Ecosystem and Socio-economic Resilience Analysis and Mapping

A pilot assessment in White-bellied Heron habitats along Punatsangchhu and Mangdechhu basins, Bhutan

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Developing Ecosystem-based Solutions for Managing Biodiversity Landscapes in Bhutan

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ACRONYMS

ADB	Asian Development Bank
AHP	Analytical Hierarchy Process
ASC	Alternative Specific Constant
CL	Conditional Logit
CLM	Conditional Logit Model
COVID -19	Corona Virus
CVA	Climate change Vulnerability Assessment
CVI	Climate Vulnerability Index
DCE	Discreet Choice Experiment
DoFPS	Department of Forests and Park Services
EbA	Ecosystem-based Adaptation
ESRAM	Ecosystem and Socio-economic Resilience Analysis and Mapping
ESs	Ecosystem Services
ESVD	Ecosystem Services Valuation Database
FAO	Food and Agriculture Organization, United Nations
FGD	Focus Group Discussion
GBIF	Global Biodiversity Information facility
GCM	Global Climate Models
HEP	Hydroelectric Power
HWC	Human-Wildlife Conflict
IPCC	Inter Governmental Panel on Climate Change
KG	Kilogram
LULC	Landuse and Land Cover
LVI	Livelihood Vulnerability Index
MaxEnt	Maximum Entropy
MIROC	Model for Interdisciplinary Research on Climate
MLV	Multidimensional Livelihood Vulnerability
MLVI	Multidimensional Livelihood Vulnerability Index
MRB	Mangdechhu Basin
Nu	Ngultrum
NWFP	Non-Wood Forest Product
PHCB	Population and Housing Census of Bhutan
PRB	Punatsangchhu basin
RCP	Representative Concentration Path
RNR	Renewable Natural Resources
RSPN	Royal Society for Protection of Nature
SDM	Species Distribution Model
USD	United States Dollar
WTP	Willingness To Pay

GLOSSARY OF BHUTANESE TERMS

Chhu	Stream/River
Chiwog	Refers to the basic electoral precinct
Dzongkhag	District
Gewog	An administrative block composing a group of villages in Bhutan
Khengpas	An ethnic group of Bhutan, found primarily in the Zhemgang, Trongsa and Mongar Districts of south-central Bhutan
Lhotshampas	A heterogeneous Bhutanese people of Nepalese descent
Mangdeps	Mangdep speaking people in eastern areas of Wangduephodrang district and the western areas of Trongsa in the central Bhutan
Ngalops	Dzongkha speaking Bhutanese ethnic group dominant in Western and Northern Bhutan
Ngultrum	The currency of Kingdom of Bhutan
Sharchops	Sharchop (meaning "easterner"), are Tshangla speaking populations of mixed Tibetan, South Asian and Southeast Asian descent that mostly live in the eastern districts of Bhutan

SUMMARY

The project command area is a socio-economically diverse and ecologically rich area. Administratively, the study area falls into part or entirely in 38 Chiwogs under 21 Gewogs of six districts. Around 9,600 households are estimated to be living in the study area. Based on the socio-economic survey covering 1,237 households, the biodiversity assessment, the climate vulnerability assessment, and WBH habitat suitability assessments, the key findings are:

Socially diverse subsistence communities

The study area is socially diverse with communities inhabited by *Ngalops, Sharchops, Lhotshampas, Khengpas,* and *Mangdebs* from 31 Gewogs under six Dzongkhags. The majority (67.4%) of the households are headed by females. Education-wise, more than half (66.9%) of the respondents are illiterate and about only 25% of the respondents have attended formal education.

Mixed farming is the primary occupation of the people. Although all households undertake both agriculture and livestock farming, 85.9% consider agriculture farming as the important source of livelihood while 10.7% consider livestock rearing as the primary source of livelihood. Agriculture is therefore the main source of income for 75.6% of the respondents, followed by others 50.6%, business 8.3%, livestock 7.4% off-farm 6.6%, and 4.5% remittances. Cardamom is an important source of cash income for the respondents in Tshanglajong Chiwog, Nangkhor Gewog under Zhemgang Dzongkhag. The cardamom and oranges are the main sources of cash for the respondents in Tsirang and Dagana, and for some respondents in Wangduephodrang Dzongkhag. Dairy cattle and poultry are commonly raised in all the study areas, while pigs and goats are mostly raised in Dagana and Tsirang dzongkhags partly for commercial purposes.

Human-Wildlife Conflict (HWC) and water shortage - major challenges to communities

HWC is widely reported as a serious problem by 79.38% of the respondents across all the study areas, which is higher than 70% reported for the country in 2017. The impact of this issue is mostly in the form of damage to crops, which 63% of the respondents felt are on the rise. Further, this impact of wildlife damage to crops coupled with labour shortage is responsible for the increase in fallow land and reduction in crop yield. The respondents have adopted several measures either supported by external agents or self-initiated to combat human-wildlife conflict. Electric fencing and physical guarding were reported to be very effective despite the high costs. Though only a small proportion of the households have actually had the opportunity to avail this technology, their effectiveness seems to have generated an immense expectation for government and external agency assistance to address wildlife crop damage and predation.

Shortage of water for drinking and irrigation is another commonly reported issue faced by over 51% of the respondents across the study areas. Areas critically affected by water shortage for irrigation include Talo, Dzomi, Guma, Chubhu, Toedwang, and Lingbukha Gewogs of Punakha and Barshong under Tsirang Dzongkhags.

Climate change and its impact on crop production are rated 'serious' by 48.54%. 26.42% reported degradation of soil fertility as an issue.

Households also faced with the issue of non-availability of timely inputs to agriculture production and difficulty of marketing. 24.89% of the respondents raised the non-availability of timely inputs as seriously affecting crop and livestock production. Lack of piglets was reported as a serious hindrance to pig farming. Similarly, a shortage of water was also raised as a constraint to pursuing fishery as a livelihood option.

About 23.5% of respondents mentioned marketing agricultural products as difficult and therefore a major constraint to alternative income sources.

The importance of farmers' groups and their benefits from them are well understood by the respondents. More than 90% of the respondents believe that the farmers' groups enhance social cohesion by instilling a high sense of we-feeling, improving reciprocity, willingness to help and support each other, self-sufficiency, and strengthening the relationship and solidarity among group members.

Biologically rich area

From the biodiversity assessment, it is clear that the study area is biologically diverse with prime forests, riverine ecosystems, and agroecosystems which not only provide the perfect habitat for the critically endangered WBH but also provide the agrarian communities with a range of products and ecosystem services.

The terrestrial biodiversity along either side of the Punatsangchhu river comprises conifers, deciduous and evergreen forest trees and shrubs. A total of 80 tree species, 85 species of shrubs, and 90 species of herbs were recorded. Within the overall understanding of the area as biologically rich, it may be noted that there are pockets along the forest and riverine ecosystem that have been subject to disturbance and degradation. Stretches of WBH habitat along Punatsangchhu have been under development pressure with increased disturbance. Invasive shrub species such as *Chromolaena odorata* and *Ageratina adenophora* and herbs such as *Parthenium hysterophorus* were also recorded. In addition, 48 bird species were recorded by the RSPN team.

Likewise, Mangdechhu River Basin (MRB) recorded 74 species of trees and 52 species of shrubs. WBH habitats along Mangdechhu are primarily evergreen and deciduous broadleaved forests that were relatively intact under low development pressures. Forest plot surveys also recorded the presence of invasive species such as *Chromolaena odorata* and *Mikania micrantha. About* 37 bird species were recorded by the RSPN team. The area is home to one of the world's most magnificent and critically endangered species, the WBH. Although the study did not specifically conduct a population survey, over twenty WBHs are recorded to be inhabiting the area.

In terms of aquatic biodiversity, 27 species of fish belonging to nine families in Punatsangchhu were recorded. The most abundant fishes were found in Basochhu and Phochhu followed by Dangchhu and Dikchhu. A total of 14 fish species belonging to four families were recorded from the aquatic survey in Mangdechhu. The spring water source and small stream flowing adjacent to the Berti eco-camp were noted as the spawning ground for Golden Mahseer (*Tor putitora*), Copper Mahseer (*Neolissochilus hexagonolepis*) and *Garra* spp as evident from fingerlings recorded in this location. The endemic torrent catfish (*Exostoma mangdechhuensis*) was recorded from and known to be mostly confined to the Dakpaichhu. The most abundant fishes are found in Bipapangchhu followed by Dakpaichhu and Bertichhu.

Provisioning and regulatory ecosystem services are widely acknowledged

The Ecosystem Services (ES) valuation showed that the local communities acknowledged the largest number of goods and services under the provisioning ecosystem service category. Local people are able to rationalize and comprehend most of the ecosystem goods and services that are directly relevant to their day-to-day needs. Hence, local people identified more provisioning and regulating services and less supporting and cultural services. Two inferences can be derived from this:

- Since most of the ecosystem services are reported for provisioning services, it can be inferred that local people's knowledge of other services like regulating, supporting and cultural services are minimal. Future conservation programs must think of how these ecosystem services are made to be understood.
- Provisioning ecosystem services such as fresh water for drinking and irrigation, fuelwood and timber play a prominent role in the livelihood activities of the respondents. Conservation programs targeted toward improving these ecosystem services can be more effective since these are the ones that can be directly measured by households. Future conservation programs must focus on improving access to these services.

The majority of the respondents in both the basins opined that there has been no change in ecosystem services, which is an indication that the local people's needs for the goods and services are generally within the regeneration capacity of the ecosystems. However, there are also certain provisioning services that people demand the most and are reported to be decreasing. Continued demand and uncontrolled appropriation of products and services can impose pressure on the resource.

The choice experiment suggests that surveys that identify preferences and WTP for ecosystem services in specific WBH and Potential-WBH areas can provide a reliable basis for household demand for conservation programs in Bhutan. High protest rates for any proposed fees or labour costs for environmental services can be circumvented by designing appropriate incentives that support conservation programs. These programs can be designed toward providing or improving the ecosystem services that are most preferred by communities. For example, a focus on improving water for drinking and irrigation services can positively incentivize communities to engage in conservation measures that may involve monetary or labour contributions.

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The choice of ecosystem services is important for assessing the economic viability of rural projects. In this study, irrigation and drinking water and fuelwood played an important role in generating choices away from the status quo. Responses from the valuation survey demonstrated farmers' willingness to pay in both monetary and non-monetary terms for programs geared towards conservation. While some preferred labour contribution as more feasible, there were also those who expressed a preference for a monetary contribution. Consideration of such preferences is essential for the formulation of community-based conservation programmes. Without considering these preferences, conservation efforts and programs may receive little attention in the field.

Besides estimating the cost of benefitting from ecosystem services, this study also identifies the value of and preference for individual services. The study also brought to light the differences in preferences for ecosystem services among different cohorts and socioeconomic conditions. Since the method was used to find out whether there are specific ecosystem services that they value the most, it should be reiterated that future programs must understand that households have a distinct set of preferences

over the ecosystem goods and services. One-third of the respondents preferred the status quo over alternative changes in ecosystem initiatives. This study revealed that:

- households understand the value of species like WBH and the indirect benefits it brings with it. Households showed a very significant preference over the presence of habitat for WBH in their area. This means future programs along the line of WBH conservation may prove to be effective.
- While households showed a specific preference for ecosystem services, they seem less willing to bear the cost for the benefits they derive. This is true for Potential WBH and MRB areas. This is specifically true of areas where WBH habitats are found. For example, there is demand for WBH habitat in their area but they are less likely to bear the cost. These tradeoffs are difficult for farmers. For this, any future programs must note the ability of the farmers to bear any cost of conservation.
- Socio-economic forces like ownership of TV, gender of household head, presence of conservation measures, and HWC were known to influence household preference for ecosystem services. For instance:
  - » The presence of TV has a more informed preference over ecosystem services.
  - » Gender is an important consideration in assessing demand for forest products such as fuelwood and leaf litter. It is found that male-headed households value timber. This kind of gender-based preference can help in understanding communities and designing effective conservation programs.
  - » In Berti, most people were not interested in being members of FUG because of the unavailability of tree species in their forest for timber extraction.
- The benefits from watershed services are much higher for downstream users compared to upstream households. This suggests that participation in watershed activities may increase if government programs exploited this information on differential preferences.

An acknowledgement of these preferences could make a big difference in making future conservation policies more effective and allow proper planning. Variables must be studied and accounted to drive the change of preference towards alternatives favourable than the status quo.

The above choice preference of the communities seems to be well reflected in the monetary value of the ecosystems. The benefit transfer method applied to deriving the monetary value of the forest, orchards, cropland, and riverine (rivers/ lakes) ecosystems revealed that forest and cropland ecosystems provide maximum value. The total mean value of the ecosystem services in the study area is estimated at US $ 11.5 million. At the household level, the value of ecosystem services was estimated at the US $ 9,384 per household. Forests accounted for 67.45% followed by cropland which accounted for 28.75% of the value.

Climate vulnerable communities

The Vulnerability Assessment revealed that the area in the Punatsangchhu basin is more vulnerable than the area in the Mangdechhu basin. All the Gewogs assessed as *'Highly vulnerable'* fall in Punatsangchhu. Smallholders and subsistence farmers are more vulnerable to increased exposure, higher sensitivity, and low adaptive capacity. Hence, small variations in precipitation and temperature affect the farmers in terms of their livelihood strategies, water availability, and food production.

Farmers are mainly constrained by the limited source of income and livelihood diversification options emanating from climate variability that generally causes the shortage of water, land fragmentation, and the occurrence of invasive species.

Based on the above, the study recommends that Chiwogs under *'Highly vulnerable'* Gewogs should be accorded higher priority for EbA interventions to initiate climate-smart agriculture and livelihood diversification activities including water management and HWC mitigation.

Shrinking and shifting WBH habitats

Results from the MaxEnt species distribution model suggest that the existing WBH habitat is not only shrinking but also shifting towards the lower parts of Punatsangchhu basin and Mangdechhu river basins. The study concludes that WBH habitats along Punatsangchhu covering parts of Punakha and Wangduephodrang districts and areas along Mangdechhu bazin in Trongsa are highly disturbed. On the other hand, lower parts of Punatsangchhu extending to parts of Tsirang, Dagana and Bertichhu areas along Mangdechhu appear more suitable.

While the MaxEnt model agrees with Wangduephodrang, Punakha, and Zhemgang as the most suitable habitats of current times, it suggests that the suitability range will change depending on the climate scenario in the future. Under climate scenario RCP 8.5 for the year 2041-2060, the model predicts that the WBH habitat will expand more towards Zhemgang and Sarpang districts.

01 INTRODUCTION

White-bellied Heron at Punatsangchhu basin/RSPN Archive

1.1 Background

Climate change is the single most overarching threat to life on earth. The manifestations of decades of competing quests for economic development are gradually unfolding in the form of changing ecological and natural resource systems. This convergence of climatic and ecological changes is affecting the well-being of people and communities, especially in developing countries. Degradation of natural resource systems and associated loss of ecosystem services are driving communities into livelihood options to cope with or adapt to the changing climatic and ecological systems. The impact is so significant that strategies to increase resilience while enhancing human wellbeing are urgently needed (Wise et al., 2014). In addition, it is imperative that the symbiotic relationships between ecological, socio-cultural and economic are considered seriously and analyzed critically for probable solutions from different contexts. One of the recent approaches used by researchers is Ecosystem-based Adaptation (EbA), a method used in assessing, mapping and gaining recognition in the areas requiring critical interventions. This entails gaining a deeper understanding of local ecosystem services and livelihood options for integration into development, climate change adaptation, and natural resource management policy and planning processes. Ecosystem and Socio-economic Resilience Analysis and Mapping (ESRAM) is one such method that is increasingly being adopted to identify EbA approaches.

The Royal Society for Protection of Nature (RSPN) is pioneering the application of EbA approaches in Bhutan. Through the German government supported project '*Developing Ecosystem-based Solutions for Managing Biodiversity Landscapes in Bhutan*', RSPN is promulgating the use of EbA approaches to the management of the critically endangered White-bellied Herons (WBH) in the country. The primary objective of the project is to establish approaches and tools for the protection and managing WBH habitats along the Punatsangchhu and Mangdechhu basins in Bhutan. The outcome of the project is effective adaptive ecosystem solutions for WBH conservation in Bhutan (and other Himalayan countries) created through habitat restoration and livelihoods enhancement. Through the successful implementation of the ecosystem-based conservation measures, the project is expected to result in a stable or increasing WBH population in Bhutan and other Himalayan countries.

This study addresses one or more of the project objectives. In particular, this study fulfills two of the project objectives i.e., i) Ecosystem-based biodiversity survey and community engagement strategies for WBH conservation based on the ESRAM approach designed and applied and ii) Capacity of all stakeholders in planning and implementation of ESRAM study, EbA and livelihood options strengthened. In fulfillment of the above two outputs, RSPN fielded the *ESRAM* field assessment in White-bellied Heron habitats along the Punatsangchhu and Mangdechhu basins. This entailed development of ESRAM methodology based on which the ESRAM field assessment was carried out.

This report brings out the findings from the ESRAM assessment. The report is comprised of four chapters with dedicated chapters on the primary components of ESRAM i.e., Socio-economic, Biodiversity, and Climate Change Vulnerability Assessment.

1.2 Country context

Bhutan is located on the southern slopes of the eastern Himalayas, landlocked between the Tibetan Autonomous Region of China to the north and the Indian states of Sikkim to the west, West Bengal and Assam to the south, and Arunachal Pradesh to the east. Covering an area of 38,394 km^2, the country lies between latitudes 26°N and 29°N, and longitudes 88°E and 93°E. Though located in one of the most rugged and fragile eco-regions in the world, the country is renowned for its rich biodiversity and natural resources owing to its extreme altitudinal variations. Within the elevations ranging from 97 meters in the south to over 7,500 meters above sea level in the north, Bhutan has six agro-ecological zones. This variation provides the country with rich natural capital upon which the country's social, cultural, and economic way of life is based.

The rich biodiversity and forest landscapes covering 70.46 percent of the landmass only provides the country with rich natural resources. Approximately 51% of Bhutan falls under designated Protected Areas (PAs), comprising five national parks, four wildlife sanctuaries, a strict nature reserve and several biological corridors connecting the PAs[1]. This makes Bhutan one of the few net carbon sink economies in the world[2]. Bhutan is also endowed with rich water resources. The hydrology of Bhutan correlates with the monsoon rainfall pattern from Bay of Bengal which has significant variation across time and space. Mean annual rainfall ranges from 500 mm to 5,000 mm generating long term mean annual flow of these rivers is 2,325 m^3/s, which is equivalent to 73,000 million m^3 per year. The country is drained by five major north-south rivers namely Amochhu, Wangchhu, Punatsangchhu, and Mangdechhu and Drangmechhu that join the Brahmaputra river to ultimately drain into the Bay of Bengal.

Economy wise, Bhutan remains the least developed country. About 60% of its estimated 750,000 population is still engaged in subsistence agriculture. Though it was earmarked for graduation from LDC in 2023, the country's GDP per capita of US S$ 3,122.4 suffered a major drawback with a negative GDP growth rate from the COVID-19 pandemic and associated restrictions in 2020, 2021, and 2022. The impact of the COVID-19 pandemic is further aggravated by climate change.

The country remains vulnerable to the impacts of climate change and will disproportionately bear the impacts of climate change, exacerbated by a lack of resources and capacities to address the impacts. More than 40 Global Climate Models (GCM) used by the IPCC in its Fifth Assessment Report are reported to conform that the average temperature over Bhutan during winter (December to February) is likely to increase by up to 1.5°C in 2016-2035, and by up to 3.0°C in 2046-2065 under Representative Concentration Path (RCP) 4.5. During summer (June to August), the likely increase in temperature projected by three-quarters of the climate models is by up to 1.0°C in 2016-2035, and by up to 3°C in 2046-2065 under RCP 4.5. The *median* of the projections suggests winter warming of 1.5 to 2°C, and summer warming of 1.0° to 2.0°C. Likewise, climate change projections for Bhutan carried out by the Asian Development Bank (ADB), reported that all models agree on a projected rise in temperature and warming pattern across Bhutan with greater changes projected for the winter season. In the case of rainfall, the majority of models predict an increase in annual rainfall. In the case of precipitation, the agreement among models was reported to be not as strong as for temperature but a general pattern of increasing rainfall was projected by most models. Temperature changes, unpredictable monsoon patterns, droughts and increases in pests and diseases will likely impact agriculture, hydropower along with other infrastructure developments, forest cover, biodiversity, and water resources.

1 Department of Forests and Park Services, 2016, National Environment Commission, 2016
2 Ministry of Agriculture and Forests, 2017

1.2.1 About study area

Within the context of the above national context, the ESRAM assessment was carried out in the prime WBH habitat areas along the Punatsangchhu and Mangdechhu hydrological basins (Figure 1.1). The study area comprised the natural areas and human settlements in two of the five major river basins of Bhutan located along observed and potential habitats of the critically endangered WBH along the Punatsangchhu and Mangdechhu rivers basins.

