. In addition, the existence of large predators such as the tiger and the snow leopard are already threatened by shrinking or fragmented habitats making them more vulnerable to the impacts of climate change. Therefore, implementing species specific conservation programs that include securing habitats for persistence of species which are at risk or threatened by the impacts of climate change is an absolute priority.

There are no systematic studies in the country to quote examples of climate change impacts on species as well as species response albeit a few local observations and perceptions. Survey 2010 lists population change in a number of animal species (Table 1) and about 16 plant species with observed changes in flowering time (Table 2.)

Table 2: Observed changes in flowering time of different plant species (Survey 2010).

Eco-floristic zones	**Species**	**Flowering time (Current)**	**Flowering time (10-20 years ago)**
High Mountains	*Rhododendron spp.*	March	April
	Magnolia sp.	March	April
Inner valleys	*Rosa sp.*	May	June
	Juglans sp.	July	August
	Rhododendron sp.	Feb-May	Apr-June
	Populus sp.	December	January
Mid valleys	*Michelia doltsopa*	February/March	April
	Prunus sp.	March	April
	Castanopsis sp.	April	May
	Quercus sp.	January	February
Foothills	*Erythrina sp.*	August	September
	Terminalia sp.	September	October
	Bombax sp.	October	December
	Daubanga sp.	September	November
	Bauhinia sp.	August	September
	Justicia adatodha	December	January

Further, invasive and weedy species pose another threat to native plant and animal diversity. Survey 2010 reported a significant increase in the diversity of invasive species such as *Parthenium, Opuntia, Eupatorium, Lantana, Commelina, Galinsoga, Phyllanthus*. Climate change is believed to expedite the colonization of some areas by invasive species in both terrestrial as well as fresh water ecosystems, which will have severe ramifications on native species (Campbell et al, 2009, CBD, 2009). Local newspapers have also carried articles on the emergence of 'foreign weeds' attributed to hotter climates by local residents (Kuensel, 7th July, 2007). Such increase of noxious invasive species may result in the decline of native species diversity in addition to lowering the production of agricultural crops through competition.

5. Impacts of climate change on Local Communities and their livelihoods

The livelihoods of local communities will be adversely affected if climate and land-use change lead to losses in biodiversity, including loss of habitats (Gitay et al 2002). Some possible scenarios include destruction of vegetation as a result of heavy grazing or exposure of soil that encourages the establishment of southerly weedy species under a warmer climate leading to adverse impacts on local livelihoods (Gitay et al, 2002). An example close to home would be loss of alpine habitat leading to the loss of *Ophiocordyceps sinensis* and high value medicinal plants which will have significant impacts on the livelihoods of high altitude pastoral communities. For example, in 2010 alone, the total revenue earned from the sale of *Ophiocordyceps sinensis* was approximately two hundred thousand USD (DAMC 2010).

What is also not apparent immediately is the erosion of cultural practices, beliefs and traditional knowledge that will occur through the disappearance of local plant species or what is termed as loss of "Bioculture" (Maffi, 2007; Singh et al, 2011). It is apparent that climate change will accelerate the loss of traditional knowledge related to the use of medicinal plants, wild and domesticated animals, and cultural elements associated with this biodiversity reflected in song and dance, etc., resulting in the loss of a traditional heritage, an era, a way of life (Gitay et al, 2002, Singh et al, 2011). This "biocultural" loss could also act as a factor that increases poverty. Therefore the documentation of traditional knowledge and practices and the recognition of the role that local communities can play in relation to climate change needs to be strengthened through community involvement in local and national planning processes to adapt to climate change.

6. Potential impacts on biodiversity through climate change adaptation and mitigation activities.

Not all activities initiated to adapt to climate change will result in beneficial impacts on biodiversity. In fact some adaptation measures could result in potential loss of biodiversity and mal-adaptations for future climate change.

Hydropower

At present the installed hydropower capacity in Bhutan is 1488 MW. In the next 20 years, the energy sector plans to develop another six hydropower projects with a combined capacity of over 4385 MW. The country is pursuing hydropower as a means of reducing the country's dependence on traditional solid fuels, e.g. fuel wood, which is much more environmentally damaging and expensive. Furthermore, as a major source of revenue, hydropower development provides a strong economic rationale for environmental conservation, as its sustenance depends on the sustainable management of the watersheds. The state of the environment and the conditions of the watersheds as well as the impacts of the hydropower projects on the surrounding natural environment are yet to be ascertained. As per reports, the most commonly reported impacts of hydropower projects are disturbance in river flow and degeneration of aquatic life. In addition, construction of dams, access roads and power transmission lines have a bearing on land stability and biodiversity, more so in a mountainous country with a fragile ecology like Bhutan.