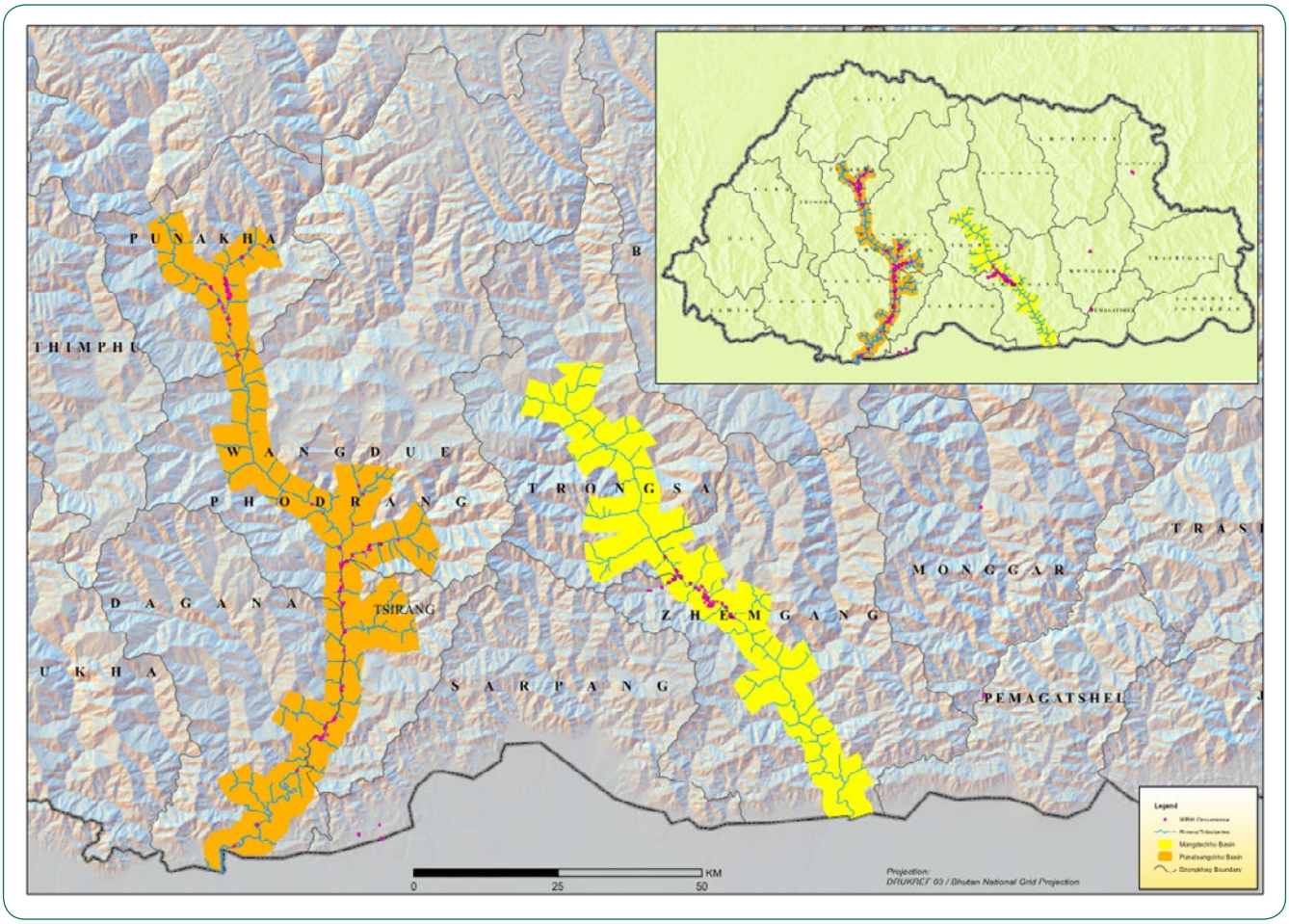


Figure 1.1: Map of Bhutan showing the ESRAM study area

The second-largest heron in the world, WBH is known to occur only in the Eastern Himalayan foothills of Bhutan, North-East India, and Northern Myanmar (Kushlan and Hancock 2005). There are 50-249 matured individuals known to occur in its entire range (Birdlife International 2013). However, now the global population is expected to be less than 60 individuals remaining in these countries (WBH International conference, 2015). The habitat range is usually confined below 1500 masl. In Bhutan, an average of 14-30 individuals are known to occur from the analysis of successive annual population surveys conducted by RSPN since 2003. It is observed along the major river basins and tributaries associated with it. According to Pradhan (2007), about six active nests were recorded in Bhutan in 2007 located at six different sites along the river basins of central Bhutan. However, most of these sites are now disturbed significantly due to the massive hydroelectric scheme and other factors that are believed to have recently caused the bird to disappear from much of its past sighting places.

In Bhutan, two major river basins are known for the abundant distribution of the WBH - *Punatsangchhu* and *Mangdechhu* basins. Therefore, these two river basins were selected for the purpose of this study. The river system harbouring potential WBH habitats are *Phochhu, Mochhu, Bertichhu,* and its tributaries in central Bhutan. *Punatsangchhu* basin, to date, is found to be the most preferred habitat for herons with 14 individuals sighted in 2021 along its basin while Mangdechhu has eight individuals (RSPN 2021). The assessment was conducted within the boundaries of the green highlighted areas in the two river basins (Figure 1.1). An overview of the study areas in the two river basins is described below:

Punatsangchhu River Basin (PRB)

Punatsangchhu is one of the major rivers in Bhutan that flow across the western region through six administrative districts of Gasa, Punakha, Wangduephodrang, Tsirang, Dagana, and Sarpang. Phochhu and Mochhu are its major tributaries with an estimated contribution of more than 80% of the flow volume. The study area along PRB lies between latitudes 27° 08' 44.68", 27° 38' 29.12" and longitude 89° 51' 41.06", 90° 41' 52.68". With altitude variations ranging from 485 to about 2000 meters above sea level (masl) the habitat along *Punatsangchhu* can be classified as subtropical dry chirpine ecosystem (Sherub 2004). High temperature and low rainfall are major characteristics of this ecosystem with temperature variation of maximum 24-39°C and minimum -2 to 6°C (ibid).

The study area under PRBs covers four districts of Punakha, Wangduephodrang, Dagana and Tsirang. The ecosystems in the basin range from warm broadleaf zones in the lower elevations to alpine and temperate blue pine zones in the northern higher elevations. The Puntsangchhu and its tributaries comprise the riverine ecosystems parts of which have been identified as a habitat of the critically endangered WBH.

The PRB is also a socio-economically vibrant area with much of the human settlements concentrated along either side of Punatsangchhu and its tributaries. Based on the Population and Housing Census of Bhutan (PHCB) 2017, an estimated 13469 households distributed across four districts, 34 Gewogs, and 162 Chiwogs inhabit the area (Table 1.1)

Table 1.1: *Number of households in the Chiwogs that fall in the WBH habitat areas of Punatsangchhu*

Districts	Gewogs	Chiwogs	Households
Dagana	11	34	2,565
Punakha	10	39	2409
Tsirang	6	29	1,282
Wangduephodrang	7	60	1,771
TOTAL	**34**	**162**	**8,024**

Note: *The household number are deduced for Chiwogs in the WBH habitat areas based on Population and Housing Census of Bhutan (PHCB) 2017*

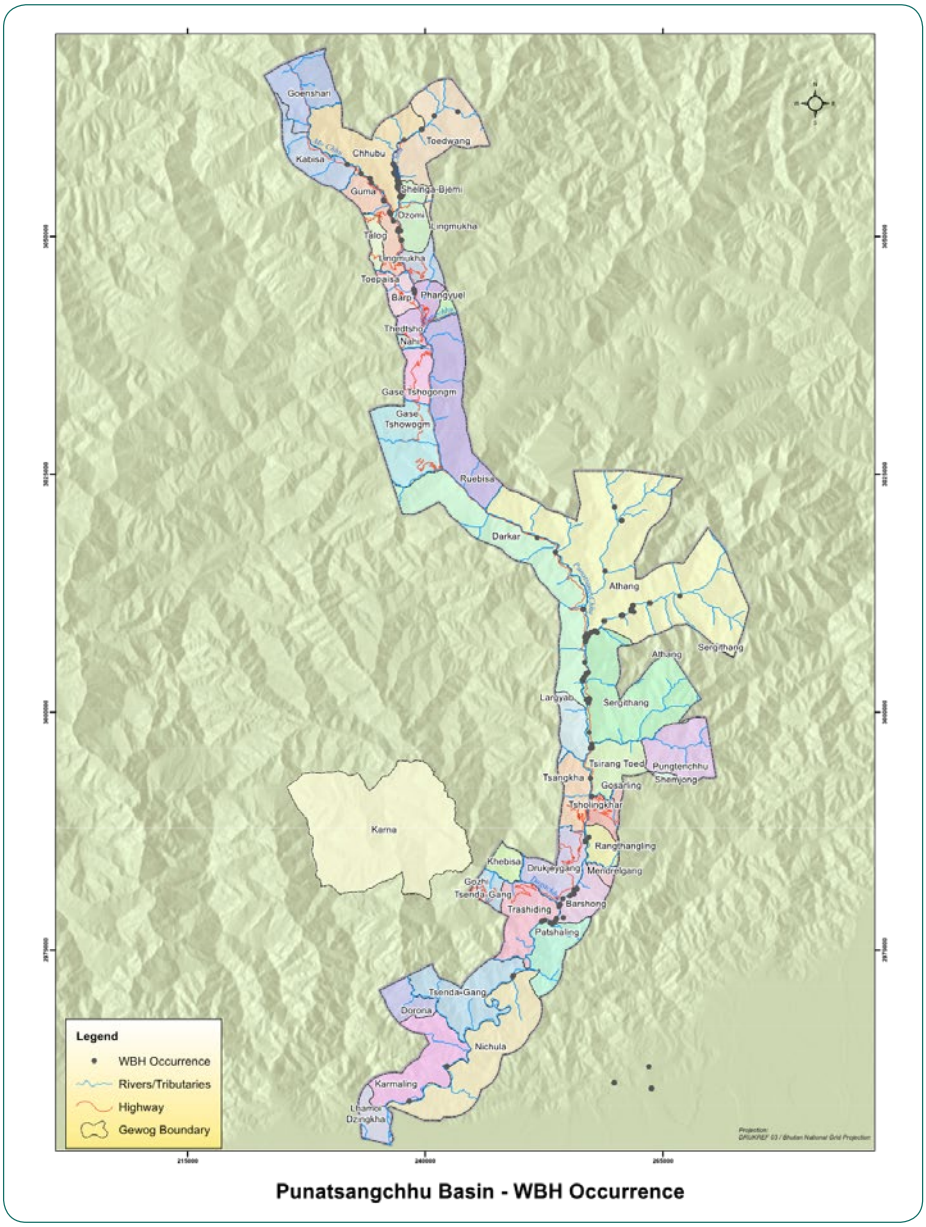


Figure 1.2: White-bellied Heron occurrence in PRB

Mangdechhu basin

The study area in the Mangdechhu basin (MRB) covers two districts, 4 Gewogs, 21 Chiwogs and 1,541 households. A detailed breakdown of number of households in the Chiwogs that partly or entirely fall in the study area is given in Table 1.2

Table 1.2: Number of households in Chiwogs that fall in WBH habitat areas of Mangdechhu

Districts	Gewogs	Chiwogs	Households
Trongsa	2	11	796
Zhemgang	2	10	745
TOTAL	**44**	**21**	**1,541**

Note: *The household number are deduced for Chiwogs in the WBH habitat areas based on Population and Housing Census of Bhutan (PHCB) 2017*

Mangdechhu is a major drainage flowing through the central region of Bhutan stretching across Gasa, Wangduephodrang, Trongsa, Zhemgang, and Sarpang administrative boundaries. The study area in Mangdechhu lies between latitudes of 27° 08′ 45.99″, 27° 10′ 14.99″ and longitudes of 90° 37′ 50.98″ and 90° 41′ 21.59″. The altitude ranges from 553 to 752 masl. The vegetation according to Sherub (2004) is subtropical dry chirpine ecosystem. The maximum temperature ranges from 24-39°C and minimum temperature ranges from -2 to 6°C. It receives an annual rainfall ranging from 56-389 cm. Chirpine (*Pinus roxburghii*) is the dominant canopy species (ibid). Sherub (2004) predict occurrence of 192 bird species in this habitat including WBH. Despite being moderate in bird diversity, it supports 10 species of globally significant birds, for instance *Aceros nipalensi, Tragopan blythii, Spelaeornis caudatus, Spenocichla humei, Harpactes wardii, Actinodura nipalensis, Tickellia hodgsoni, Alcippe ludlowi, Yuhina bakeri* and *Ardea insignis*. The communities falling in the stipulated project area are indicated in the maps (Figure 1.3) below.

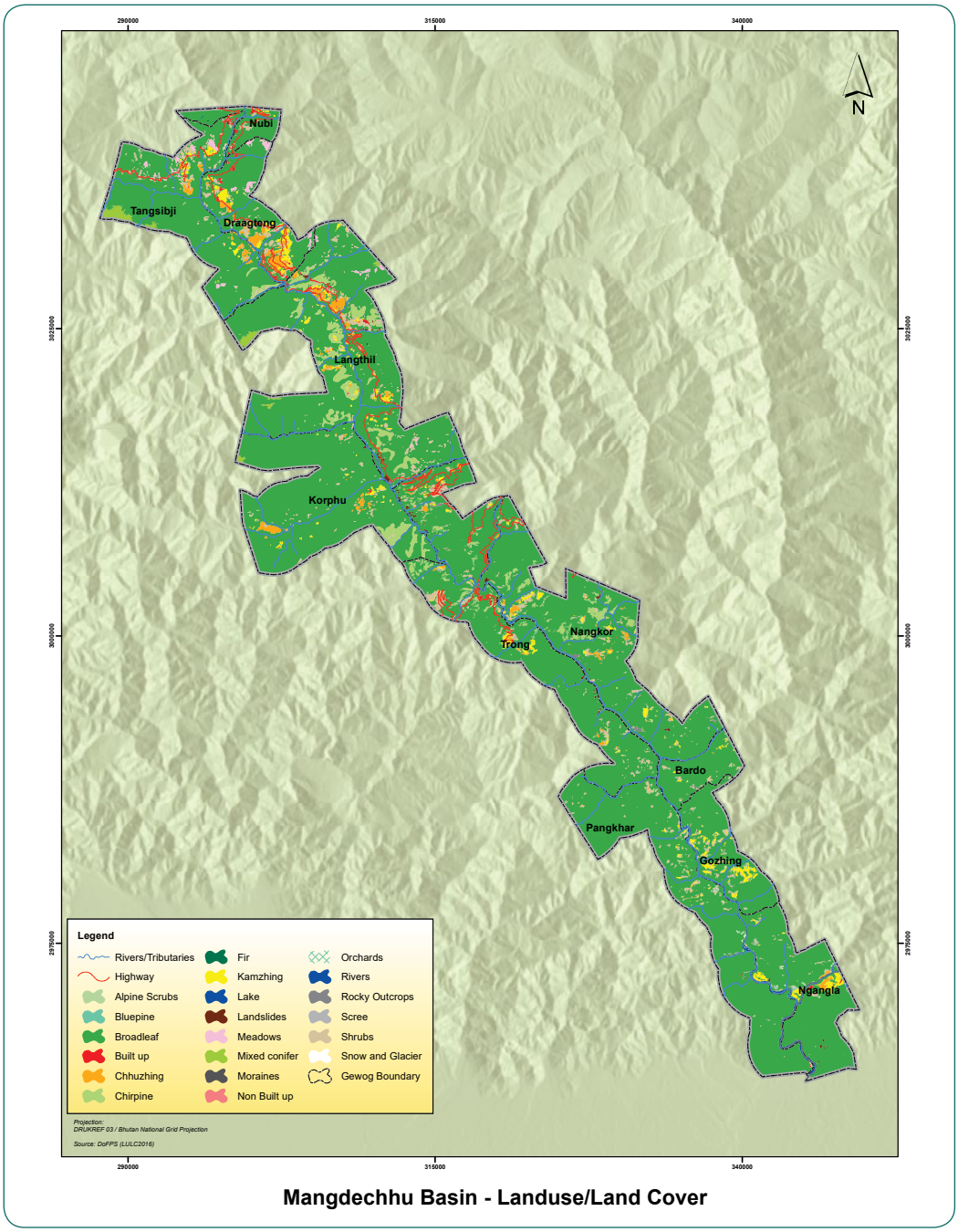
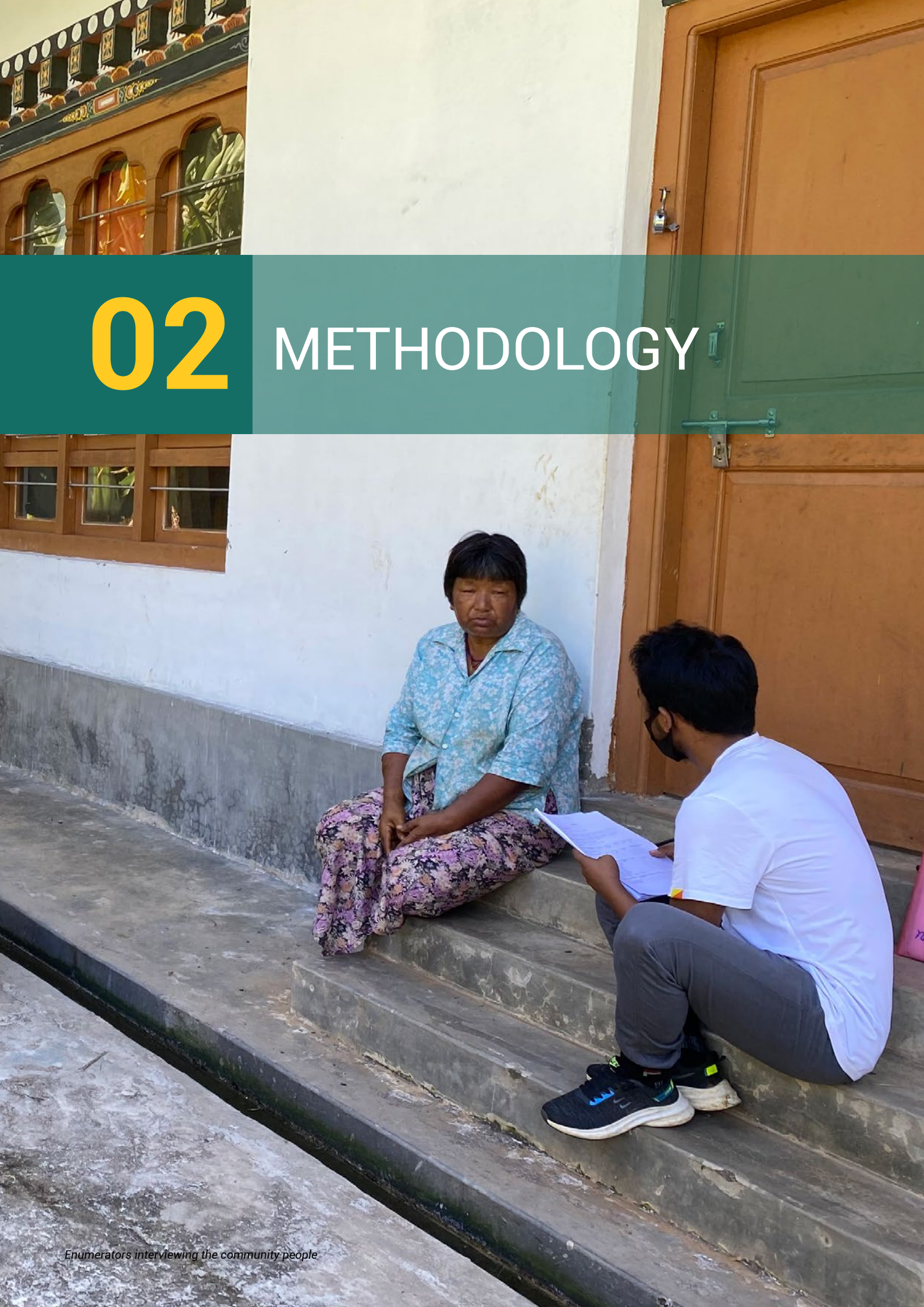


Figure 1.3: *Map of study area in the MRB*

02 METHODOLOGY



Enumerators interviewing the community people

The methodology employed for this study is based on the overarching conceptual framework for ESRAM, which comprises three main assessment components namely i) Environmental assessment, ii) Socio-economic assessment and iii) Climate vulnerability assessment. Each component employs specific methodologies and protocols that are briefly explained below.

2.1 Conceptual framework of the ESRAM study

For the purpose of ESRAM exercise, the conceptual framework developed by the UN Statistical Commission's Experimental Ecosystem Accounting system (EU 2013), was adopted and modified. This framework describes "ecosystem accounting as a coherent and integrated approach to the assessment of the environment through the measurement of ecosystems and the flows of services from ecosystems into economics" and other human needs. Figure 2.1 represents the ESRAM conceptual framework illustrating the assessment and mapping of environmental or ecosystem conditions, governance and socio-economic status, and climate change to arrive at human and species vulnerability, habitat resilience, and options for ecosystem-based adaptation.

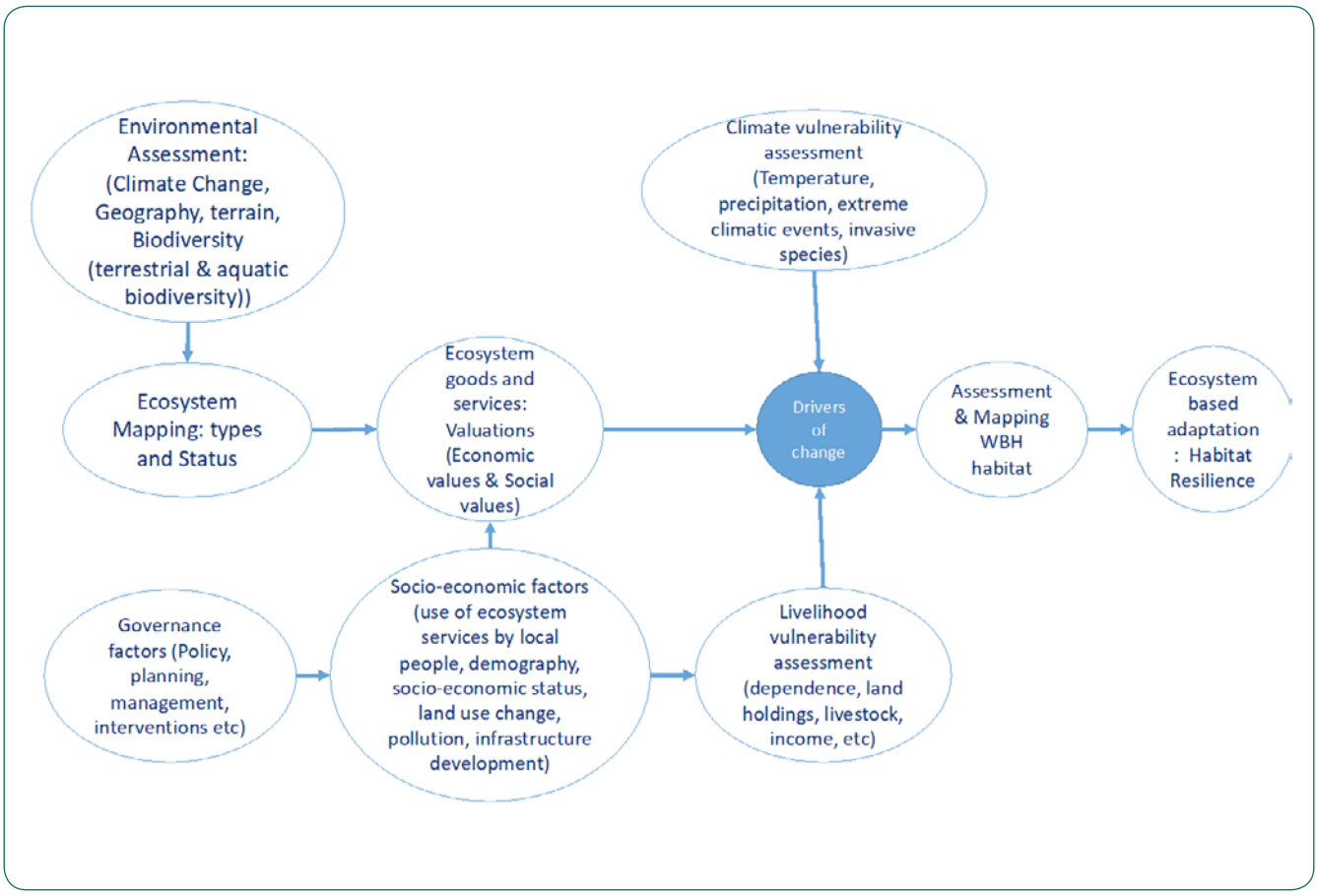


Figure 2.1: ESRAM Conceptual Framework

The ESRAM framework is conceptualized on the association of the vulnerabilities of global human communities to the impacts of the simultaneous occurrence of climate and ecological changes. Climate change induced ecosystems degradation and loss of ecosystem services have direct effect on human wellbeing. The impacts are so significant that strategies to increase resilience while enhancing human wellbeing are urgently needed (Wise et al., 2014). It is therefore vital that appropriate approaches to

address ecosystem degradation and adaptation to the changing climate needs to be explored. For this, it is imperative that the symbiotic relationships between ecological, socio-cultural, and economic are considered seriously and analysed critically for probable solutions from different contexts. The EBA methodologies can be applied and implemented by multidisciplinary teams where the methodology encourages to considering and putting the needs of local people at the forefront through a participatory process. Further, the qualitative, as well as quantitative data, is generated and analysed holistically to better understand the interactions of socio-ecological systems.

One aspect of the socio-ecological systems is the value humans attach to the ecosystem services and how such services are affected by the changing climate and ecological systems. Ecosystem services are vital for human survival and that they are continuously modified for human needs resulting in compromised wellbeing as well as habitats of wildlife such as WBH (MEA, 2005; de Groot et al, 2010). The range of ecosystem services such as provisioning, regulating, supporting, and cultural services provide substantial support for human survival. However, until and unless the economic valuation of goods and services are performed, knowing the relative importance of ecosystem services to humans as well as sustenance of environment itself would not be known (Daily et al., 2009; Schild et al., 2018).

Ecosystem Services (ESs) are defined in three different ways such as "…the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life (Daily 1997, "…..the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life (Daily 1997)", "…the benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza et al 1997)", and "…the benefits people obtain from ecosystems (MA 2005)". These definitions suggest that ESs can be further grouped into provisioning, supporting, regulating and cultural services (MEA, 2005). ESs are one of the components where the 'ecosystem assets' encompass spatial areas containing a combination of biotic and abiotic components and are measured in terms of (i) ecosystem type, (ii) ecosystem extent, (iii) ecosystem condition, and (iv) ecosystem services (Fisher et al 2007). The economic valuation provides the opportunity to establish the use-value as well as non-use values. When the use and non-use values are recognized, it is highly likely that the sustainability of the environment would be higher.

Likewise, enhancing ecosystem resilience is crucial in the context of climate change impacts to reduce the disaster risks where the ecosystems would protect humans from physical exposure. However, there may be instances in which policies promoting resilient ecosystems (say protected areas) may prove counterproductive, especially through restrictions on access to ecosystem services.

Once ecosystem services are assessed and mapped, their resilience can be measured which is helpful in planning and decision making. Ecosystem resilience is defined as the "inherent ability of the system to absorb perturbations and bounce back to its normal state without losing its critical functions" (Holing, 1973) and ecosystem can be considered "resilient if it adapts to changes and maintains an active state that is stable, functioning, and supplying necessary services to its users" (Carpenter et al, 2003; Elmqst et al, 2006; Standish et al, 2014).

In our approach to assessment and mapping, the environmental assessment would provide the basic understanding of ecosystem goods and services where the ESs are categorized based on the definitions used by Fisher et al (2009). On the other hand, the ESs are affected by socio-economic factors where one of the major variables could be forest degradation due to various activities. Such activities could be influenced by governance factors such as plans and policies. Such activities in turn affects the

ecosystem goods and services. The status of the ecosystem services would be assessed in terms of local peoples' vulnerability to climate change. As local people bear more and more impacts, these in turn will force them to increase dependency on the ecosystems, therefore the Climate Vulnerability could be one of the drivers of ecosystem change. Similarly, the socio-economic status of local people may also affect the ecosystem quality depending on the local peoples' degree of dependency. Since this project is geared to generate habitat resilience to climate change, the vulnerability of habitats to climate change will also be assessed which would contribute to the main goal of this project with habitat resilience as the outcome.

Guided by this overall ESRAM framework, this study employed specific methodologies for assessment of i) socio-economic status of communities in the study area, ii) the state of biodiversity, and iii) ecosystem and livelihood vulnerabilities to climate change.

2.2 Socio-economic survey

For the ESRAM study, the socio-economic survey consisted of three modules covering areas of inquiry on i) the general socio-economic status, ii) valuation of ecosystem services and iii) vulnerability to climate change. The survey questionnaires focused on gathering data and information required for understanding the socio-economic conditions, ecosystems and ecosystem services, and vulnerability of ecosystems and communities to climate change in the WBH project areas. The methods and aspects of the study covered under the three survey modules are briefly described below:

2.2.1 Module A: Socio-economic survey

The socio-economic survey employed the commonly used household surveys and focus group discussion (FGD). The following areas were covered:

- Demographic conditions (Household and community demography, gender, migration, age, education, etc.)
- Economic conditions (Household livelihood, economic activities, and income sources, livelihood challenges, income-generating and employment opportunities, and human-wildlife conflict and control measures)
- Ecosystem and community resources (Natural resource types and community dependence, their knowledge on WBH and natural resources use, base and trend, land use pattern and changes, settlements, conflicts and synergies and challenges in resource management)
- Social structure and development facilities (Farmers' groups and membership, social networks, community cohesion, future community development opportunities such as tourism and recreational business opportunities, etc.)
- Policy implications (WBH conservation measures and their effects, household and community access to resource use, interventions, community participation, etc.)

2.2.2 Module B: Valuation of ecosystem services

Of the different methodologies available for the valuation of ecosystem services, the Discrete Choice Experiment (DCE) was employed as the primary methodology for this study. DCEs have recently emerged as an attractive method for researchers and policy makers. The methodology goes beyond the traditional assessments to allow for quantitative information on the relative importance of various ecosystem characteristics that influence conservation measures. This method provides quantifiable data that can better guide the selection of the most appropriate strategies for the conservation of ecosystems. It also goes beyond the traditional listing and rating exercises of ecosystem services that do not provide information on preference and willingness to pay for ecosystem services. DCEs are also referred to as being attribute-based, DCEs are also *survey*-based. That is, they rely on what respondents *say* they will do—also referred to as stated preference data—rather than what they do— referred to as revealed preference data. The survey questionnaire included data and information collection on:

- Ecosystem services availed by households in the study area
- Perspectives on trends in ecosystems services
- Household preference for choice set with the cash choice, and the second, the labor alternatives

Based on available data, a benefit transfer method was also employed to estimate the value of ecosystem services in the study area. This method used the value of four land cover types, which include cropland, orchard, forest, lakes, and rivers. These values are adopted from a paper carried for Bhutan's ecosystem service valuation (Kubiszewski et al. 2013).[3] It may be noted that the values adopted in this paper are originally taken from the Ecosystem Services Valuation Database (ESVD) and compiled by the International Ecosystem Services Partnership. Further, the values used for the paper represent the values of the ecosystem that resembles the context of Bhutan. The similarity of the context is defined in terms of a similar ecosystem comparable to Bhutan. The dollar value for 2021 was updated by using the consumer price index. The value estimation is carried out for four land cover types measured in hectares. Detailed methods and processes employed in data collection and analysis are available in a separate report.

2.2.3 Module C: Climate change

This component of the study entailed the collection, entry, and analysis of data to generate the indices of vulnerability to climate change. The term 'vulnerability' is used widely in development and adaptation contexts and the usage of the term varies and is contextual. This study employs the IPCC framework approach for calculating climate change vulnerability assessment (CVA). Hence, vulnerability is defined as 'a function of exposure, sensitivity, and adaptive capacity. It refers to various climate hazards associated with climate change and variability to which a population or populations is exposed. Exposure is defined as "the nature and degree to which a system is exposed to significant climate variations", and sensitivity as "the degree to which a system is affected, either adversely or beneficially, by climate related stimuli". Adaptive capacity on the other hand is defined as "*the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences*". It is defined as 'the propensity or predisposition to be adversely affected' and describes exposure and vulnerability as the determinants of risk.

3 Ida Kubiszewski, Robert Costanza, Lham Dorji, Philip Thoennes, and Kinga Tshering 2013. An initial estimate of the value of ecosystem services in Bhutan. Ecosystem Services, Vol 3. Pages e11-e21. Science Direct, Elsevier 2013.

Based on the above, questionnaires for collecting information on household experiences and perspectives for climate change resilience/ vulnerability assessment were integrated with the socio-economic survey questionnaires. Data and information collected for each of the variability components are:

1. Adaptive capacity: Socio-demographic profile, Livelihood strategies, Social network
2. Sensitivity: Health, Food, Water
3. Exposure: Natural hazards, Climate variability

The data generated from this survey module were used for CVA which is discussed later in a separate section.

2.3 Biodiversity assessment

The environmental component of the study primarily consisted of biodiversity assessment. The biodiversity assessment approach used was aligned with the Biodiversity Monitoring and Social Survey Protocol of Bhutan 2020 (DoFPS 2020a). Rapid assessment of vegetation, fish diversity, avifaunal diversity, aquatic macroinvertebrate diversity, basic water quality based on physicochemical parameters, diversity of butterflies, and incidental documentation of mammals and herpetofauna was conducted in two river basins. A slightly modified sampling design and methods were used for the assessment of different taxa. No detailed statistical analysis and indices were calculated, except for vegetation and fish diversity but the diversity checklist as a baseline for species biodiversity within the landscape. The detailed methodologies and findings are included in a separate technical report.

2.4 Climate change resilience/Vulnerability assessment

Based on the IPCC definition of 'vulnerability', the data required for CVA were gathered under module C of the socio-economic survey. Relevant data from the biodiversity survey were also used in analysis of data for generating the Multidimensional Livelihood Vulnerability Index (MLVI), Livelihood Vulnerability Index (LVI), and Climate Vulnerability Index (CVI). The IPCC methods adopted for deriving the vulnerability indices are based.

2.4.1 Multidimensional Livelihood Vulnerability Index (MLVI)

MLVI is designed to measure Multidimensional Livelihood Vulnerability to climatic, environmental, and socio-economic change at Gewog level, district level and basin level which captures the change predominantly in rural, mountainous, river basins. The MLV is synonymously used as the livelihood vulnerability. Indicators of livelihood vulnerability were adapted from Hahn et al., (2009) and Panthi et al. (2016). The livelihood vulnerability is a function of adaptive capacity, sensitivity, and exposure which is comprised of seven major components and 58 indicators as described below:

Exposure

Exposure covers the natural hazard and climate variability where the occurrence of and amount of damage from natural disasters at the household level; the variability of temperature and precipitation; and the occurrence of extreme temperature and rainfall are recorded.

Sensitivity

Sensitivity comprises health, food, and water as major components where indicators such as household's food and water security, status of housing and location of agricultural land.

Adaptive capacity

Adaptive comprises a socio-demographic profile, types of livelihood strategies, and social network. Since agriculture production is the main income source of people in the ESRAM study site so it is included under the must be included and also the climate change susceptibility depends on characteristics of agricultural land and crop diversity, so these indicators are included under the livelihood strategies indicators.

2.4.2 Livelihood Vulnerability Index (LVI)

Since the indicators under each component are measured on different scales therefore a standardization of the index is required. The indicators are standardized based on the following formula: Index S_d = where S_d is the original sub-component for location d, and Smin and Smax are the minimum and maximum values, respectively. The minimum and maximum values were used to transform the indicator into a standardized index so it could be integrated into the specific components. For example, variables measured in frequencies such as the 'percent of experiencing a shortage of water in day-to-day life,' the minimum value is set at 0 and the maximum at 100. For instance, a household that does farming and raises animals is less vulnerable than a household that only does farming. Using this logic, the inverse of the crude indicator is computed. The maximum and minimum values of the sub-components are transformed and standardized.

2.4.3 Creating Vulnerability Index

After each standardized value, an index for each major component of vulnerability is created, by averaging the standardized sub-components using the following equation: M_d = where M_d is one of the eight major components for specific location d, the S_{di} represents the sub-components, indexed by i, that make up the major component, and n is the number of sub-components in each major component. Once values for each of the major vulnerability components for that location are calculated, those components are averaged using the following equation to obtain the district-level LVI: LVI_d = which can also be written as LVI_d = where LVI_d, is the Livelihood Vulnerability Index for the specific location such as dzongkhag d, equals the weighted average of all the major components. The weights of each major component, *Wmi*, was determined by the number of sub-components that make up each major component and all the sub-components contributing equally to the overall LVI (Sullivan et al. 2002).

2.4.4 Calculating Climate Vulnerability: IPCC framework approach

An alternative method developed by Hahn et al. (2009) for calculating the LVI based on the IPCC vulnerability definition which according to the IPCC framework, livelihood vulnerability is defined as a function of system exposure, sensitivity, and adaptive capacity was used. Under the sensitivity category, the sectors such as water, food, and health are included while socio-demographic profile, livelihood strategy, and social network are included under adaptive capacity. Exposure includes natural disasters and climate variability which is measured by the number of natural disasters as well as climate variability in the last 10 years using meteorological data from stations located in the selected districts. The sub-components will be used to calculate the VI-IPCC. The use of index diverges from the LVI in how the major components are combined (Pandey and Jha, 2012; Panthi et al, 2015).

The major components will be first combined according to the categorization into exposure, sensitivity and adaptive capacity as follows: CF_d = where CF_d is an IPCC defined contributing factor (exposure, sensitivity and adaptive capacity) for the district d, M_{di} is the major component for the district d, indexed by i, Wmi is the weightage of each major component, and n is the number of major components in each contributing factor (Hahn et al 2009; Panthi et al, 2015). Once exposure, sensitivity, and adaptive capacity are calculated the three contributing factors will be combined using the following equation: $VI\text{-}IPCC_d$ = (Exposure – Adaptive capacity) * Sensitivity, where the VI-IPCC index ranges from -1 (least vulnerable) to +1 (most vulnerable).

2.5 WBH habitat suitability assessment and mapping

Considering that the conservation and protection of WBH are at the core of this ESRAM exercise, the WBH habitat suitability assessment and mapping were carried out. This entailed collecting data and employing the data on WBH occurrence data from across the country. The data were collected from field observation and the Global Biodiversity Information Facility (GBIF). A total of 175 points were recorded.

Using the WBH field observation coordinates, Maximum Entropy (MaxEnt) (Phillips, 2017) was used for ecological modelling. MaxEnt is widely used in species distribution modelling (SDM) to predict the habitat of target species such as mammals, plants, and birds (Phillips, 2017). MaxEnt is user-friendly, accepts presence-only data, batch-able, performs with the least number of occurrence data, produces useful models (produces robust results), and handles continuous and categorical variables using regularization parameters. MaxEnt is open-source modelling software that is available online for download.

Modelling in MaxEnt requires two types of data, i.e., geographic coordinates (presence only) and environmental variables. The geographic coordinate data is species occurrence data collected from the field. The bioclimatic variables in the WorldClim (version 2) database obtained from Worldclim.org were used for modelling the current potential distribution areas. It contains 19 environmental variables which are the average for the years 1970-2000. The dataset is at the spatial resolution of 30 seconds (~1 km^2). The Model for Interdisciplinary Research on Climate (MIROC) 6 model was used for future prediction at the spatial resolution of 2.5 minutes. The downscaling and calibration (bias correction) was done with WorldClim version 2.1 as baseline climate. The monthly values were averaged over 20 year periods (2041-2060). The Representative Concentration Pathway (RCP) 2.6, RCP4.5, and RCP 8.5 were used for the distribution of WBH under different climatic scenarios.

For the WBH habitat suitability assessment, the Food and Agriculture Organization (FAO) classification system for habitat suitability was applied i.e., S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), and N (not suitable) based on the ecological requirements for heron habitat. One of the popular and well-used approaches for classifying factors that are arranged in a hierarchical structure is Analytical Hierarchy Process (AHP) method.

The detailed technical process employed in modelling the distribution and assessment of habitat suitability is available in a separate report produced as part of the ESRAM study.

2.6 Mapping of degraded and potential habitat restoration sites

A GIS analysis was also carried out to identify degraded forest areas in the ESRAM study area. The perceptions of what constitutes a 'degraded forest' vary greatly. Much of the variation depends on the main point of interest such as biodiversity conservation, carbon sequestration, wood production, soil conservation, or recreation (FAO 2009). In this assessment, areas in which tree cover existed earlier that are currently devoid of tree cover were identified as degraded.

GIS analysis of satellite images was used for the identification and mapping of the degraded area within the WBH site. Remotely sensed data (high-resolution satellite imagery data) provides a major opportunity to capture new and improve upon the spatial representation of the degraded site locations from Land Use Land Classification (LULC) 2016 and *DoFPS mapping exercise of degraded forest*. In the absence of comprehensive satellite imagery data availability covering the study area, Google Earth imagery was employed for the mapping. With multi spectral high-resolution imagery available the identification and mapping were carried out accurately. The extent or boundary of the degraded area was directly digitized/vectorized and classified into respective layers during the process of on-screen digitization. Anomalies and occlusions observed during the mapping owing to the terrain and topography were confirmed with field verification.

In identifying degraded areas in the study area, the following aspects of land use within the study area from the LULC 2016 study were used.

Forests: Areas of land with trees spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent. It does not include land that is predominantly under agricultural or urban land use (National Forest Policy of Bhutan, 2011).

Landslides (Ls): This class includes the mass movement of soil debris due to gravitational force triggered by other factors such as rainfall and earthquakes. (LULC 2016).