Use of Bioenergy

While the energy sector in the country is aiming to provide electricity to all by 2013 (BPCL, 2009), there are still large sections of society that are dependent on the use of firewood as a source of energy. Bhutan consumed 724,597 tonnes of firewood during 2005 which accounted to 58.96 percent of the total primary energy supply. The residential consumption of fire wood accounted to 75 percent of the total fire wood consumed, of which 96.2 percent was in the rural areas (Dhital, 2009). This emphasizes the importance of considering the potential impacts on biodiversity as well as loss of and change to habitats because of high dependence on wood and clearing of forests for sustenance. However, mitigation activities aimed at reducing fuel wood such as bioenergy plantations could also have adverse impacts on biodiversity through replacement of areas with higher biological diversity. This clearly points to the need to consider proper site selection and management practices in the current plantation approaches to ensure that benefits are harnessed and adverse impacts are reduced.

7. Existing gaps in understanding and addressing climate change impacts on biodiversity.

7.1. Lack of comprehensive data and information on biological diversity

The existing data is confined to the higher plants, animals and birds and needs to be updated while there is little or no information on other taxonomic groups, especially the lower plants, invertebrates, herpetofauna, fungi, and microorganisms.

Specific areas of research in determining the impacts of climate change on biodiversity will need basic data on different ecosystems and ecosystem services as well as on species, all of which are poorly documented or have not been documented at all in the country. For instance, there is a lack of basic data on the number and location of lakes except for glacial lakes and the prevalent biodiversity, rendering it impossible to study the impacts of climate change on this ecosystem. There is also a lack of comprehensive information on the composition, distribution and dynamics of forests in the country.

Therefore an urgent priority is to carry out a comprehensive inventory and catalogue the status of biological diversity in the country before they are lost forever to enable the formulation of effective biodiversity conservation and sustainable utilization programs and action plans in response to the emerging climate change scenarios.

7.2. Lack of research priority and robust knowledge

While there has been a host of observations made by the local communities and general public on the changing climate, there is still a severe lack of scientific evidence on the impacts and vulnerability of biodiversity to climate change in the country. Meteorological observation data is limited to temperature and rainfall and available for less than two decades from stations that are concentrated in the mid valleys and the southern belt. Such data is inadequate to draw robust conclusions for climate change analysis and acts as a huge impediment in developing and implementing proper adaptation measures. There is an urgent need to improve the meteorological observation system and install stations across different eco-floristic zones of the country and develop capacity to carry out experimental and modeling studies to address the threats of climate change to ecosystems, biodiversity and general human wellbeing.

The vulnerability of species and ecosystems to the impacts of climate change is well documented outside the country. However huge gaps exist in the country in terms of knowledge on species at risk, keystone and range restricted species and the impacts of climate change on species' response. Therefore there is a need to provide research priority towards studies on the impacts of climate change and species response in a systematic manner with focus on keystone species, flagship species, habitat specialists, etc., to ensure that these species do not become extinct.

It is also important to strengthen existing studies on invasive plant species, forests pests and diseases to protect natural ecosystems, prevent biodiversity loss and to monitor their interactions with climate change.

The weak knowledge and research base also makes it impossible to determine whether the biodiversity changes are due to environmental degradation driven by other factors or due to climate change.

7.3. Poor education and awareness on climate change and biodiversity concerns.

In general, there is poor or no understanding on impacts of climate change on biodiversity at all levels. This can be attributed to the lack of information and limited outreach since climate change as a real threat has emerged only recently. Where agricultural biodiversity is concerned, it fares a little better because several recent expositions, seed and animal fairs as well as exchange of knowledge between farmers have been supported and carried out on the importance of agro biodiversity as insurance for food security in the face of climate change. While on the ground estimation of agro biodiversity is still ongoing through government support, the study on wild crop relatives remains very weak or non-existent.

Another challenge is the limited access to many of the *geogs* and villages in isolated and scattered terrain. This renders it difficult for information and awareness campaigns to penetrate to the grass root level to raise local stakeholder awareness and enable them to participate in the planning process to ensure the prioritization of climate change concerns in local development plans.

Therefore proper strategies have to be drawn up and concerted efforts must be channeled into educating the whole country on the impacts of climate change on biodiversity. This will ensure the country's preparedness against the impacts of climate change through awareness and strengthened capacities of all the stakeholders and reduce vulnerability.

7.4. Lack of convergence of policy and practice

There are a number of policies in the country addressing the environment, forests, biodiversity, food security, etc. While the environment is considered a crucial pillar of the national development philosophy of gross national happiness, the specific concerns of climate change and its impact on the environment in general and biodiversity in particular is lacking. Nevertheless, with the reality of climate change, it has become necessary for the country to address climate change concerns through the development of coherent policies and implementation of ecosystem based approaches.

Bhutan's National Adaptation Programme of Action (NAPA, 2006) is the first and only document that focuses purely on urgent and immediate needs to address vulnerabilities to climate change in the country but biodiversity issues are not reflected as immediate short-term priorities. In order to ensure persistence of biological diversity, policies for climate change adaptation and mitigation have to be sound and farsighted and respect the role that diverse natural ecosystems play.

7.5. Lack of capacity

There is a lack of national capacity in terms of institutional, human and financial resources across the board in dealing with climate change and its effects on biological diversity. Inadequate capacity acts as a barrier in understanding the responses of biodiversity to climate change and in implementing activities related to climate change adaptation and biodiversity conservation.