Built-up Areas (BA): Built up areas include artificial constructions covering the land with an impervious (e.g., concrete, CGI sheet, thatch) surface. It includes airports, rural settlements, urban areas, schools & institutes, industrial areas, hospital premises, sewage treatment plant, sports and leisure facilities and roads. (LULC 2016).

Non-Built-up Areas (NBA): This class is defined by absence of the original (semi-) natural cover mainly due to anthropogenic factors. It includes waste dump sites, mines, stone quarries and other extraction sites. (LULC 2016).

The use of satellite image-based assessments and mapping allowed for the mapping of degradation captured at that period of imaging only. With the lack of temporal data, derivation of time series degradation data was not possible. Although mapping of all cases of land degradation was not possible, employment of remote sensing techniques did provide valuable clues and help in the identification of potential hotspots of ongoing degradation.

03 FINDINGS

Agriculture fields, Bali village, Chubu Gewog, Punakha/Norbu Wangdi

3.1 Socio-economic status

In this section, we describe the social and economic condition of the study area based on responses to survey questionnaires. The first part deals with the socio-economic condition of the study area. The second part deals with the valuation of ecosystem services

3.1.1 Socio-economic status of the study area

The socioeconomic status of the communities in the current WBH and potential habits is discussed in this section. The data presented are drawn from the household interviews, observations made, and key informant interviews. The status refers to the current social and economic conditions of the respondents focused on the household demography, livelihood activities, income sources, agriculture and livestock activities, human-wildlife conflicts, and the state of natural resources base and utilization by the rural communities, the community organizations and benefits enjoyed by the members, and WBH conservation efforts in the study areas.

3.1.2 Characteristics of the respondents

A total of 1237 respondents were interviewed of which 62.5% were females and 37.5% male. (Table 3.1 & Appendix 1.1). The respondents consisted of *Ngalops*, *Sharchops, Lhotshampas*, *Khengpas*, and *Mangdibs* ethnic groups from 31 gewogs under six districts. The majority, (67.9%) were *Ngalops* due to the larger sample size from the districts with Ngalop settlements. About 74.6% of the respondents were between the age of 21-60 years and about 0.7% were below 20 years. Occupationally 91.11% of the respondents were farmers, 6.31% were business 1.78 % were employees, and others 0.81% which includes carpenters, monks, etc.

The majority (67.4%) of the households are headed by females and 32.6% by males (Appendix 1.2). Among dzongkhags covered by the study, all the houses of the respondents are headed by females except in Dagana and Tsirang districts.

Table 3.1: Demography of the respondents

No	Demographic characteristics	Total	Percent (%)
1	**Gender**		
	Male	464	37.5
	Female	773	62.5
2	**Age**		
	Below 20 years	9	0.7
	21 - 40 years	445	36
	41 - 60 years	478	38.6
	Above 61 years	305	24.7

3	**Education Level**		
	None	828	66.9
	Primary	130	10.5
	Middle secondary	101	8.2
	High school	68	5.5
	Undergraduate	22	1.8
	Master	3	0.2
	Others	85	6.9
4	**Ethnic group**		
	Ngalop	839	67.9
	Sharchop	41	3.3
	Lhotshampa	165	13.4
	Khengpa	147	11.9
	Mangdep	33	2.7
	Others	10	0.8

Regarding the education level, more than half (66.9%) of the respondents are illiterate. However, about 25% of the respondents have attended formal education like primary (10.5%), middle secondary (8.2%), high school (5.5%), and undergraduate and graduate about 2.1%. Considering the increasing national literacy rate, the observed literacy rate is encouraging as the education level of communities is important for bringing any social or development changes in the rural communities. Because with education comes skills; through education, an individual or household will acquire certain skills, and an educated household has a higher chance of gaining skills than a household without any education.

3.1.3 Livelihood sources

A livelihood is simply defined as activities, assets, and access that jointly determine the living gained by an individual or household (Ellis 1998). As in the case of rural communities elsewhere in the developing world, farming is the prevalent source of livelihood for rural communities in Bhutan. About 60% of the population is engaged in small-scale mixed crop-livestock farming to survive on as a source of income. Likewise, respondents in the study areas pursue a variety of activities for their livelihood such as agriculture, livestock, off-farm activities, and business for their livelihood, of which 85.9% and 10.7% of the respondents consider agriculture and livestock very important respectively (Figure 3.1). In general, respondents pursue subsistence mixed crop and livestock farming as the main livelihood activities supplemented by diverse small-scale income-generating activities based on emerging and situational opportunities.

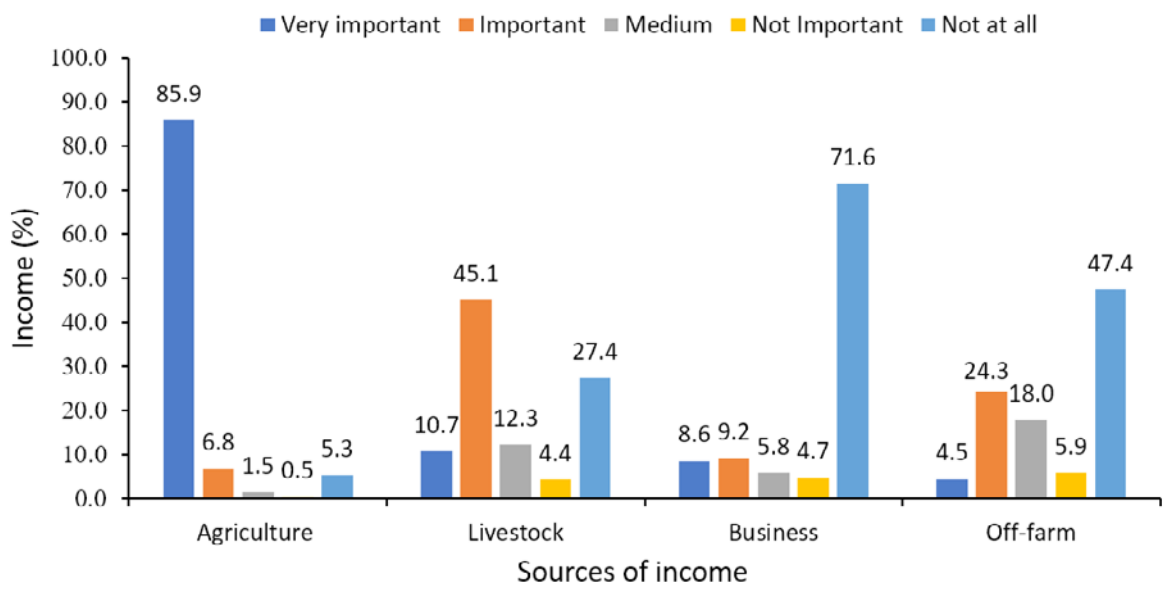


Figure 3.1: *Livelihood activities of the respondents.*

Agriculture and Livestock Activities

Despite some variations between the districts, agriculture and livestock are the dominant farming activities pursued by most of the respondents. In agriculture, paddy and maize are commonly grown by all the respondents supplemented by some horticultural crops like vegetables, oranges, and cardamom. The crop and livestock production is mostly subsistence, with meeting the family need as the priority and only surpluses are sold or exchanged for cash. In livestock, dairy cattle and poultry are raised in all the study areas, while pigs and goats are mostly raised in Dagana and Tsirang districts partly for commercial purposes. However, the shift away from farming or abandonment of farming is evident mainly because of labour shortage, increasing crop damages by wild animals, and negative impacts of the emerging climate change. For example, the adversity of climate toll is evident from the recent (October 2021) irregular rainfall and its damage to the harvested paddy in Punakha, Wangdue, and Paro districts exposing vulnerabilities of farming and the livelihood of the farmers. As reported by Clarke & Barker (2012), farmers' move toward off-farm and business or trade, to look for better opportunities or economically viable activities, and this is already evolving in the study areas.

3.1.4 Income

Sources of income

Like in most rural areas of developing countries, rural livelihood in Bhutan is also a complex structure consisting mostly of agriculture supplemented by livestock, with some dependent on non-farm activities to earn better income to attain a sustainable livelihood for the household. In this respect, the respondents depended upon several activities for generating income for the household.For example, agriculture is rated as the main source of income by 75.6% of the respondents, followed by others 50.6%, business 8.3%, livestock 7.4% off-farm 6.6%, and 4.5% remittances (Figure 3.2).

Although the crop and livestock (Appendix 1.3) are the primary sources of household income, as mentioned above due to the complexity of the rural livelihood, the clear distinction of income sources is unsure due to multiple subsistence activities pursued by the households. For example, farming

supplemented by small family businesses is a common and emerging practice for some respondents in all the study areas. Therefore, as shown in Figure 3.2, the probability of overlap between income sources categorized as business and others is very high, since most respondents owning family businesses are farmers.

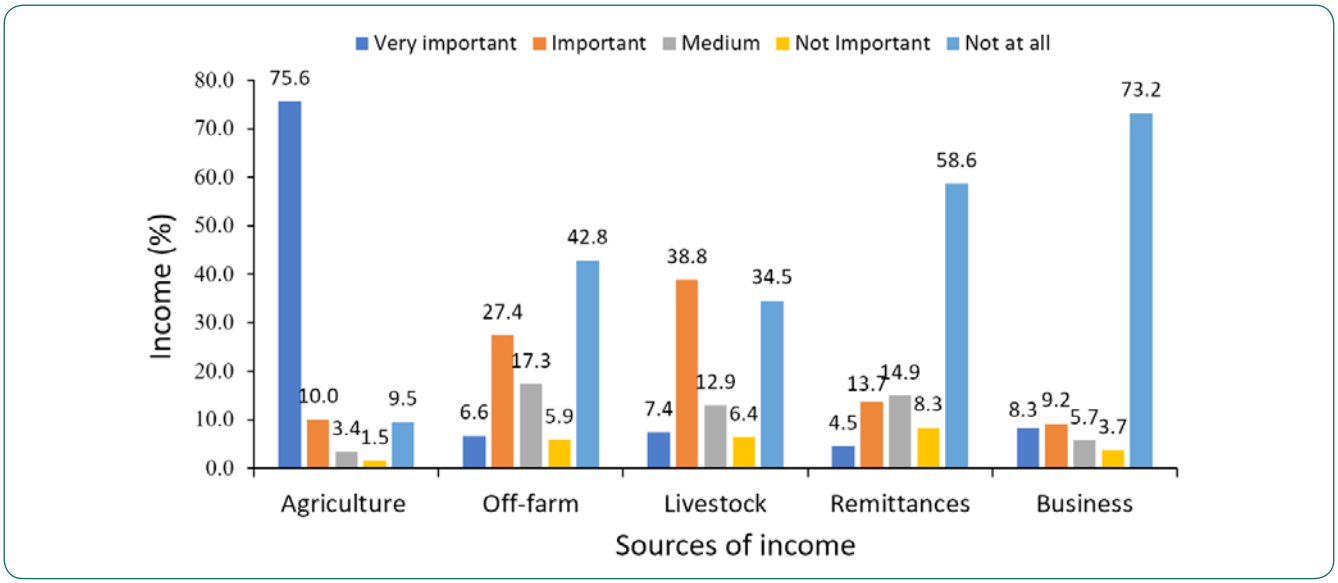


Figure 3.2: Livelihood activities of the respondents

Likewise, cardamom is an important source of cash income for the respondents in Tshanglajong Chiwog, Nangkhor Gewog under Zhemgang district. Cardamom and oranges are the main sources of cash for the respondents in Tsirang and Dagana districts, and for some respondents in Wangdue district. At the national level, remittance from abroad is an important source of revenue. However, only 2.5% of the respondents' reported that remittance is very important (Figure 3.2 and Appendix 1.4).

Annual Income

The annual income of a household is the combined net income of all members of a particular household for a given age level. It is difficult to estimate or acquire the annual household income of the respondents due to the sensitivity of the topic as well as the absence of a proper record system. However, to understand the respondents' annual income, the respondents were categorized into different income groups. As shown in Figure 3.3, the majority (44.7%) of respondents' annual income is lower than Nu. 50,000, while 30.7% earned between Nu.51,000-100,000 and about 15.7% between the ranges of Nu.101,000-200,000. The majority (74.7%) of the respondents (lower two income groups combined) earned less than Nu. 100,000 per year clearly reveals the dependence on subsistence agriculture.

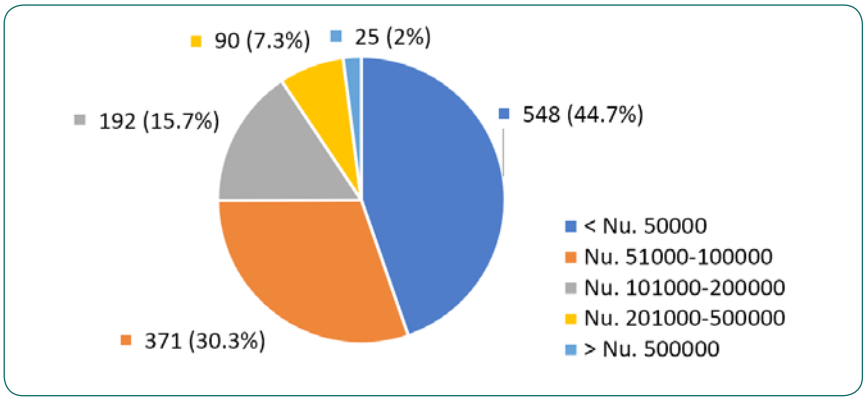


Figure 3.3: Respondents' Income Sources

3.1.5 Collective action and social cohesion

Farmers' groups and membership

The smallholder farmers in general lack financial power, knowledge, networks, and resources which limits their participation in livelihood-enhancing activities. Therefore, organizing smallholder farmers into groups helps them overcome some of these challenges through collective actions. There are several groups formed in the study area for different purposes (Figure 3.4). The farmers' group can be broadly classified into agricultural, livestock, forestry management, and others. The community forest management group (74%) is found in all the study areas followed by vegetable production groups (14.30%).

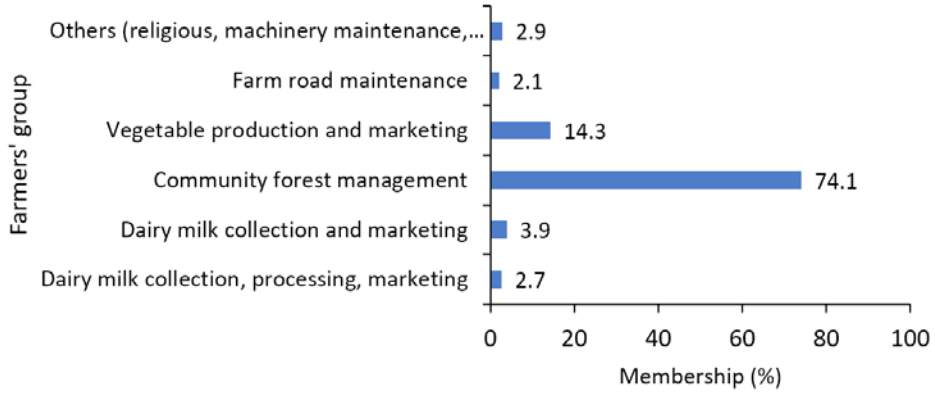


Figure 3.4: Types of Farmers' Groups

Based on the membership and type of group they belong to, respondents reported group members availing a number of benefits (Figure 3.5). For example, respondents belonging to the Community Forestry Groups benefit from the collection of firewood, timber, flag poles, and non-timber forest products from the community forests. Similarly, marketing access, group savings and loans, and receiving subsidized material extension support are some of the benefits enjoyed by respondents for being members of farmers' groups. The farmers' groups present avenues for smallholder farmers in marketing their produce, accessing inputs, and availing extension advice and services which are usually not possible at the individual level.

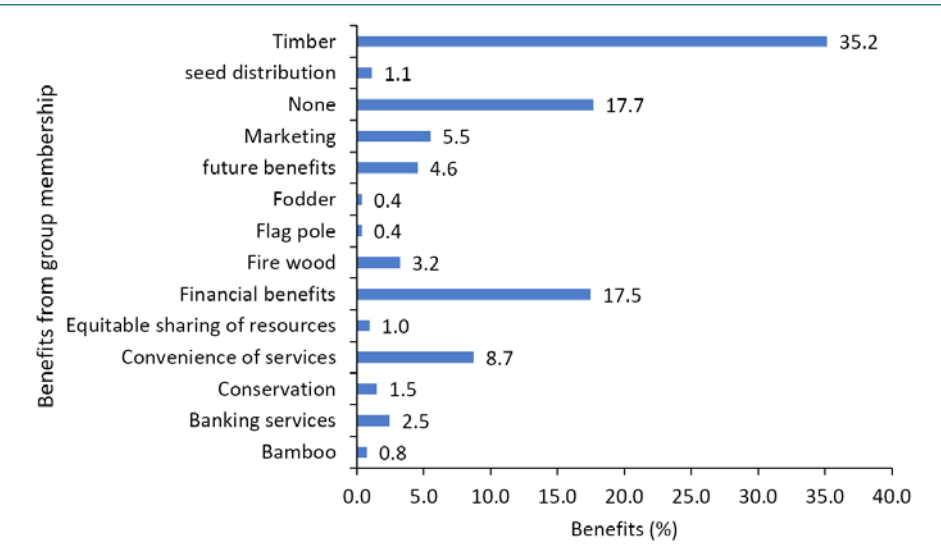


Figure 3.5: Benefits from membership in the group

Performance, participation, and social cohesion

Apart from the material and financial benefits, group formation promotes social cohesion (strength of relationships and a sense of solidarity) among the members of the group. In this respect, more than 90% of the respondents believe that the farmers' groups enhance social cohesion by instilling a high sense of we-feeling, improving reciprocity and willingness to help and support each other, self-sufficiency, and strengthening the relationship and solidarity among group members (Figure 3.6).

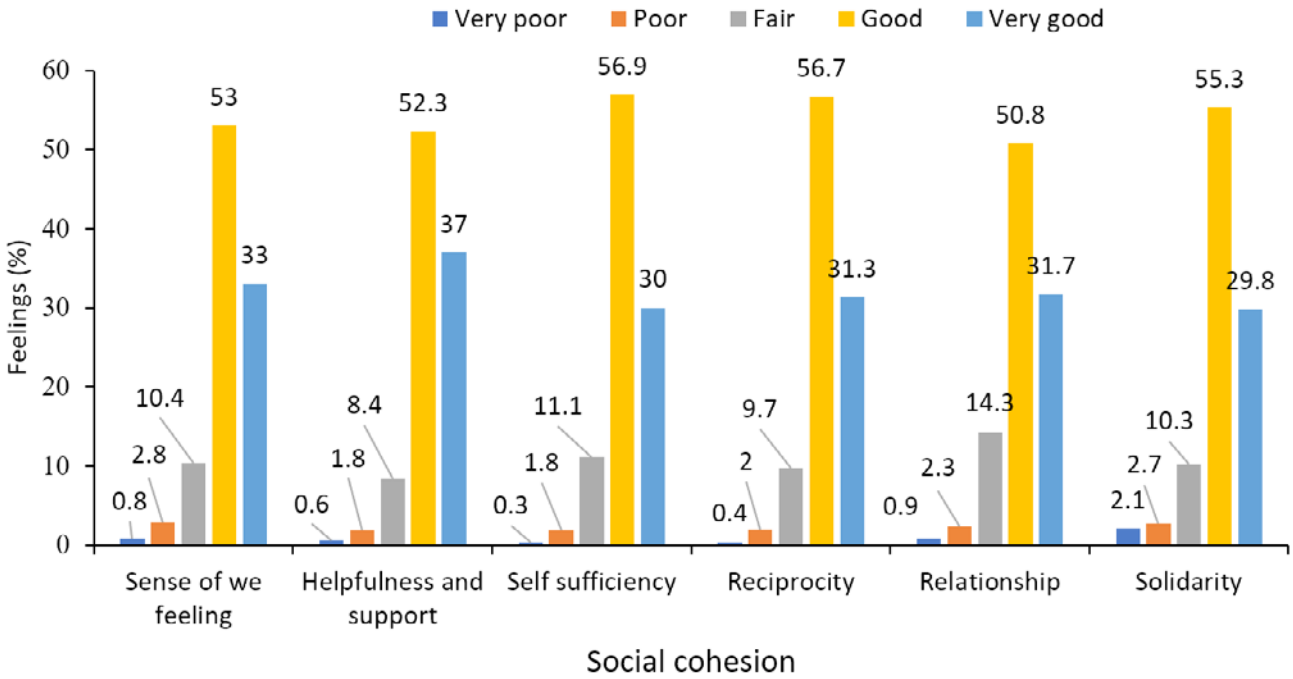


Figure 3.6: *Respondents' Perception on FG's Contribution to Cohesion*

Perception of farmer group contribution to cohesion

The respondents across the study areas are positive about farmer groups' contribution toward social cohesion. For example, about 89.3% of the respondents rated either good or very good for farmers' groups improving the helpfulness and support among members, and enhancement of the sense of 'we-feeling' by 86%. Maxwell (1996) defines social cohesion as building shared values and communities of interpretation, reducing disparities in wealth and income, and generally enabling people to have a sense that they are engaged in a common enterprise, facing shared challenges, and that they are members of the same community. Therefore, a socially cohesive community is desirable as it works towards the well-being of all its members, creates a sense of belonging, promotes trust, and offers members opportunities to grow.

Regarding the performance of the existing farmers' groups (Figure 3.7), about 87.1% of the respondents either agree or strongly agree that the groups are performing well, and 85.9% perceive group approaches as useful and beneficial to the farmers. Similarly, about 88.3% of the respondents agree that members actively participate in group activities. It is encouraging that 83.3% of the respondents feel that farmers now understand the need and benefits of the farmers' groups, as such 76.2% expressed the formation of form groups may be of interest to the farmers. This presents the opportunities to explore forming or engaging the existing farmers' groups in livelihood enhancement activities and also WBH conservation programs.

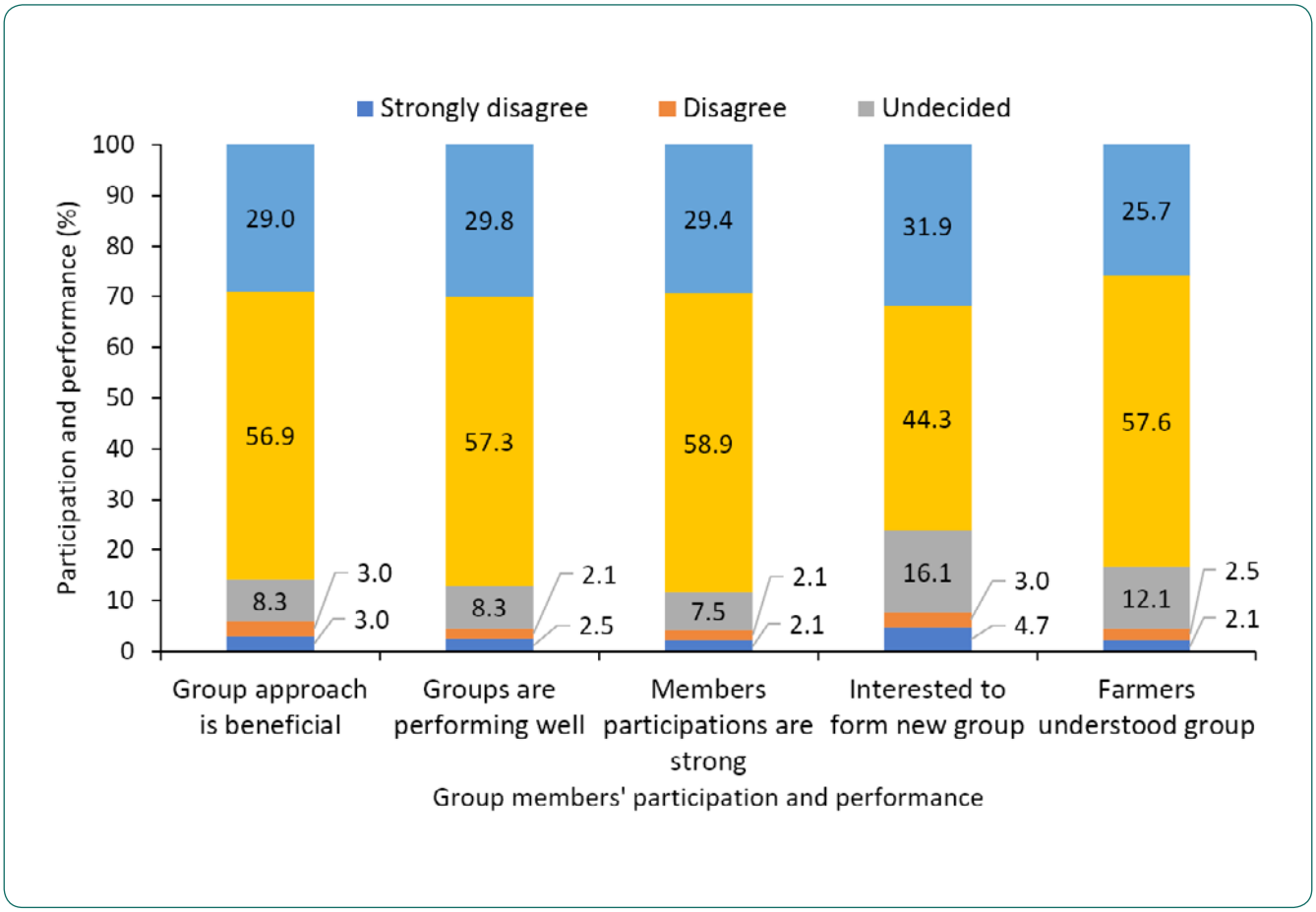


Figure 3.7: *Perception of performance of farmer groups and member participation*

Participation in conservation

Conservation activities are important for coexistence with wildlife, but it is equally critical to engage the community for the success of the interventions. Afforestation, controlling illegal activities, awareness programs, changes in agricultural practices, and the introduction of new protection measures were some of the conservational activities in which the respondents' participation was evaluated (Figure 3.8 and Appendix 1.5).

About 57.3% of participants have participated in afforestation programs and were reported to be useful by 58.6%. Likewise, awareness and training programs were attended by 57.8% of the respondents and 60.4% found them useful. About 37.7% of respondents have participated in checking illegal activities, 34.1% changing crop activities, and 24.3% in taking up new protection measures. These conservation initiatives are essentially targeted to mitigate human-wildlife conflicts as well as to safeguard the environment. However, the acceleration of any conservation initiatives requires the farmers' participation in wildlife management decisions. Looking at respondents' participation in the conservation activities it is possible to conclude that farmers are receptive to conservation activities.

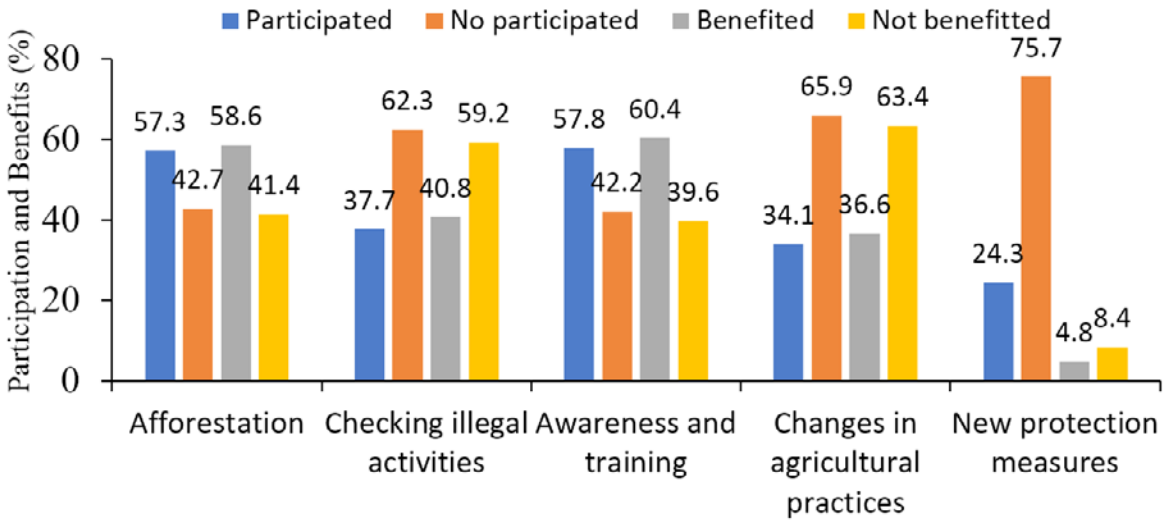


Figure 3.8: Respondents' participation and benefits from conservation

Many of the respondents are aware of the possible sanctions and consequences of not participating in the conservation programs. The fear of legal consequences and exclusion from future potential promotional programs and incentives (compensations) are some of the factors that motivate their participation. However, 961 respondents i.e., 95% of the respondents reported that compensation for the wildlife destruction is not provided as informed. They feel that there are some discrepancies between what is promised and what is practiced in the field. The respondents received compensations ranging from Nu. 600 to Nu. 50,000 based on the magnitude of the destruction. However, many respondents were not satisfied with the compensation scheme, either due to delay or have not received it at all.

3.1.6 Livelihood issues and challenges

In most developing countries, smallholder subsistence farmers face several livelihood constraints related to day-to-day household needs as well as agriculture and livestock production. Drinking and irrigation water scarcity, weak resource base, small and fragmented landholdings, lack of entrepreneurship skills, weak financial facilities or high cost of borrowing, inadequate infrastructure, limited access to markets, rigid socio-cultural factors, and now adverse climate changes are some of the common challenges they faced by Bhutanese farmers, though in varying degrees across communities. Given that agriculture and livestock farming are the primary source of livelihood for the majority of the communities in the study area, issues and challenges that confront the residents of the study area are linked to crop and livestock production.

Challenges in crop production

Communities in the study area are faced with a number of challenges in pursuing crop production. Figure 3.9 captures the opinion of the respondents on factors of production and the level of seriousness of the challenges associated with these factors.

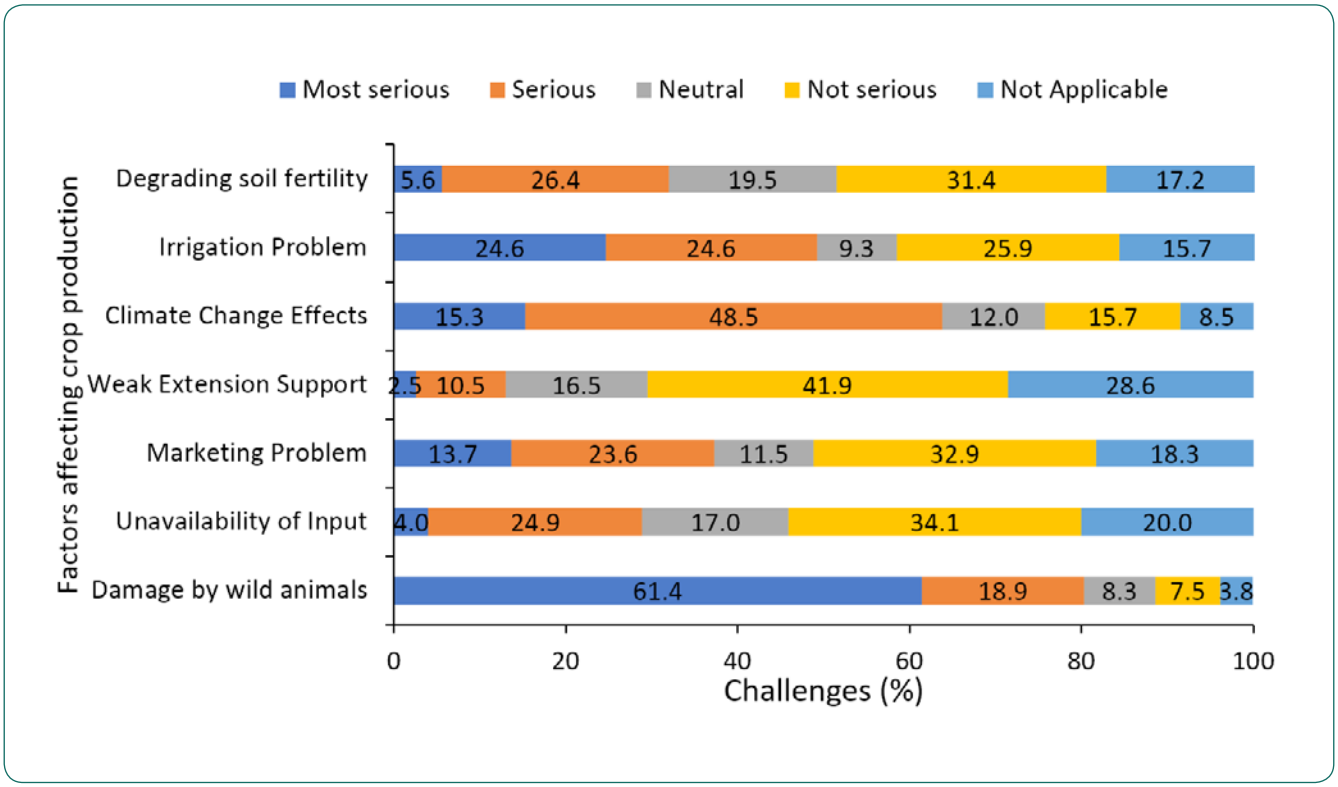


Figure 3.9: *Factors affecting crop production*

As presented in Figure 3.9, farmers in the study area do not view soil fertility, availability of inputs, and extension support as problematic. Rather, farmers are confronted with four major challenges. They are i) Wildlife crop damage, ii) shortage of Irrigation water iii) climate change iv) limited access to market, v) degrading soil fertility, and vi) unavailability of inputs. Each of these issues is discussed below:

Crop damage by wild animals

In Bhutan, the Human-Wildlife Conflict (HWC) has become a critical issue with 60% of the population directly dependent on livestock and crop production for their livelihoods. The percentage seems higher in the ESRAM study area. Over 80% of the respondents rated crop damage by the wild animals as the most serious issue, which is much higher than 70% reported for the country in 2017 (NSBB, 2017).

A deeper look at the issues revealed that about 96% of the respondents perceived that their crops are damaged by wildlife and 63% reported an increasing trend in the incidences of damage. Crop destruction by wild animals has hugely impacted crop yield, it is viewed as one of the most serious issues of human-wildlife conflict. Although 58% of the respondents reported a decline in livestock predation by wildlife, however, 22.5% believed predation is on the rise, especially among respondents from the villages located in or proximity to protected forests and park areas like Jigme Singye Wangchuck National Park.

Wildlife poaching is reported to be declining. This may be due to the presence of a strict monitoring system or a positive outcome from the engagement of farmers in the conservation activities and educational programs implemented by the relevant organizations and projects. Although about 60% of the respondents believe no loss in animal habitat but reported an increase in encroachment into habitat due to developmental activities. Human-wildlife conflict is a serious issue for crop production but not for human lives. Among the wild animals, pigs, monkeys, and barking deer are considered the most destructive and nuisance for crop production (Appendix 1.4).

Most of the respondents expressed the serious impact of human-wildlife conflicts being felt on crop loss. As shown in Figure 3.10, about 64.2% of the respondents reported wild animals damage on crops frequently or very frequently led to reduction in crop yield. Similarly, about 20.5% expressed either frequently or very frequently shifting in livelihood activities, 16.4% reduction in crop production area. However, only 3.9% felt wildlife crop damage led to abandonment of cultivation, and 13.4% resorted to changing their cropping pattern to adjust and combat the HWC. Although not very significant yet it is evident about the different impacts of HWC on rural communities. Human-wildlife conflict, and its serious impact on crop production continue to remain a long-standing unresolved national issue.

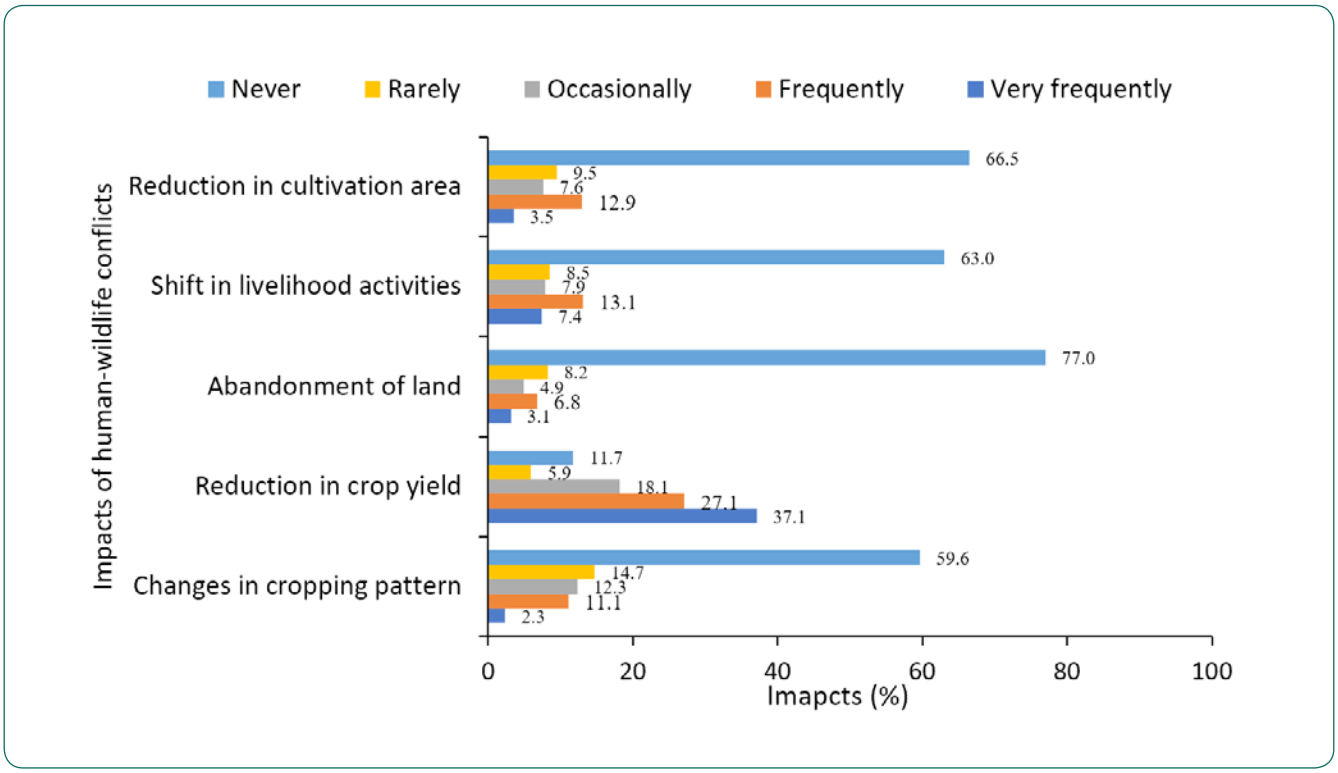


Figure 3.10: Impacts of Human-Wildlife Conflicts

Inadequate irrigation water

Inadequate irrigation water is a common and serious issue across the study areas with over 50% of the respondents having experienced problems with inadequate irrigation water in the last 12 months. 51.24% of the respondents in WBH areas of Punatsangchhu basin have reported experiencing inadequate irrigation water in the last 12 months (see Table 3.2)

Table 3.2: Number and percentage of household in WBH areas of Punatsangchhu that experienced irrigation water shortage

		Dagana	Punakha	Tsirang	Wangdue	TOTAL	%
Irrigation water problem in the last 12 months	**Yes**	43	333	61	81	518	51.24
	No	44	302	37	110	493	48.76

Likewise, about 45% of the respondents in WBH areas in Mangdechhu basin have reported having experienced inadequate irrigation water in the last 12 months (Table 3.3)

Table 3.3: Number and percentage of Household in WBH habitat areas of Mangdechhu that experienced irrigation water shortage

		Trongsa	Zhemgang	TOTAL	Percentage
Irrigation water problem in the last 12 months	**Yes**	26	48	74	44.85
	No	8	83	91	55.15

Although irrigation issues are reported all across the study area, Gewogs in which more than 50% of the respondents have raised issues with inadequate irrigation water are given in Table 3.4.

Table 3.4: Gewogs in which more than 50% of respondents raised irrigation water issues

Basin	Dzongkhag	Gewogs
Punatsangchhu	Dagana	Tsangkha
	Punakha	Dzome, Guma, Lingmukha, Talo, Toedwang
	Tsirang	Barshong, Tsholingkhar, Tsirangtoe
	Wangduephodrang	Rubesa, Thedtsho
Mangdechhu	Trongsa	Korphu, Langthil
	Zhemgang	-

Climate change

Climate change and its impact on crop production were rated serious by 48%, soil fertility degradation by 26 %, marketing problems by 23%, and unavailability of inputs on time by 25% is viewed as serious issues in crop production. Climate change is a global issue and is believed to impact agriculture by alteration in weather patterns such as untimely and erratic rainfall causing scarcity of water or drought. Further, as per Allara, Kugbei and Gbehounou (2012), increase in temperature induces infestation of pests and diseases, changes the phenology and cropping pattern, and decreases the crop yield.
Unavailability of agriculture inputs.

Regarding the availability of the Renewable Natural Resources (RNR) extension support, the majority of the respondents were satisfied with the services. However, 13% expressed dissatisfaction with untimely responses and support and see it as a serious issue.

Labor shortage

In addition to the different challenges mentioned above, labour shortage is a serious concern raised by the respondents. As substantiated by views shared by the key informants, labour shortage escalated by rural-urban migration is seen as a serious threat to the sustainability of rural farming especially by draining the active young labor from agriculture. The increase in fallow land and reduction of crop cultivation areas were reported as the direct impacts of labour shortage, damage by wild animals and climate change.While no specific study was conducted to assess the impact of rural-urban migration, rural households and farming activities were primarily managed by older people.