Currently, the overriding importance of socio-economic development and poverty eradication in the country and limited resources has also resulted in low attention for climate change and biodiversity loss. This is further compounded by the lack of sufficient donors to fund core environmental management activities leading to limited expertise and resources to carry out adaptation and mitigation activities. Therefore capacity building needs to be prioritized in the broad areas of institutional building, technology transfer, technical expertise and infrastructure strengthening. The specific areas that need to be addressed include research and assessment, monitoring, extension and training, and policy development.

7.6. Weak linkages and coordination amongst stakeholders

There are a number of institutions working on biodiversity and related fields in the country. However, currently there is weak coordination and linkage between biodiversity stakeholders in the country as well as with donors and amongst donors. This has resulted in a lack of synergy of different efforts in the country to strengthen the country's ability to adapt to climate change. The coordination of information sharing and dissemination is a cross-sectoral issue which is crucial for an integrated and holistic response to climate change at national and regional levels. In view of the limited human and financial resources and in order to ensure the optimal utilization of these resources as well as progressive advancements in the field of biodiversity persistence and climate change, it is important to identify the most effective mechanisms of collaboration and minimize duplication of works.

8. Strategies and actions

This action plan was developed through a series of multi-stakeholder consultative workshops with representations from national, regional and international biodiversity organizations. The strategies and actions outlined in this action plan are based on gaps identified by various working groups and survey 2010 results.

An adaptation strategy, which integrates the wise use of biodiversity and ecosystem services, is adopted as it can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity (CBD, 2009). However, where relevant, species specific adaptation strategies are included since species' response will ultimately determine the ability of ecosystems to adjust and persist under changing climate (Campbell et al, 2009). In addition, assessing the status of species is one of the widely used indicators for monitoring biodiversity trends and loss (Allen et al, 2010).

The overall goal of this action plan is to enable persistence of biodiversity to adapt to climate change, reduce vulnerability from its impacts, and to engender the sustainable socio-economic development of the country.

To attain the above goal, the action plan is guided by the following key objectives:

1. To improve understanding on climate change science and the impact of climate change on biodiversity and derived ecosystem services.
2. To increase awareness on climate change impacts on biodiversity and capacity to respond by the local communities.
3. To minimise impacts of climate change on biodiversity to maintain/enhance continuous flow of services for human wellbeing.
4. To minimise impacts of other stressors (Invasive species, land use and land cover change, fire, pest and diseases, etc) on biodiversity under changing climate.
5. To mainstream climate change and biodiversity in national plans and programs.

Objective 1: To improve understanding on climate change science and the impacts of climate change on biodiversity and derived ecosystem services.

Strategy 1.1: Gathering comprehensive data and information on the biological diversity of the country including derived ecosystem services.

Action 1.1.1: Identify gaps in the existing data on climate change and biological diversity and complete documentation of biological diversity of the country, including but not limited to vascular and non-vascular plants, fungi, birds, mammals, amphibians, invertebrates, herpetofauna, aquatic biodiversity, microbes, etc.

Action 1.1.2: Expand existing facilities for voucher specimen repository for prioritized groups of biological diversity.

Action 1.1.3: Complete the on-going inventory of wetland and freshwater ecosystems.

Action 1.1.4: Identify and establish subject matter specialist groups (including retired experts) to inventory and document the biological diversity of the country.

Action 1.1.5: Review forest cover and forest types and standardise the current forests classification and ecological zones.

Action 1.1.6: Institutionalize regular reporting on the state of the forests.

Action 1.1.7: Strengthen studies on valuation of ecosystem services best adapted to the local situation.

Strategy 1. 2: Enhancing understanding of climate change impacts on biodiversity.

Action 1.2.1: Develop effective mechanism for co-ordination, collection, and sharing of meteorological data amongst relevant stakeholders through establishment of meteorological stations of uniform standards along different eco-floristic zones of the country.

Action 1.2.2: Institutionalize and strengthen capacity for meteorological data collection and climate forecasting.

Action 1.2.3: Develop ecological criteria for identifying those species and ecosystems at greatest risk from climate change through expert consultative meetings/workshops.

Action 1.2.4: Identify possible climate change indicator species to monitor the impacts of climate change.

Action 1.2.5: Conduct long-term and short-term research on impacts of climate change on those ecosystems and species identified to be at high risk.

Action 1.2.6: Develop downscaled models to predict climate change impacts on biodiversity at species and ecosystem levels.

Action 1.2.7: Strengthen and institutionalise regular monitoring and status reporting of critical ecosystems and species at risk.

Action 1.2.8: Institutionalize and incorporate reporting on impacts of climate change on biodiversity into the state of environment reporting.

Action 1.2.9: Strengthen technology transfer, sharing of best practices and research results within the regional institutions and partner countries on understanding impacts of climate change on biodiversity.

Objective 2: To increase awareness of climate change impacts on biodiversity and capacity to respond at all levels..

Strategy 2.1: Implementing effective communication and education programs on impacts of climate change on biodiversity.