Livestock production challenges

Livestock farming is usually integrated into the crop production activities in the lowlands of Bhutan. Therefore, raising dairy cattle, goats, pigs, and poultry birds is common to supplement household income and support crop production activities for draft power or manure. Many issues like unavailability of inputs, insufficiency and limited access to grazing land, predation by wild animals, an outbreak of diseases, access to extension support, and poor-quality local breeds were identified to assess the perception of the respondents' seriousness of the constraints in livestock farming. As shown in Figure 3.11 most of the respondents either disagree or strongly disagree about different challenges being serious hindrances to livestock farming. These could be the respondents who are more into crop production, who either own only a few or no livestock.

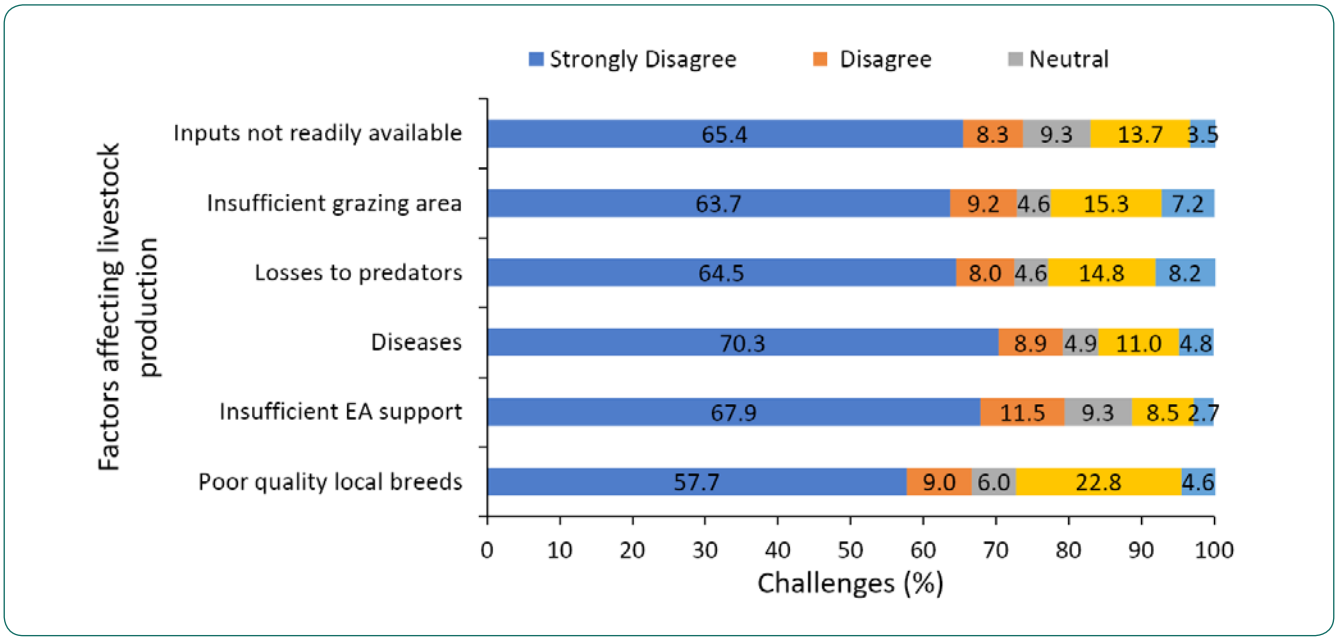


Figure 3.11: *Farmer perspective on the level of seriousness with factors of livestock production*

The poor quality of local breeds is seen as a limitation in livestock production by 27% of the respondents, followed by predation by wild animals by 23% (much higher than 12% as reported in the 2017 state of the nation report), insufficient grazing land by 22%, weak extension support by 18%, unavailability of inputs on time by 17%, and diseases by 16%. These are the respondents for whom livestock represents an important source of household income. For example, raising goats and poultry are common especially in Barshong, Rangthaling, Tsholingkhar and Tsirangtoed Gewogs of Tsirang district and Kaana, Laaja, Tsangkha, Khebisa, Tashidhing and Tsendagang Gewogs of Dagana district. RSPN has supported the construction of piggery and poultry sheds, and fishponds in some of the villages under these gewogs within the WBH habitats to support and enhance the livelihoods of the farmers. However, many respondents reported not being able to continue pig and fish farming due to the unavailability of piglets and water shortage respectively. As a result, the facilities (pig sty and pond) received by the farmers remain unutilized despite the strong interest expressed by the farmers to continue.

Drinking water issues

Owing to the rugged terrain in which most communities are based, access to adequate drinking water is highly variable even within one village. Although 97% of the respondents in *Punatsangchhu basin* have reported piped drinking water supply, over 50% have experienced water availability issues in the last 12 months and about 46% reported inconsistent water supply. Households that reported drinking water issues are faced with various issues such as inconsistent water supply (See Table 3.5).

Table 3.5: Status of household drinking water supply in the WBH habitat areas of Punatsangchhu basin (Household Respondents)

Variables/ Districts		Dagana	Punakha	Tsirang	Wangdue	TOTAL	%
House with piped drinking water	**Yes**	91	621	103	187	1002	97.19
	No	3	23	1	2	29	2.81
Drinking water problem in the last 12 months	**Yes**	45	341	49	94	529	51.06
	No	49	298	53	107	507	48.94
Consistent water supply	**Yes**	50	343	57	111	561	53.74
	No	44	302	44	93	483	46.26
Water quantity has decreased in the last 10 years	**Yes**	48	396	50	93	587	58
	No	46	235	53	91	425	42

Likewise, over 97% of the respondent in Mangdechhu basin reported that households have piped drinking water supply. However, 58% reported that they have faced problem with drinking water supply in the last 12 months and 44% faced inconsistency in their water supply (Table 3.6).

Table 3.6: Status of household drinking water supply in the WBH habitat areas of Mangdechhu basin

Variables/Districts		Trongsa	Zhemgang	TOTAL	Percentage
House with piped drinking water	**Yes**	29	128	157	93.45
	No	6	5	11	6.55
Drinking water problem in the last 12 months	**Yes**	24	74	98	58.33
	No	11	59	70	41.67
Consistent water supply	**Yes**	13	62	75	44.64
	No	22	71	93	55.36
Water quantity has decreased in the last 10 years	**Yes**	19	60	79	47.31
	No	16	72	88	52.69

3.2 Status of biodiversity

A total of 40 sampling sites were covered for rapid biodiversity assessment in the Punatsangchhu and 30 sampling sites in Mangdechhu basins study area. The number of sampling sites for both the vegetation and freshwater biodiversity survey considered was equal for both the river basins.

3.2.1 Terrestrial biodiversity

Vegetation

The vegetation survey focused on three categories of forest types surveyed in the study area which included: a) prime forest, b) riverine forest, and c) agrobiodiversity – focused on tree species found adjacent to human settlements. Among these three forest types, 13 samples were considered as agrobiodiversity forest, 15 prime forest, and 12 riverine forests. Districts wise, nine samples were from Tsirang, 3 from Dagana, 19 from Wangdue, and 9 from Punakha. The altitudinal range of the sampling plots varied from 274–1,723 m above sea level.

Punatsangchhu basin

In the 40 sampling sites, 80 tree species were observed. From these 80 tree species recorded in the study area, chir pine (*Pinus roxburghii*) had a maximum entry of 71 number followed by 23 entries of Alder (*Alnus nepalensis*) and 19 entries of *Albizia* spp. These species are secondary species and their presence in high numbers in the sampling plots basically indicates that the study area is fairly disturbed. The mean height of the trees in the sampling plots was 12.46 m (± 6.26 SD) with a maximum height of 35 m (*Sapindus rarak*) from Dikchhu in Wangduephodrang district – a riverine forest. The diversity calculated using Basal Area and Relative Basal Area is -2.8 which is good but negative sign indicates that the index is influenced by richness which is otherwise not calculated here. In relation to the WBH habitat which requires tall trees for nesting, the sampling sites had no trees tall enough for the birds for nesting. However, there is evidence that tall trees required for nesting are available on cliffs, difficult to access sites and areas away from human activities/settlements. These sites were not accessible to the vegetation survey team.

In Punatsangchhu, 85 species of shrubs were recorded *Chromolaena odorata* had the highest count with 25 followed by *Ageratina adenophora*, *Rhus chinensis* and *Artemisia* sp. 13 each. Both the *C. odorata* and *A. adenophora* are invasive species. Similarly in the herb category, *Bidens pilosa* had 15 counts followed by *Chromolaena odorata* with 10 and 9 counts on *Parthenium hysterophorus* with. Both the *C. odorata* and *P. hysterophorus* are invasive species.

The species of PRB were classified into conifers, deciduous shrubs, deciduous trees, evergreen shrubs and evergreen trees. The average basal area was 0.52 for conifer, 0.98 for deciduous trees, 0.04 for evergreen shrub, and 0.91 for evergreen trees.

Mangdechhu basin

In Mangdechhu basin, a total of 30 sampling sites were enumerated which had 74 tree species.The highest count of tree species was observed in the case of *Murraya paniculata* (n=70) followed by *Citrus sinensis* (orange with n =40) – cultivated area too was surveyed in this river basis, *Sapium insigne* (n=31) and *Schima wallichii* (n=29). The height of the tallest tree was 80m (*Toona ciliata*) followed by 61m (*Tetrameles nudiflora*) and Chir pine (*Pinus roxburghii*) growing to 50m tall. (Since the height of the trees was estimated using a digital rangefinder and the top of the trees are often not visible, erroneous height measurement is possible.) The mean height of trees was 17.39 (±13.76 SD). The diversity index calculated based on Basal Area and Relative Basal Area using DBH is -3.108, which is appreciable.

In the shrub category, 52 species were recorded. *Murraya paniculata* was prevalent with 115 counts followed by members of Rubiaceae with 37 counts. *Chromolaena odorata*, which is an invasive species, was represented with 4 counts only. Likewise, there were 92 species recorded in the herb category. *Oplismenus* sp. had a maximum count of 21 numbers followed by three species of ferns with 16 counts, and *C.odorata* and *Mikania micrantha* with 15 counts each. The latter two species are invasive species.

Within each vegetation classification type for all 40 sampling sites combined, the average basal area for Conifer tree species was 2.099, for deciduous broadleaved forest it was 1.142 and for the evergreen broadleaved forest it was 2.555. This indicates that the area has more evergreen broadleaved tree species.

Mammals

Punatsangchhu basin

The sampling plots in the study area basically had no signs of mammals except a report of sighting a bear across the Punatsangchhu river basin and wild pig signs in a plot near Dangchhu. However, this does not mean that the study area does not have mammal diversity, but their presence was not detected in the sampling plots during the rapid survey. However, a publication by Chhetri and Savage (2014) reported the presence of a Smooth-coated otter (*Lutrogale perspillata*) from Phochhu and the lower section of Punatsangchhu river.

Mangdechhu basin

In the Mangdechhu study area, droppings of sambar (*Rusa unicolor*), Indian Muntjac deer (*Muntiacus muntjak*), wild pigs (*Sus scrofa*), and Golden langur (*Trachypithecus geei*), and squirrels were observed. The Golden langur is endemic to the region and its distribution is restricted to a small area in Bhutan and Manas National Park of India.

During the sampling trip, the fish survey team observed Eurasian otters from three different sites. There was a group of eight otters near Berti, three near Tsaidang zam, and two at about Dakpaichhu.

Reptiles

Punatsangchhu basin

The survey team encountered a Bronzeback tree snake (*Dendrolepis* sp.) near Chanchey in Tsirang district. Snakes and lizards such as King Cobra, Common Garden Lizards, Monitor Lizards, Black Krait and Monocled Cobra among others are also reported from the study area.

Mangdechhu basin

While the survey team did not encounter snakes in the sampling plots during the survey, a road kill specimen of Bronzeback tree snake (*Dendrolepis* sp.) was encountered at Tingtibi (Zhemgang district). Similar to the Punatsangchhu study area, this region also has species such as King Cobra, Monocled Cobra and various types of pit vipers.

Avifauna

The rapid inventory of birds conducted in both river basins observed the presence of diverse species of avifauna. The significant distribution difference of bird diversity was observed among the different types of forest cover along the rivers of WBH landscape in both the basins. A total of 63 bird species were observed in the study area. The elevation ranged from 250–1500 masl in the study area. From 250 -500 masl consisted of broadleaved forest (BF), 500-1,000 masl consisted of mixed broad-leaved and chirpine forests (BFCP), and 1000-1500 masl consisted of chirpine (CP) forest. 25, 28, and 46 species were recorded from each of the forest types of BF, BFCP, and CP respectively. The eBird dataset record of Bhutan indicates the occurrence of these species abundantly during winter and early spring seasons in Bhutan with many migratory birds' arrival in major rivers. The highest density and occurrence are reported from upper Punatsangchhu of the study area dominated by Chirpine forests.

Birds having similar habitat and niche preference to WBH like Grey Heron, Great Cormorant, Osprey, and Pallas's Fish Eagle. Pallas' Fish Eagle, Crested Serpent Eagle, Mountain Hawk Eagle, Peregrine Falcon, White-tailed Eagle and Large-billed Crow are also found along the WBH landscape and can be

potential threats to WBH and their and egg and fledglings. Since the study was carried out with only a one-time field survey with limited resources and time-bound, no further analysis was carried out.

3.2.2 Aquatic biodiversity

Fish

Punatsangchhu

Among 40 sampling sites, the survey team could not capture fish from two sites. Only 17 fish species were captured during the monsoon trip, which is far less than expected. This could be due to high (flood) water in the river due to the monsoon. So a team had to be sent again in mid-November to the Balwani river area (Tsirang) which is a warm water region and this water was covered during the monsoon trip. During the repeat survey, six sites were sampled in and around Balwani (Tsirang) and 18 species were recorded. Combined effort provided 27 species comprising nine families. Considering both the survey, Snow trout (*Schizothorax richardsonii*) was very common (n=243 mature) followed by Copper mahseer (*Neolissochilus hexagonolepis*) with 50 individuals examined. The maximum length of fish caught from this study region was 55 cm and similarly, a maximum weight of fish caught here was 1.7 kg for a Snow trout as well. The team also recorded a Golden mahseer of 53 cm length with 1.1 kg. The most abundant fishes were found in Basochhu and Phochhu followed by Dangchhu and Dikchhu. Brown trout (*Salmo truta*) was introduced in Bhutan in 1941 (released in rivers and lakes) which was brought to Haa fish hatchery in 1939. This species is carnivorous and preys on native fish and macroinvertebrates.

Mangdechhu

In this study area, 30 sampling efforts were made. However, only 14 fish species consisting of four families could be recorded during the field survey. This was mainly attributed to the limitation posed by high water level due to the monsoon. The team encountered a fingerling of Golden Mahseer (Tor putitora) at about Takabi eco-camp site, Birte, Zhemgang district. The spring water source was clear and the number of fingerlings of Copper Mahseer (Neolissochilus *hexagonolepis*) and *Garra* spp. indicate that the water is used for spawning ground by these species, including that of Golden Mahseer.

Snow Trout (*Schizothorax richardsonii*) was the most common species observed in this study area (n=60 adult, n=11 juvenile) followed by *Neolissochilus hexagonolepis* (n=61 adult, n=9 juvenile). The largest catch was that of a Copper Mahseer weighing 4.1 kg and measuring 80.2 cm in length. The mean length and weight of fishes caught were 16.32 cm (±13.35 SD) and 166 g (±494.53 SD). This study area has endemic torrent catfish (*Exostoma mangdechhuensis*) which is mostly confined to Dakpaichhu of MRB. The most abundant of fishes are found in Bipapangchhu followed by Dakpaichhu and Bertichhu, Zhemgang district.

Amphibians

Punatsangchhu basin

The survey team observed *Amolops* sp. as incidental records. However, in both the study area, study of amphibians, reptiles, birds and mammals would require a separate study.

Mangdechhu basin

While a detailed survey for this group of animals during the short time was not possible, the team could observe *Amolops* sp. and a tree frog.

Crustacea

This group includes crabs and freshwater shrimps – decapods, and this group of animals are understudied and their records are scanty in Bhutan.The survey team observed freshwater crab (*Himalayapotamon* sp.) in both the study areas. The *Himalayapotamon* sp. reported from MRB was stunned using an electro-shocker and collected for identification. The specimens were released back live into the same spot after observation and confirmation of species.

3.2.3 Other factors recorded during the study

Soil stability and plantation potential

In case of MRB majority (16/30) sampling plots were reported as stable and had no signs of erosion (ref Table 3.7 below). Likewise, most of the sampling plots in PRB were either in the category of moderately stable (16/40) or stable (13/40). In terms of plantation potential, many sampling plots had moderate potential (8/30), some potential (8/30) or high potential (8/30). However, in the case of Punatsangchhu, 50% (20/40) plots have low plantation potential and 22.5% (9/40) have no potential for plantation. This assessment was however based only on the number of sampling plots (*30 in Mangdechhu* and *40 plots in Punatsangchhu basin*) and the results may not be conclusive. A detailed assessment of the plantation potential and field assessment may be required.

Table 3.7: *Soil stability and plantation potential*

Type	Category	Number of sampling plots		Total
		Mangdechhu	***Punatsangchhu***	
Soil stability	Unstable	0	9	9
	Moderately stable	4	16	20
	Stable	16	13	29
	Very stable	9	2	11
Plantation potential	No potential	0	9	9
	Low potential	4	20	24
	Moderate potential	8	5	13
	Some potential	8	4	12
	High potential	8	2	10

Human activities affecting Biodiversity

Lopping of trees for fodder collection for cattle affects forest quality. The incidences of lopping in the MRB were higher as compared to that in PRB (Table 3.8). In the case of mining, MRB had no mining activities in the vicinity of the sampling plots, whereas mining activities were observed in the vicinity of five sampling plots in the PRB. Similarly, fire incidents were noted in PRB but absent in the case of MRB.

Table 3.8: *Lopping intensity, grazing, timber extraction and forest fires*

Activities	Intensity/type	Number of sampling plots		Total
		MRB	***PRB***	
Lopping	Absent	4	23	27
	1-3 trees	9	10	19
	4-6 trees	4	7	11
	7-9 trees	7	0	7
	Heavy, 10 or more lopped	6	0	6
Grazing	Absent	6	16	22
	Less	6	11	17
	Moderate	6	11	17
	Heavy	9	2	11
	Very heavy	3	0	3
Timber extraction	Absent	14	15	29
	Less	4	13	17
	Moderate	3	10	13
	Heavy	7	2	9
	Very heavy	2	0	2
Fire	Absent	30	34	64
	Recent	0	3	3
	Old	0	3	3

3.3 Status of ecosystem services

Ecosystem services are essentially the direct and indirect benefits that human society acquires from nature. This chapter looks at the various ecosystem services and products recognized by the local people as being availed from their surrounding ecosystems. The chapter then attempts to assess the value of the ecosystem services based on DCE and benefit transfer methods.

3.3.1 Types of ecosystem services

The concept of ecosystem services is used here to find out how individuals value ecosystems. A simple exercise such as asking households to report the different services obtained from nature can give a glance into the value of the ecosystem. The services include all the direct and indirect benefits contributed by the ecosystem toward the well-being of the household. The ecosystem services availed by the communities are categorized into provisioning, regulating, supporting, and cultural services (see Figure 3.12 and Appendix 2.1) for details. This provides a better understanding of the ecosystem services that are used mostly by households.

Figure 3.12: Ecosystem services availed by communities in and around WBH habitat areas

Provisioning services are ecosystem services that describe the material or energy outputs from ecosystems such as food, water and raw materials that people obtain directly from nature. Regulating services are those benefits derived by humans as a result of the natural processes and functioning of the ecosystem example regulating the quality of air and soil or providing flood and disease control. Supporting services are those benefits provided by ecosystems in the form of space for plants and animals to survive thereby enabling the diversity of plants and animals. Cultural services are non-material benefits that people derive from nature such as aesthetic, mental, and spiritual benefits. *Figure 3.12* shows the list of goods and services under each of the four categories of ecosystem services availed by communities in and around the WBH habitat areas.

Provisioning Services

The highest number of goods and services identified by the farmers belonged to the provisioning services category. Since most of the respondents were farmers, the products and benefits directly obtained from the ecosystem were easily comprehensible to them resulting in a higher number of services identified under the provisioning category. A total of 24 products were identified as under provisioning services. *Figure 3.13* illustrates the most widely acknowledged provisioning services i.e., i) Fresh water for drinking and irrigation, ii) Timber, iii) Fuelwood for cooking and heating iv) Non-wood forest products (NWFPs), v) Wild fruits and vegetables, vi) Flag poles, vii) Bamboo, viii) Construction stones, ix) Fodder trees, x) Fodder, xi) Beetle leaves, xii) Sand and clay, xiii) Raw material for incense, xiv) Fish, xv) Leaf litter used as animal bedding and ultimate production of farm manure, xvi) Tea leaves, xvii) Medicinal/ holy springs, xviii) Medicinal plants, xix) Fibre (pulp of paper) xx) Dye plants, xxi) Bush meat, xxii) Edible insects, xxiii) Essential oil, xiv) Wood burr, xxii) Limestones.