Action 2.1.1: Identify right/appropriate organization to co-ordinate communication and education programs on climate change impacts and biodiversity.

Action 2.1.2: Develop education and communication materials on climate change and biodiversity linkages.

Action 2.1.3: Incorporate climate change and biodiversity issues in the school and university curricula.

Action 2.1.4: Conduct awareness and education programs on climate change and biodiversity through all forms of media and communication outreach.

Strategy 2.2: Establishing an effective communication and outreach mechanism to improve coordination and dissemination of information amongst relevant stakeholders.

Action 2.2.1: Identify nodal agencies that would provide regular inputs on climate change and biodiversity related information and publications.

Action 2.2.2: Identify a lead agency to co-ordinate, collate and disseminate information received from the nodal agencies.

Action 2.2.3: Disseminate climate change and biodiversity information through development or integration into existing biodiversity portals/websites and by other means.

Strategy 2.3: Strengthening capacity to respond to the impacts of climate change on biodiversity and reduce vulnerability.

Action 2.3.1: Conduct capacity needs assessment for addressing impacts of climate change on biodiversity.

Action 2.3.2: Strengthen capacity based on needs assessment to understand and address impacts of climate change on biodiversity.

Action 2.3.3: Conduct awareness campaigns and trainings for strengthening local community capacity to adapt to impacts of climate change on biodiversity and livelihoods.

Action 2.3.4: Expand education and training of local communities in the sustainable management of private/community forestry and Non Wood Forest Products (NWFPs).

Action 2.3.5: Incorporate traditional knowledge and local community perspectives in climate change adaptation and coping mechanisms.

Objective 3: To minimise impacts of climate change on biodiversity to maintain/enhance ecosystem health and continuous flow of ecosystem services.

Strategy 3.1: Strengthening the functionality of protected area systems and biological corridors under changing climate.

Action 3.1.1: Review and realign current protected areas and biological corridors and their management plans, taking into account their functionality and efficacy under changing climate.

Action 3.1.2: Fully operationalize protected areas and biological corridors to increase resilience to climate change and ensure the continued delivery of ecosystem services.

Action 3.1.3: Develop and implement sound protocol/guidelines and eco-friendly technologies for infrastructure development within the protected areas, biological corridors, and conservation areas to minimize the negative impacts and ensure their functionality.

Action 3.1.4: Strengthen enforcement of Environmental Impact Assessment (EIA) requirements and monitoring for infrastructure development within the Protected Areas systems and conservation areas.

Action 3.1.5: Create and manage regional level landscape and ecological connectivity through strengthened trans-boundary collaboration.

Action 3.1.6: Strengthen transboundary collaboration on movement and trade of wildlife and wildlife products.

Strategy 3.2: Ensuring sustainable forest management to mitigate and adapt to climate change.

Action 3.2.1: Review the current forest management planning and codes of practices, taking into account changing climate, biodiversity and ecosystem services.

Action 3.2.2: Develop national REDD-plus strategy and road map, considering biodiversity safeguards.

Action 3.2.3: Implement plans and measures proposed in the national REDD+ strategies to secure REDD+ benefits (monetary, technology, human capacity).

Action 3.2.4: Strengthen participatory forestry management programs including community forestry, farm/agro-forestry and private forestry programs

Action 3.2.5: Strengthen research and monitoring capacity on NWFPs and institutionalize regular monitoring program.

Strategy 3.3: Strengthening species conservation and management program.

Action 3.3.1: Identify threatened, endemic and keystone species, and assess their population status, ranges and habitats.

Action 3.3.2: Implement a robust conservation and management program of species with high conservation significance, in particular Royal Bengal tiger and snow leopard.

Actions 3.3.3: Review the list of threatened and protected species under Schedule I of the Forests and Nature Conservation Act of Bhutan, 1995, considering the impacts associated with climate change.

Strategy 3.4: Implementing improved technologies for efficient use of natural resources.

Action 3.4.1: Implement improved timber felling and sawing techniques to minimize destruction of the surrounding vegetation and waste respectively.

Action 3.4.2: Promote and facilitate the use of efficient wood/timber treatment techniques to increase the durability of construction materials.

Action 3.4.3: Develop and promote energy efficient technologies in construction, heating and cooking, etc.

Action 3.4.4: Develop and implement efficient technologies for harvesting and processing of NWPFs.

Strategy 3.5: Conserving agro-biodiversity to promote adaptation of crops and livestock to changing climatic conditions.

Action 3.5.1: Conduct genetic diversity assessment and mapping of major food crops and livestock breeds of the country.

Action 3.5.2: Strengthen *ex-situ* conservation facilities, collections, and services.

Action 3.5.3: Conserve diverse agricultural systems and landscapes including crop wild relatives and their habitats.

Action 3.5.4: Strengthen on-farm conservation of landraces of crops and native livestock breeds.

Action 3.5.5: Promote and strengthen crop diversification and integration with other farming activities.

Action 3.5.6: Strengthen capacity of local communities to manage local crop and livestock diversity under changing climate.