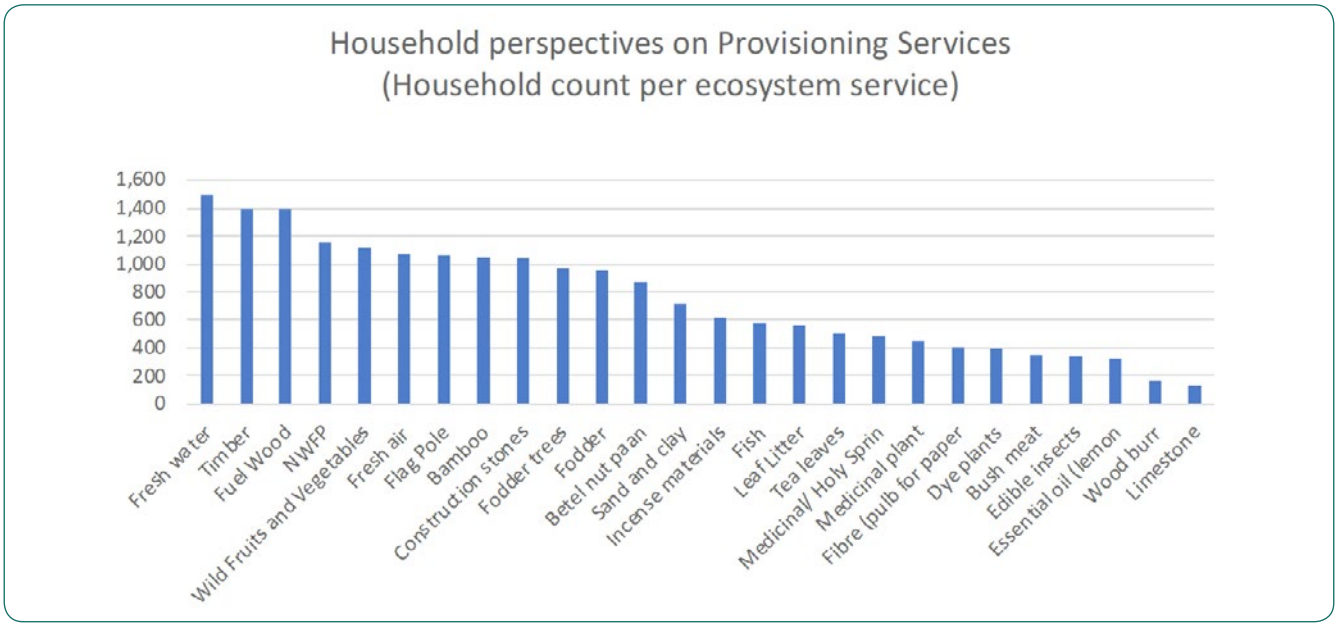


Figure 3.13: *Household perspectives on Provisioning Services (count per ecosystem service)*

Regulating Services

The study noted that the farmers recognize the regulating services of ecosystems. A total of 13 services were noted under this category. The most common services acknowledged by the farmers are: i) Land productivity, ii) Sustained fresh water, iii) Improved vegetation, iv) Windbreak, v) Carbon sequestration, vi) Soil protection and erosion control, vii) Reduced forest fire, viii) Groundwater recharge, ix) Pollution control, x) Local weather regulation, xi) Biological reproduction xii) Flood regulation, xiii) Wastewater treatment, xiv) Pollination (Figure 3.14).

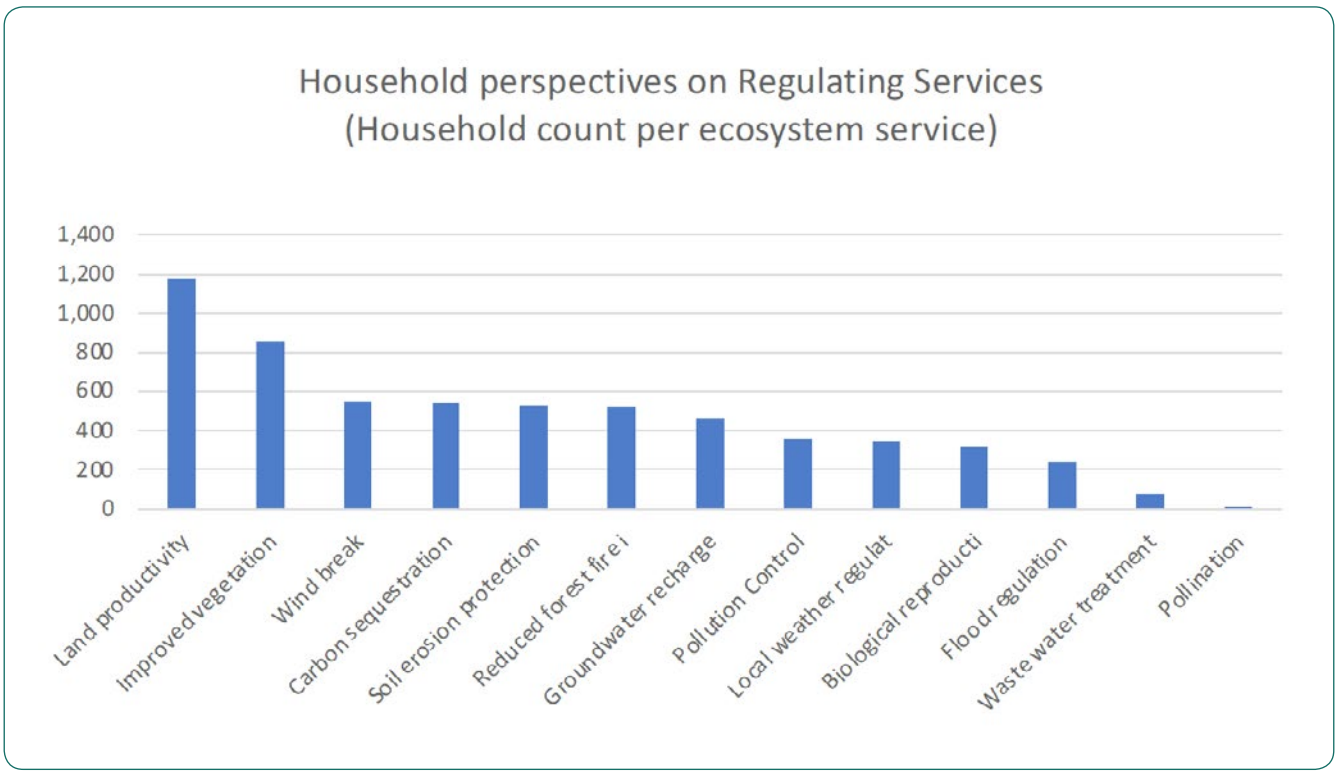


Figure 3.14: Household perspectives on Regulating Services (count per ecosystem service)

Supporting Services

Farmers were also able to comprehend the role of ecosystems in providing support services. Although they are indirect and intangible benefits, the most common supporting services identified by respondents are i) Soil productivity, ii) Wildlife and plant habitats, iii) Biodiversity, iv) Pollination, v) Nutrient cycling, vi) Maintenance of genetic diversity and vii) Improved vegetation cover (Figure 3.15).

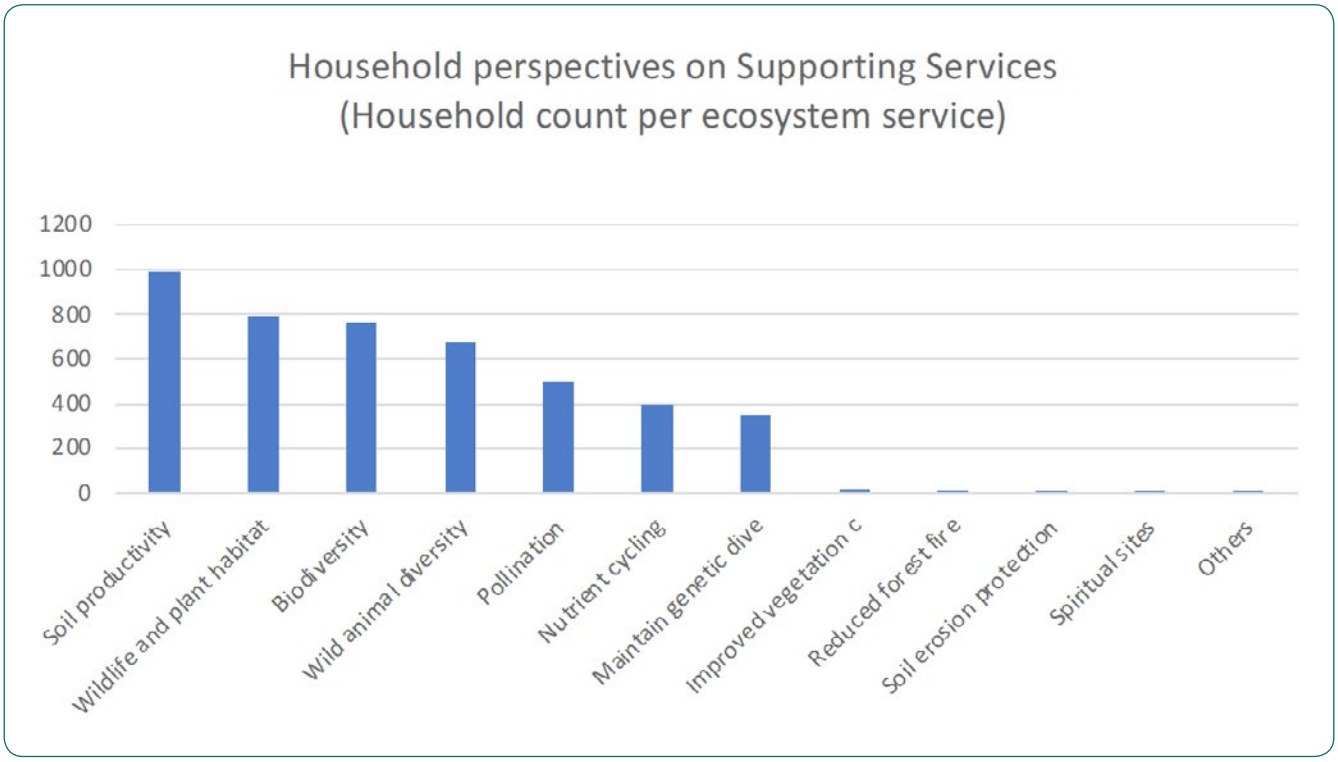


Figure 3.15: Household perspectives on Supporting Services (count per ecosystem service)

Cultural Services

The cultural services that the local people recognize as coming from the natural ecosystems are i) Seat of guardian dieties, ii) Spiritual sites, iii) Traditonal monument, iv) Pilgrimage site, v) Tourism/ Recreation, vi) Recreation, vii) Picnic spot, viii) Aesthetic (see Figure 3.16).

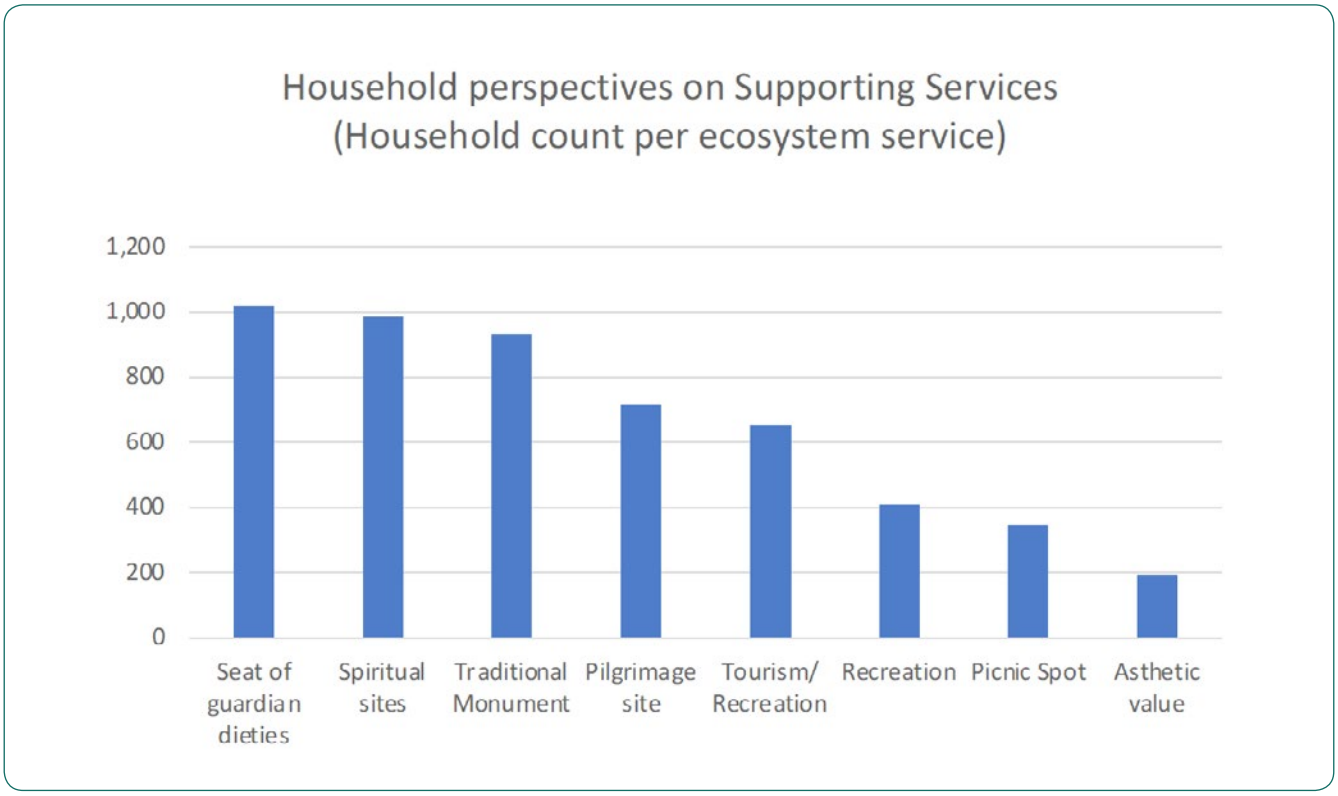


Figure 3.16: *Household perspectives on Supporting Services (count per ecosystem service)*

The study reveals the maximum dependence of communities on the provision services to ecosystems. From the above, it is evident that the list of products and benefits under provisioning services far exceeds the number of benefits derived from other types of ecosystem services. This, in a way, suggests the dependency of local people on the provisioning services of the ecosystems. It is clear the value of provisioning ecosystem services is highly valued by local people. However, unregulated and ineffective management systems allowing uncontrolled appropriation of products and services could damage and degrade the ecosystems. Hence, the way in which the services are availed is not just an environmental concern but also of economic concern pertaining to the livelihood of the households, which is mostly natural resource-based.

3.3.2 Household perceptions on trends in locally important services

As expected in any developing countries, the number of services or rent seeking behavior is mostly observed in the provisioning services followed by regulation. The number of services for supporting and cultural services is almost similar. Fuelwood, timber, fresh water and fodder are among the most sought-after services and the dependence on them seem to be high. Land productivity and improved forest cover are dominating regulating services. For supporting, it is mostly realized in terms of biodiversity, soil productivity and wildlife diversity. In the cultural services, households value their environment as a seat of guardian deities and spirits, traditional monuments, and pilgrimage sites (Appendix 2.2). This could be primarily due to the nature of the occupation of which farming seems to dominate.

A total of 40% to 56% of respondent households perceive that provisional services like timber (56.29%), NWFP (52.20%), bush meat (50.14%), edible insects (49.41%), fuelwood (46.35%), fish (42.98%), and fodder (39.56%) have decreased over the last decade. On the other hand, more than 50% of the respondent households feel that provisional services like medicinal/holy springs (77.25%), fresh air (68.91%), medicinal plants (59.60%) flag poles (56.06%), incense materials (54.68%), essential oil (53.03%, dye plants (51.40) and sand and clay for construction (49.3%) have remained the same. Overall, 45.86% of the respondents feel that provisional services have not changed, 35.36% feel the services have decreased, and 18.77% feel the services have increased.

Up to 40% of the households actually feel the regulating services have decreased over the last decade while more than 50% feel the following regulating services have remained unchanged i.e., local weather regulation (75.64%), wastewater treatment (75.64%), Flood regulation (72.69%), Groundwater recharge (58.28%), Carbon sequestration (57.30%), Nutrient cycling (56%). Overall, 57.34% of the respondents opined that regulating services have not changed, 13.88% feel the services have decreased and 28.78% feel the regulating services have increased.

In terms of supporting services, up to 378 households i.e., 38.45% of the respondents felt that the supporting ecosystem services have actually decreased while up to 59.68% of the respondent opined that two of the supporting ecosystem services i.e., Biological reproduction (59.68%), and pollination (55.82%) have remained unchanged. Overall, 42.49% of the respondents perceive the supporting services have not changed while 26.87% and 30.64% felt that the supporting services have decreased and increased respectively.

472 households i.e., 72.50% of the households responded that tourism aspects of cultural ecosystem services have decreased. On the contrary, between 82% to 95.17% of respondents believe the following cultural ecosystems services have remained unchanged. They are the seat of guardian deities (95.17%), traditional monuments (92.39%), spiritual sites (90.58%), pilgrimage sites (89.39%), recreation (89.24%), picnic spots (82.08% and Aesthetics (82.05%) have not changed (See Appendix 2.3 for detailed trend analysis of ecosystem services). As in the case of other services, 80.32% of respondents felt that the overall cultural services of the ecosystems have remained intact (not changed). Only 11.40% felt that the cultural services have decreased while 8.28% felt the cultural services have increased.

From the above, it is evident that local people are more cognizant of the provisional ecosystem services both in terms of the number of products they obtain from their ecosystem as well as the changes in their availability. This could be because households cannot really judge the changes in intangible services whereas provisioning services that local people appropriate directly from their surrounding environment are tangible and easy to relate to.

Attempts to compare local people's perception of the trends in ecosystem services revealed similar patterns across PRB and MRB. In both river basins, people do not feel drastic changes in provisioning, regulating, supporting, and cultural ecosystem services. Table 3.9 shows respondents in both river basins believe all types of ecosystem services have not changed while smaller portions of the respondents feel the services have decreased and even smaller portions of the respondents felt that the services have increased (Refer Appendix 2.3 for details).

Table 3.9: Comparison of trend in ecosystem services between PRB and MRB

Ecosystem Services	Decreasing		No Change		Increasing	
	MRB	PRB	MRB	PRB	MRB	PRB
Provisioning Services	2.5	17.46	2.72	19.44	1.11	9.16
Regulating Services	0.5	3.05	1.45	8.84	0.65	5.6
Supporting Services	0.55	3	0.77	4.36	0.38	3.68
Cultural Services	0.18	1.43	0.86	11.25	0.27	0.77

The analysis was further carried out to assess people's perception of the trends in ecosystem services in WBH habitat and potential WBH habitat areas. In both the categories, the unchanging trend of provisioning services including the other three services is similar to before. No significant differences have been observed. 'No change' is the dominant opinion of respondents in both current WBH habitat areas as well as potential WBH habitats. The dominance of dependence and reporting of services is higher for provisioning services (Refer Table 3.10). This dependence of communities on provisioning services is evident between the basins and across parts of districts that fall in the WBH habitat areas (Refer Appendix 2.4 and 2.5 for details).

Table 3.10: Comparison of trends in ecosystem services between Current and Potential WBH habitats (in the percentage of respondents)

Ecosystem Services	Decreasing		No Change		Increasing	
	Current	Potential	Current	Potential	Current	Potential
Provisioning	18.26	1.7	19.99	2.17	9.62	0.66
Regulating	3.13	0.42	9.49	0.81	5.72	0.53
Supporting	3.12	0.43	4.67	0.46	3.76	0.3
Cultural	1.47	0.14	11.24	0.87	0.92	0.12

From Table 3.9 and Table 3.10 above, the majority of the households have opined that all categories of ecosystem services remained unchanged be it in PRB or MRB and WBH habitat or potential WBH habitat areas. This is suggestive of the variations in the type of ecosystems and associated services across the study area.

The set of statistics under the two tables must be interpreted with caution when comparing PRB with MRB and WBH with potential WBH. One of the take-home messages from this trend analysis is the comparison of the trends. Within the 'No Change' trend, 19.44 % of households in PRB and 19.99% in current WBH habitat reports a significant percentage compared to MRB and potential WBH area. The number of higher percentages in the current WBH habitat compared to potential-WBH is expected considering that both PRB and current WBH areas have more number of respondents. Within the river basin cohort, most households felt that ecosystem services are unchanging while an almost equal proportion of respondents felt the ecosystem services are decreasing. For example, close to 22% of the respondents feel unchanging provisioning services, 19% report it is 'decreasing'. Only 10.26 % felt

that it is 'increasing'. The statistics are similar across the WBH cohort. It is higher in the 'no change' trend but this is not so different from the number who feel it is decreasing. As indicated in the previous section, the number of people reporting on these trends are higher in provisioning services compared to regulating, supporting and cultural services. This means provisioning services are more numerous when compared to other ecosystem services which are taken by households from the ecosystem.