4: To minimise impacts of other stressors of biodiversity (invasive species, fire, pest and diseases, etc.) under changing climate.

Strategy 4.1: Developing and implementing measures to protect natural ecosystems and agriculture production against invasive species.

Action 4.1.1*:* Update the national invasive species list and their current distribution, and prioritize high risk species.

Action 4.1.2: Develop invasive species management strategies, including threat abatement plans and strategies, taking into account the potential effects of climate change on their ecology.

Action 4.1.3: Strengthen institutional collaboration and coordination in research, information sharing, and management of invasive species.

Action 4.1.4: Strengthen national capacity and formulate policy to regulate the entry and monitoring of alien species in the country, including protocols for introducing alien species.

Action 4.1.5: Conduct public education and awareness on invasive species and its impacts on natural ecosystems and agriculture production.

Strategy 4.2: Developing and implementing a comprehensive forest fire management program, taking into account the changing climatic conditions.

Action 4.2.1: Strengthen fire ecology research under different ecosystems in the light of climate change.

Action 4.2.2: Experiment fire as a management tool for those ecosystems with history of fire as natural disturbance regime for maintenance of biodiversity (eg: High altitude rangeland).

Action 4.2.3: Strengthen national fire management program in terms of human capacity, technology, equipment, coordination, surveillance and response system, etc.

Action 4.2.4: Strengthen awareness and capacities of local communities in combating and managing forest fires.

Strategy 4.3: Strengthening national capacity on identification and management of pests and diseases, taking into account the potential effects of climate change on their ecology and epidemiology.

Action 4.3.1: Conduct comprehensive inventory of the current pests and diseases affecting plants and animals.

Action 4.3.2: Consolidate and upgrade the existing pest and disease laboratories to international standards to provide efficient services.

Action 4.3.3: Strengthen technical capacity on pests and disease surveillance, identification, management and monitoring.

Objective 5: To mainstream impacts of climate change on biodiversity into national plans and programs

Strategy 5.1 Developing tools and guidelines to mainstream climate change impacts on biodiversity.

Action 5.1.1: Develop protocols for policy scanning to ensure that impacts of climate change on biodiversity are factored into national policies.

Action 5.1.2: Develop tools and guidelines to address climate change impacts on biodiversity in national and local development plans and programs.

Strategy 5.2: Mainstreaming climate change impacts on biodiversity into national plans and programs.

Action 5.2.1: Review, assess and realign institutional set up and mandates of biodiversity conservation organizations for effective coordination, synergy, and service delivery.

Action 5.2.2: Incorporate climate change impacts on biodiversity into Five Year development planning guidelines.

Action 5.2.3: Incorporate a provision for assessing the impacts of climate change on biodiversity in the Environment Impact Assessment procedures.

Action 5.2.4: Strengthen local capacity and community engagement in incorporating and implementing biodiversity and climate change adaptation and mitigation activities into local and national development plans and programs.

Action 5.2.5: Integrate existing and emerging knowledge on biodiversity and climate change into biodiversity management plans and development programs to ensure climate proofing.

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Annexures   Annexure I

Major ecosystems of Bhutan (Adapted from BAP, 2009 & 2002 & Chettri, et al, 2009)

Ecosystem Type	Characteristic Flora	Characteristic Fauna
Alpines/Sub alpine ecosystem (between the tree line at 4000 m to the snow line at 5,500 m)	Alpine meadows, scrubs, herbs, fungi. Eg: *Picrorhiza kurooa and Fritillaria delavayi, Meconopsis simplicifolia, Dactylorhiza hatagirea (CITES Appen. II), Ophiocordyceps sinensis*	**Mammals:** Marmot, Snow leopard, Blue sheep, Pika, Red fox, Musk deer **Birds:** Tibetan snow cock, Snow partridge, Grandala, Lammergeier, Himalayan monal pheasant, Alpine accentor, Oriental skylark, Blood pheasant.
Forest Ecosystem (between 150 m to 4000 m)		
Juniper/Rhododendron Scrub	*Juniperus recurva J. squamata, Rhododendron lepidotum, Morina nepalensis, Thalictrum chelidonii, Pedicularis megalantha*	**Mammals:** Wild dog, Barking deer, Serow, Musk deer, Takin. **Birds:** White-browed rose finch, Snow pigeon, White-browed bush robin, Golden bush robin, Blood pheasant, Fire-tailed sunbird
Fir Forest	*Abies densa, Juniperus pseudosabina, Skimmia laureola, Viburnum nervosum, Rheum acuminatum, Maddenia himalaica*	**Mammals:** Musk deer, Leopard, Yellow throated martin. **Birds:** Rufous-vented tit, Grey-crested tit, Orange –flanked bush robin, Long tailed thrush, White-browed fulvetta, Eurasian tree creeper
Hemlock Forest	*Tsuga dumosa, Larix griffithiana, Gaultheria fragratissima, Panax pseudo-ginseng, Daphne bholua, Arundinaria griffithiana*	**Mammals:** Sambhar, Serow, Black bear, Barking deer. **Birds:** Black-throated tit, Black-throated fulvetta, Green-tailed sunbird, Rusty-flanked tree creeper, Lesser cuckoo
Spruce Forest	*Picea brachytyla, Rosa macrophylla, Taxus baccata, Picea spinulosa, Acer cappadocicum, Larix griffithiana, Hydrangea sp.*	**Mammals**: Sambhar **Birds:** Black-throated tit, Rusty-flanked tree creeper, Black-throated fulvetta
Blue Pine Forest	*Pinus wallichiana, Berberis asiatica, Cotoneaster griffithii, Lyonia*	**Mammals:** Leopard, Sambhar, Goral

	ovalifolia, Rhododendron arboretum, Arisaema consanguineum	**Birds:** Green-backed tit, Yellow-billed blue magpie, Grey-backed shrike, Red-billed cough, Common kestrel, Collared blackbird, White-throated laughing thrush
Evergreen/Oak Forest	*Acer campbelli, Castanopsis hystrix, C. tribuloides, Elatostema hookerianum, Quercus lamellosa, Skimmia arborescens*	**Mammals:** Tiger, Leopard, Barking deer, Sambhar, Wild dog **Birds**: Kaleej pheasant, Leaf warbler, Grey-winged black bird, Green-backed tit, Chestnut-breasted partridge, Wood snipe
Cool Broadleaf Forest	*Acer campbelli, Betula alnoides, Exbuclandia populnea, Lindera pulcherrima, Persea clarkeana, Symplocos dryophila*	**Mammals:** Leopard, Black bear, Barking deer, Red panda. **Birds:** White-throated laughing thrush, Rufous-necked hornbill, Chestnut-crowned laughing thrush, Snowy-browed fly catcher, Mountain hawk eagle, Tawny owl, Ward's trogon, Pygmy wren babbler, Great babbler
Chir Pine Forest	*Pinus roxburghii, Cycas pectinata, Cymbopogon flexousus, Euphorbia royleana, Woodfordia fructicosa, Grewia sapida, Buddleja bhutanica, Rhododendron arboreum*	**Mammals:** Goral, Yellow-throated martin, Barking deer. **Birds:** Black bulbul, Mountain bulbul, Grey-tree pie, Rufous woodpecker, Red-vented bulbul, Bar-winged fly-catcher shrike, Saphire flycatcher, Himalayan bulbul
Warm Broadleaf Forest	*Altingia excelsa, Bischofia javanica, Castanopsis indica, Engelhardia spicata, Macaranga postulate, Schima wallichii, Alnus nepalensis, Michelia exelsa, Morus sp., Amoora rhotica*	**Mammals:** Red panda, Barking deer, Sambhar, Tiger, Capped langur, Serow, Leopard. **Birds**: Rufous-necked hornbill, Palla's fish eagle, Great hornbill, Wreathed hornbill, Common lora, white-breasted kingfisher, Oriental turtle dove, Leaf warbler, Hodgson's hawk cuckoo, Chestnut-breasted partridge
Sub-tropical Forest	*Acrocarpus fraxinifolius, Ailanthus grandis, Bombax ceiba, Duabanga grandiflora, Shorea robusta, Pterospermium acerifolium, Acquilaria agalocha, Gmelinia arborea, Terminalia sp., Michelia*	**Mammals:** Golden langur, Capped langur, Pygmy hog, Marbled cat, Asiatic golden cat, Tiger, Fishing cat, Elephant, Clouded leopard. **Birds:** Large-billed crow, Blue whistling thrush, Pin-tailed green pigeon, Orange-

	champaca, Acacia catechu, Chukrasia tabularis, Toona ciliata, Lagestroemia sp., Phoebe sp., Artocarpus sp.	breasted green pigeon, Spotted dove, Great coucal, Rose-ringed parakeet, Asian emerald cuckoo, Blue-bearded bee eater, Blue-Bearded barbet, Large hawk cuckoo, Rufous–necked hornbill, Palla's fish eagle
Wetlands and freshwater ecosystems	*Ranunculus trychophyllus, Hydrilla verticillate, Potamogeton crispus, Ranunculus tricuspis, Acorus calamus, A. gramineus, Shoenoplectus juncoides, Typhus spp., Phragmites spp., Equisetum spp., Aconogonum alpinum, Carex spp., Juncus spp., Salix spp.,* etc.	Himalayan trout (*Barilius spp*), mahseer *Tor tor*, brown trout *Salmo trutta trutta* (introduced), etc. Marshes are winter habitat of globally threatened black-necked cranes *Grus nigrocollis*
Agricultural Ecosystem	**Major agriculture and horticulture crops** Rice , maize, wheat, buckwheat, barley, millet, legumes, apple, citrus, cardamom, ginger, potato, mustard, groundnut, etc.	**Major livestock breeds** Yaks, cattle, sheep, goats, horses, pigs, poultry

Annexure 2

List of endemic plants of Bhutan

S/N	Species	Family
1	*Allium rhabdotum* Stearn	Alliaceae
2	*Androsace hemisphaerica* Ludlow	Primulaceae
3	*Androsace ludlowiana* Handel-Mazzetti	Primulaceae
4	*Arundinella dagana* Noltie	Poaceae (Gramineae)
5	*Bhutanthera albosanguinea* Renz.	Orchidaceae
6	*Bhutanthera albovirens* Renz.	Orchidaceae
7	*Bhutanthera himalayana* Reinz.	Orchidaceae
8	*Buddleja bhutanica* Yamazaki	Buddlejaceae
9	*Bulbophyllum leopardinum* var. *tuberculatum* N. P. Balakrishnan & S. Chowdhury	Orchidaceae
10	*Ceropegia bhutanica* Hara	Asclepediaceae
11	*Ceropegia dorjei* C.E.F. Fischer	Asclepediaceae
12	*Ceropegia ludlowii* H. Huber	Asclepediaceae
13	*Ceropegia ugenii* C.E.F.Fisher	Asclepediaceae
14	*Cheirostylis sherriffii* N. Pearce & P. J. Cribb	Orchidaceae
15	*Cnidium bhutanicum* Watson	Umbelliferae (Apiaceae)
16	*Corallodiscus cooperi* (Craib) B.L.Burtt.	Gesneriaceae
17	*Corydalis aurantiaca* Ludlow	Fumariaceae
18	*Corydalis calliantha* Long	Fumariaceae
19	*Corydalis leptantha* Liden	Fumariaceae
20	*Corydalsi oxalidifolia* Ludlow	Fumariaceae
21	*Corylopsis himalayana* Griffith	Hamamelidaceae
22	*Cromapanax lobatus* Grierson	Araliaceae
23	*Cryptocarya bhutanica* Long	Lauraceae
24	*Cymbopogon bhutanicus* Noltie	Poaceae (Gramineae)
25	*Daphne ludlowii* Long & Rae	Thymelaeceae
26	*Draba sherriffii* Grierson	Cruciferae (Brassicaceae)
27	*Elatostema longicaudatum* Grierson & Long	Urticaceae
28	*Eriocaulon bhutanicum* Noltie	Eriocaulaceae
29	*Eulophia stenopetala* Lindl.	Orchidaceae
30	*Flemingia bhutanica* Grierson	Leguminosae (Fabaceae)
31	*Gentiana wangchukii* E. Aitken & D.G.Long	Gentianaceae
32	*Gentianella griersonii* E. Aitken & D.G. Long	Gentianaceae
33	*Glochidion bhutanicum* Long	Euphorbiaceae
34	*Hedychium griersonianum* R.M.Smith	Zingiberaceae

35	*Hedyotis griffithii* Hook.f	Rubiaceae
36	*Heracleum bhutanicum* Watson	Umbelliferae (Apiaceae)
37	*Herminium pygmaeum* Renz	Orchidaceae
38	*Hetaeria pelota* N. Pearce & P. J. Cribb	Orchidaceae
39	*Hoya bhutanica* Grierson & Long	Asclepediaceae
40	*Hypericum sherriffii* Robson	Guttiferae (Clusiaceae)
41	*Isodon atroruber* Clements	Labiatae
42	*Keraymonia pinnatifolia* Watson	Umbelliferae (Apiaceae)
43	*Kickxia membranaceae* Sutton	Scrophulariaceae
44	*Kickxia papillosa* Mill	Scrophulariaceae
45	*Lobelia nubigena* Anthony	Campanulaceae
46	*Lycium armatum* Griffith	Solanaceae
47	*Meeboldia digitata* (Kljuykov) Watson	Umbelliferae (Apiaceae)
48	*Musa griersonii* Noltie	Musaceae
49	*Neopicrorhiza minima* Mill	Scrophulariaceae
50	*Onosma bhutanica* (Johnston) Grierson & Long	Boraginaceae
51	*Onosma griersonii* Mill.	Boraginaceae
52	*Ophiorrhiza longii* Wood	Rubiaceae
53	*Oreorchis sanguinea* (N. Pearce & P. J. Cribb) N. Pearce & P. J. Cribb	Orchidaceae
54	*Pedicularis dhurensis* R.R.Mill	Scrophulariaceae
55	*Pedicularis hicksii* Tsoong	Scrophulariaceae
56	*Pedicularis imbricata* Tsoong	Scrophulariaceae
57	*Pedicularis inconspicua* Tsoong	Scrophulariaceae
58	*Pedicularis longipedicellata* Tsoong. Var. *lanocalyx* R.R.Mill	Scrophulariaceae
59	*Pedicularis longipedicellata* var. *longipedicellata* Tsoong	Scrophulariaceae
60	*Pedicularis ludowiana* Tsoong	Scrophulariaceae
61	*Pedicularis melalimne* R.R.Mill	Scrophulariaceae
62	*Pedicularis microloba* R.R.Mill	Scrophulariaceae
63	*Pedicularis mucronulata* Tsoong	Scrophulariaceae
64	*Pedicularis perpusilla* Tsoong	Scrophulariaceae
65	*Pedicularis porriginosa* Tsoong	Scrophulariaceae
66	*Pedicularis sanguilimbata* R.R.Mill	Scrophulariaceae
67	*Pedicularis woodii* R.R.Mill	Scrophulariaceae
68	*Pedicularis xylopoda* Tsoong	Scrophulariaceae
69	*Persea bootanica* (Meisner) Kostermans	Lauraceae
70	*Pinus bhutanica* Grierson , D.G.Long & C.N.Page	Pinaceae
71	*Pomatocalpa bhutanicum* N. P. Balakrishnan	Orchidaceae
72	*Potentilla arbuscula* var. *unifoliata* Ludlow	Rosaceae

73	*Potentilla bhutanica* Ludlow	Rosaceae
74	*Primula chasmophila* Hutchinson	Primulaceae
75	*Primula jigmediana* W.W.Smith	Primulaceae
76	*Primula sherriffae* W.W. Smith	Primulaceae
77	*Primula umbratilis* Balfour.f. & Cooper	Primulaceae
78	*Primula xanthopa* Balfour.f.& Cooper	Primulaceae
79	*Rhodiola marginata* Grierson	Crassulaceae
80	*Rhododendron bhutanense* Long & Bowes Lyon	Ericaceae
81	*Rhododendron kesangiae* Long & Rushforth	Ericaceae
82	*Rhododendron pogonophyllum* Cowan & Davidian	Ericaceae
83	*Rubus cooperi* Long	Rosaceae
84	*Rubus sengorensis* Grierson & Long	Rosaceae
85	*Saxifraga flavida* H.Smith	Saxifragaceae
86	*Saxifraga harry-smithii* Wadhwa	Saxifragaceae
87	*Saxifraga serrula* H. Smith	Saxifragaceae
88	*Saxifraga sherriffii* H. Smith	Saxifragaceae
89	*Saxifraga thiantha* H. Smith	Saxifragaceae
90	*Saxifraga vacillans* H. Smith	Saxifragaceae
91	*Schulzia bhutanica* Watson	Umbelliferae (Apiaceae)
92	*Scrophularia cooperi* R.R. Mill.	Scrophulariaceae
93	*Scrophularia subsessilis* R.R. Mill.	Scrophulariaceae
94	*Sibbaldia byssitecta* Sojak	Rosaceae
95	*Silene julaensis* Grierson	Caryophyllaceae
96	*Stipa bhutanica* Noltie	Poaceae (Gramineae)
97	*Stipa jacquemontii* Jaub. & Spach subsp. *chuzomica* Noltie	Poaceae (Gramineae)
98	*Strobilanthes accrescens* subsp. *accrescens* J.R.I.Wood	Acanthaceae
99	*Strobilanthes accrescens* subsp. *teraoi* J.R.I.Wood	Acanthaceae
100	*Strobilanthes jennyae* J.R.I.Wood	Acanthaceae
101	*Swertia crossoloma* H.Smith	Gentianaceae
102	*Swertia grandiflora* H.Smith	Gentianaceae
103	*Torenia burrttiana R.R.Mill*	Scrophulariaceae
104	*Vanda bicolor* Griff.	Orchidaceae
105	*Viola bhutanica* Hara	Violaceae

Annexure 3

List of globally threatened mammal species found in Bhutan.

Species	Global Threat Category
Pygmy Hog *Sus salvanius*	Critically Endangered
Golden Langur *Trachypithecus geei*	Endangered
Capped Langur *Trachypithecus pileatus*	Endangered
Dhole/ Wild Dog *Cuon alpinus*	Endangered
Red Panda *Ailurus fulgens*	Endangered
Bengal Tiger *Panthera tigris tigris*	Endangered
Snow Leopard *Uncia uncia*	Endangered
Asian Elephant *Elephas maximus*	Endangered
One-horned Rhinoceros *Rhinoceros unicornis*	Endangered
Asiatic Water Buffalo *Bubalus bubalis*	Endangered
Hispid Hare *Caprolagus hispidus*	Endangered
Ganges River Dolphin *Platanista gangetica*	Endangered
Assamese Macaque *Macaca assamensis*	Vulnerable
Sloth Bear *Melursus ursinus*	Vulnerable
Himalayan Black Bear *Ursus thibetanus laniger*	Vulnerable
Himalayan Musk Deer *Moschus chrysogaster*	Vulnerable
Smooth-coated Otter *Lutrogale perspicillata*	Vulnerable
Fishing Cat *Prionailurus viverrinus*	Vulnerable
Marbled Cat *Pardofelis marmorata*	Vulnerable
Clouded Leopard *Neofelis nebulosa*	Vulnerable
Asiatic Golden Cat *Catopuma temmincki*	Vulnerable
Swamp Deer *Cervus duvauceli*	Vulnerable
Gaur *Bos gaurus*	Vulnerable
Serow *Capricornis sumatraensis*	Vulnerable
Takin *Budorcas taxicolor*	Vulnerable
Mouse-eared Bat *Myotis sicarius*	Vulnerable
Sikkim Rat *Rattus sikkimensis*	Vulnerable