3.3.3 Modeling household choices

The Discrete Choice Experiment (DCE) responses were analyzed separately, first for the monetary and labor cohorts, second for WBH and potential WBH area, and then for MRB and PRB users. The data on choices were analyzed using the conditional logit model (CLM). In these regressions, the dependent variable is choice-out of three alternatives in each choice set, the selected alternative is coded as 1 and the other two alternatives are coded as 0. The choice of three policy alternatives that present different levels of each attribute i.e., the benefits and cost of ecosystem services were modelled. For example, alternatives 1 and 2 consist of increasing or decreasing levels of the drinking water, irrigation water, fuelwood etc., while the current situation consists of the status quo of the different ecosystem services. For example, if the current labour contribution is 2 days, that will be presented to the respondent. The objective is to find out which policy (hypothetical) will be chosen by respondents depending on the different ecosystem services. This enabled us to answer two things – i) to understand the demand for different ecosystem services, and ii) two how much cost the respondents are willing to pay to realize these benefits.

Appendix 2.6 shows the results for the CLM for the different cohorts. In the CL probabilistic model, the estimated coefficients can only be interpreted in terms of sign and significance. The coefficient shows effect of the ecosystem services on the choice of alternative policy options. It is interpreted in terms of how these ecosystem services affect a household's choice when they are presented with alternative policies in comparison to the current situation. For example, in the current situation in terms of irrigation water the number of months water available is 6 months. The alternative choice is either increase or decrease this ecosystem service. In short, we want to see whether the respondent chooses the alternative or the current situation. This choice decision will tell us whether all of the different ecosystem services presented as attributes influence people to make different choices. A positive coefficient will show that the specific ecosystem services influence the respondent's choice in a positive way. For example, an increase in fuelwood available per day might influence respondents to choose alternatives in comparison to the current situation. These coefficients with different signs may be either significant or not depending on the number of stars (*) shown against their coefficients. A coefficient without any star means the ecosystem service does not have a significant effect on the choice or put simply, there is a lack of demand for the ecosystem service. Significances are tested against 10% (*), 5% (**) and 1% (***) threshold. A simplified version of the result in Appendix 2.6 is shown in the Table 3.11 below.

Results (Appendix 2.6) indicate that there is a significant and consistent variable that seems to explain the choice of the respondents. It shows that communities prefer increased quantities of water (drinking and irrigation) and firewood, while their preference towards fodder, NWFP, fish, and cost in terms of fee or in terms of labor contribution. The conservation of WBH through a preference for habitat presence seems to be as important as the first group of variables. One of the variables that turn on and off in terms of its significance is timber.

There seems to be a difference in how these ecosystem services play an important role in making choices in the different cohorts. Compared to the Fee cohort, the Labour cohort shows the relevance of more ecosystem services in explaining the choice of the respondents. The increasing value of the ecosystem services seems to have significance for policy choice for Fee compared to labour cohort. For example, irrigation water when an increase in the number of water available for irrigation influences policy choice, while for the labour cohort, a decrease in the number of months of water available for irrigation influences policy choice. In simple terms, irrigation water as an irrigation water seems to play a vital role in the household choice of policy, whether in decreasing or increasing form.

Table 3.11: Demand for ecosystem services and their differences across site cohorts

	Contribution		WBH habitat		Basin	
	Mem. fee	Labour	Current	Potential	MRB	PRB
ASC	(-)***	(-)***	(-)***	(-)***	(-)***	(-)***
Drinking water	(+)***	(+)*	(+)***	(+)***	(+)***	(+)***
Irrigation water	(+)***	(-)***	(+)***	(+)***	(+)***	(+)***
Fuelwood collection	(+)	(+)***	(+)***	(+)	(+)	(+)***
Animal fodder & bedding	(+)	(-)***	(-)***	(-)	(-)**	(-)***
Timber	(+)***	(-)	(+)***	(+)	(+)***	(+)*
Fishing	(-)***	(+)***	(+)***	(+)**	(+)	(+)***
NWFP	(+)	(-)**	(-)	(+)	(-)	(+)
WBH	(+)***	(+)***	(+)***	(+)***	(+)***	(+)***
Labour-fee	(-)	(+)	(-)***	(+)	(+)**	(-)***

Comparison across WBH and potential-WBH areas shows that almost eight-out-of-nine ecosystem services are significant, while only four of the ecosystem services are important. In both areas, an increase in irrigation water, drinking water, and the presence of WBH seem to influence the choice of the policy. In the WBH area, increasing timber availability determines policy choice but not for Potential-WBH area. This trend of result is also prominent when the PRB basin is compared with MRB. Results show that eight-out-of-nine ecosystem services are important for the households in determining their choice. Increasing levels of water for drinking, irrigation, timber, and the presence of WBH habitat influences policy choice. In other words, these ecosystem services seem to be very important for households in both the river basins. However, fuelwood seems to play a vital role for the PRB basin but not for MRB.

Table 3.12 which is also a simplified version of Appendix 2.7 shows that the availability of television (TV) in a household is an influential variable in explaining people's preferences. Respondents with a connection to TV are more likely to show a preference for more ecosystem services compared to their counterparts. Households with TV find Timber as an important ecosystem compared to households without TV. Interestingly, respondents who have not participated in conservation are more likely to show a preference for more ecosystem services when we compare with those respondents who

participate in conservation measures. This is confusing at first, but further reflection shows that it could be because of dwindling resources that they begin to feel the importance of these ecosystem services. This can be confirmed from the analysis of how communities with HWC think compared to those without HWC. Here, communities with higher HWC show more ecosystem services being important in making policy choices. In places where HWC is present, households perceive increasing irrigation as important compared to places without HWC.

Table 3.12: Demand for ecosystem services and their difference across different socioeconomic cohorts

	Gender		Participation in Conservation		Television Connection		HWC	
	Female	Male	Yes	No	YES	NO	Present	Absent
ASC	(-)***	(-)***	(-)***	(-)***	(-)***	(-)***	(-)***	(-)***
Drinking water	(+)***	(+)***	(+)***	(+)***	(+)***	(+)***	(+)***	(+)***
Irrigation water	(+)***	(+)***	(+)***	(+)***	(+)***	(+)***	(+)***	(-)
Fuelwood collection	(+)***	(+)***	(+)***	(+)**	(+)***	(+)***	(+)***	(+)***
Animal fodder & bedding	(-)***	(-)***	(-)***	(-)***	(-)***	(-)	(-)***	(-)**
Timber	(+)	(+)***	(+)***	(+)**	(+)	(+)***	(+)***	(+)*
Fishing	(+)**	(+)***	(+)	(+)***	(+)***	(+)	(+)***	(+)
NWFP	(+)	(-)	(+)	(-)*	(+)	(+)	(+)	(-)
WBH	(+)***	(+)***	(+)***	(+)***	(+)***	(+)***	(+)***	(+)**
Labour/ fee	(-)***	(-)***	(-)***	(-)***	(-)***	(+)	(-)***	(-)***

One of the striking results is the role of females in opting for policy choice. The result shows that there is no significant difference between male and female-headed households. Both of the household cohorts show equal importance to all the ecosystem services. All these are presented in Appendix 2.7. More water for irrigation and drinking, fuelwood, and the presence of WBH are equally influential in explaining household choices. It means that households that are headed by both male and female have similar demand for these ecosystem services. The difference that is noticeable is timber. Households that are headed by male are concerned about timber volume since it is mostly a male job to get these resources.

3.3.4 Estimation of Willingness to Pay (WTP)

WTP for ecosystem services is also estimated. The WTP or the implicit price of individual attributes or ecosystem services included in the choice task is estimated. For the CLM since all the ecosystem services are treated as non-random, estimating WTP (Hole, 2007) is quite straightforward. The implicit price for non-random parameters is estimated as a negative ratio of coefficients between the non-random attribute and the cost attribute.

Looking at the fee and labour cohort, results (Table 3.11, Table 3.12 and Appendix 2.8) show that households show a positive preference for payment of ecosystem services in terms of fee compared to

labour. This could be because labour is considered an important resource for people in rural areas and would prefer to pay in terms of cash. In the table below, if there is a willingness to pay for ecosystem services then it is denoted with a plus (+) sign and wherever households are not willing to pay, it is denoted with a negative (-) sign. This willingness to pay measures whether a person is willing to bear the cost for the benefits derived from the ecosystem. Looking across the table two ecosystem services have a positive willingness to pay. These are timber and habitat for WBH. Looking at the first two cohorts in columns 1 and 2, households prefer to bear the cost of ecosystem services in terms of fee contribution as compared to labour. This could be because labour is a scarce resource and are mostly required in agriculture. In column 3 and 4, comparison of labour contribution was carried out between the two river basins. Households in PRB are willing to bear the cost of ecosystem benefits for eight-out-of-nine ecosystem services. This situation looks different in the MRB. In this area where irrigation is an important ecosystem service in both the basins, households are not willing to bear the cost. An interesting result from the table in columns 5 and 6 is that households in the potential WBH areas have a negative attitude towards bearing costs for ecosystem services including the cost of the presence of habitat for WBH. Irrigation and drinking water, and fuelwood were considered important ecosystem services, but in general, seem to carry a negative cost bearing attitude. Comparison across different cohorts show a stable result. Across different cohorts, drinking water, irrigation water, and WBH habitat shows that households are willing to bear the cost of deriving benefits. In fishing, timber and fodder benefits the cost or willingness to pay is negative or simply do not want to bear the cost.

Table 3.13: Comparative willingness to pay for ecosystem services

	Fee Cont.	Labour Cont.	MRB	PRB	WBH	Pot. WBH
Drinking Water	+	-	+	+	+	-
Irrigation Water	+	+	-	+	+	-
Fuelwood Collection	+	-	+	+	+	-
Animal Fodder	+	+	-	-	-	+
Timber	+	+	+	+	+	-
Fishing	-	-	+	+	+	-
NWFP	+	+	-	+	-	-
WBH	+	+	+	+	+	-

Table 3.14: Comparative willingness to pay for ecosystem services for fee contribution

	Fee	MRB	PRB	WBH	Potential WBH	Female	Conservation	HWC	TV
							Yes	Yes	Yes
Drinking Water	+	+	+	+	+	+	+	+	+
Irrigation Water	+	+	+	+	+	+	+	+	+
Fuelwood Collection	-	-	+	-	+	-	-	-	+
Animal Fodder	-	-	-	-	+	-	-	-	-
Timber	-	+	-	-	-	-	-	-	-
Fishing	-	-	-	-	-	-	-	-	-
NWFP	-	-	+	-	-	+	+	+	+
WBH	+	+	+	+	+	+	+	+	+

3.3.5 Value of ecosystem using DCE

In this section we estimate the value of ecosystem services based on the outputs from the DCE method. The ecosystem value for each Chiwog is computed by multiplying the net ecosystem value with its population. The net value is the difference between the total economic value generated in the current situation and a hypothetical increase in the quantity of each ecosystem type. We can also instead use the total value generated by the current situation and multiply it with the population of the chiwog to estimate the value of the ecosystem. We also use the WTP data generated from the previous analysis. We employ the WTP values from the sample who responded to the fee module except for the fishing ecosystem service because of negative values. We replace the negative WTP for fishing with the value estimated in the module with sample respondents from PRB. We estimated the final change in ecosystem value from eight ecosystem services using the following steps:

Step 1: Multiply the WTP value with the number of ecosystem services for current and hypothetical scenarios.

Step 2: Sum over all the ecosystem services.

Step 3: Calculate the difference between the two scenarios and express the difference in current dollar value.

Using this method, we estimated a total of 348.81 USD worth of ecosystem value per household. This value expresses the change in the ecosystem values generated if intervention leads to changes in the volume of the services to society. This value is used to find the value of ecosystems created for each chiwog (Table 3.15 and Appendix 2.9). For the sample, the total ecosystem value generated is 0.41M USD.

Table 3.15: Change in ecosystem value from intervention (in USD)

			WTP		Fee		PSC		Value	
	Current Situation	Upper Bound	Fee	PSC	Current Situation	Upper Bound	Current Situation	Upper Bound	Current Situation	Upper Bound
Drinking water	100	200	157.84	15.34	15784	31568	1534	3068	15784	31568
Irrigation water	6	9	1493	64.54	8958	13437	387.24	580.86	8958	13437
Fuelwood	100	200	4.05	8.03	405	810	803	1606	405	810
Animal bed/ fodder	1	2	258.4	-518.93	258.4	516.8	-518.93	-1037.86	258.4	516.8
Timber	100	200	36.15	1.82	3615	7230	182	364	3615	7230
Fishing	10	20	-150.11	31.81	-1501.1	-3002.2	318.1	636.2	318.1	636.2
NWFP	1	2	691.27	44.75	691.27	1382.54	44.75	89.5	691.27	1382.54
WBH habitat	1	1	2636.84	1082.81	2636.84	2636.84	1082.81	1082.81	2636.84	2636.84
									32666.61	58217.38
									445.96	25550.77

3.3.6 Value of ecosystem services using Benefit Transfer

In this section we show the estimation of the value of ecosystem services in the study area using the benefit transfer methodology. This method uses the value of four land cover types, which include cropland, orchard, forest, lakes, and rivers. These values are adopted from a paper carried out for Bhutan's ecosystem service valuation (Kubiszewski et al. 2013). The values adopted in this paper are originally taken from the Ecosystem Services Valuation Database (ESVD) and compiled by the International Ecosystem Services Partnership. The values used for the paper represent the values of the ecosystem that resembles the context of Bhutan. The similarity of the context is defined in terms of a similar ecosystem comparable to Bhutan. We updated the dollar value for 2021 by using the consumer price index. The value estimation was carried out for four ecosystem services for the ESRAM study area measured in hectares.

For cropland and orchard, we used the value reported by the respondent in the study area. For forests, lakes and rivers, we first estimated the value per household for each ecosystem service. For this, we first added the total land area for each category of the dzongkhag and divided it by the total number of households in the dzongkhag. This value of land cover per household is multiplied by our sample size to calculate the total land cover for forests and rivers. We then multiplied this area for each category by the ecosystem value generated from the ESVD adopted in the reference paper. We also express the value of ecosystem services in Ngultrum using the latest exchange value.

We estimated a total of US $ 11.5 million as mean value of all ecosystem services per year for the ESRAM study area per year. This translates to US $ 9783.99 per household per year. For generating this value, the reference values i.e., minimum, maximum, and the mean are taken from Kubiszewski et al. (2013) which was based on a total of 118 papers. This mean value is at least three times the national per capita income. Based on Table 3.16, the maximum contribution to the mean total ecosystem value comes from forests with an estimated US $ 7.78 million per year which works out to US $ 6598.94 per household per year (67.45%). This is followed by cropland with a mean value of US $ 3.32 million per year or US $ 2812.46 per household per year (28.75%). The least ecosystem service value comes from orchards and lake/ riverine ecosystems. Orchards account for US $ 0.255 million per year which is US $ 217.05 per household per year while lakes/ riverine ecosystems account for US $ 0.183 million per year or US $ 155.54 per year (1.59%).

Table 3.16: *Estimate value of cropland, orchard, forest, and lake/ riverine ecosystems in ESRAM study area using benefit transfer method*

		US $ per hac per year Kubiszewski et al. (2013)			US $ per year			Household Mean		
	Total area (ha)	Min	Max	Mean	Min	Max	Mean	US $/year	Nu/year	Percentage contribution
Cropland	1313.25	1100.44	3949.46	2524.95	1445155.46	5186623.09	3315889.27	2812.46	206012.63	28.75
Orchard	119.88			2134.69			255906.88	217.05	15899.22	2.22
Forest	1119.42	1839.59	29944.99	6950.16	2059269.36	33521015.11	7780148.11	6598.94	483372.22	67.45
Lakes/ Rivers	27.55	1599.64	21429.66	6656.43	44070.08	590387.13	183384.73	155.54	11393.50	1.59
Total	2580.10	4539.67	55324.10	18266.23	3548494.90	39298025.33	11535328.99	9783.99	716677.56	100.00

For a detailed workout of the above ecosystem services in the study area, please refer to Appendix 2.9. In the study area, the forest provides a total economic value of US$ 7.78 million or US $ 621.92 in provisioning services in food, timber, and water per household per year.

Table 3.17 shows a summary of the estimated value of each type of ecosystem service derived from the data presented in Appendix 2.9. Here, regulating services dominate the total contribution at US $ 8.65 million accounting for 75.03% of the overall value of ecosystem services. This is followed by provisioning services at US $ 1.2 million accounting for 10.46%. The value from cultural services is the least with US $ 0.03 million that make up for only 0.28% of the value of all ecosystem services. In total, ecosystem services provide US$ 1,023 worth of provisioning services per household per year (Refer Appendix 2.9 for detailed workout).

Table 3.17: Value of ecosystem services for each ecosystem services

	US $ per hectare per year			US $ per year (ESRAM Area)			Household Mean		
	Min	Max	Mean	Min	Max	Mean	US $/year	Nu./year	Percentage contribution
Provisioning services	973.57	17822.20	5616.67	384785.25	2148962.53	1206683.26	1023.48	74969.93	10.46
Regulating services	3178.60	7350.07	10280.45	3144971.02	4899119.24	8655128.19	7341.08	537733.79	75.03
Cultural services	1.38	48.27	24.82	1810.97	63384.01	32597.49	27.65	2025.25	0.28
Total	4538.29	36470.41	18264.86	3546683.93	18194602.89	11535291.00	9783.96	716675.20	100

We use the mean household value of the ecosystem services and multiplied with the population in each chiwog in the study area to generate the total ecosystem value in each chiwog (Appendix 2.10).

3.4 Climate change vulnerability

3.4.1 Climate Vulnerability Indices

District level analysis show that Trongsa is relatively more vulnerable (0.1497), followed by Zhemgang (0.1479) while the Wangduephodrang district shows relatively lesser vulnerability index (0.1053) (Refer Figure 3.17). It should be noted that the term 'district' here applies to the part of the district that falls in the ESRAM study area. The analysis is tagged with district but there are a only few Gewogs covered under the study areas demarcated within the two-river basins. Under Trongsa and Zhemgang districts only two Gewogs such as Korphu & Langthil and Nangkor & Trong are included.

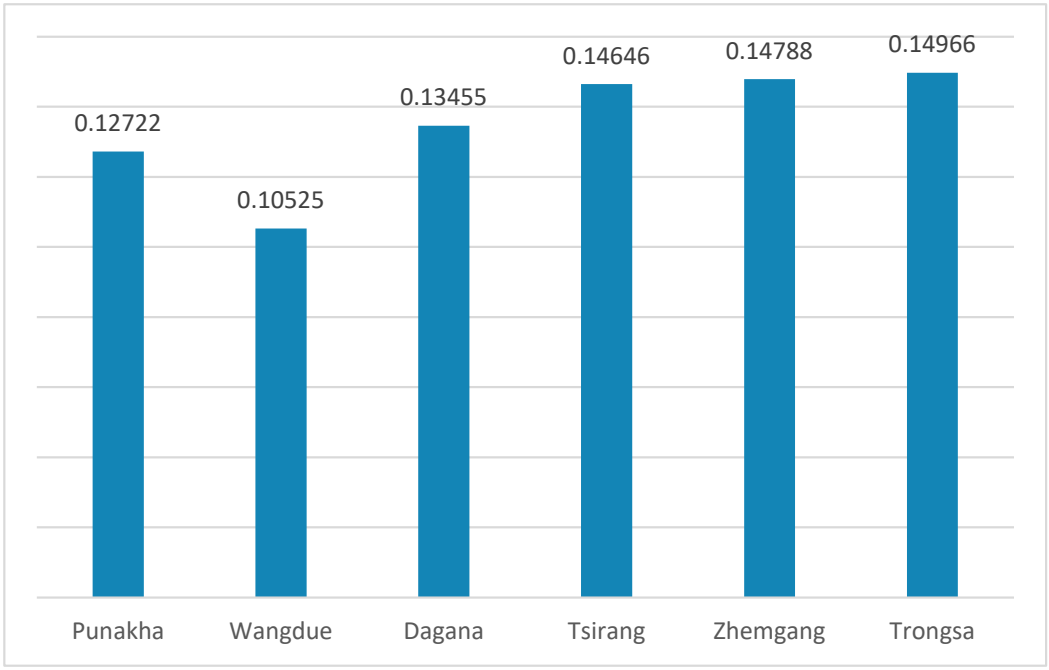


Figure 3.17: *Livelihood Vulnerability Indices of study districts*

Among the major components Trongsa district showed higher vulnerability (0.4189), followed by Wangdue (0.3860) concerning socio-demographic profile while Tsirang showed more vulnerability concerning livelihood strategies (0.1654). Among other major components are Zhemgang (0.1233) and Trongsa (0.1008). Concerning food production, Punakha Dzongkhag showed higher vulnerability, Tsirang concerning water and Natural disasters and climate vulnerability Tsirang, Punakha and Dagana districts showed more vulnerability (Table 3.18).

Table 3.18: *Livelihood vulnerability at district level*

Major components	Dagana	Punakha	Tsirang	Trongsa	Wangdue	Zhemgang
Socio-demographic profile	0.3275	0.3576	0.3926	0.4189	0.3860	0.3143
livelihood strategies	0.1297	0.1025	0.1654	0.1153	0.0979	0.1212
Social Network	0.0796	0.0914	0.0893	0.1008	0.0728	0.1233
Health	0.0560	0.0305	0.0498	0.0418	0.0260	0.0597
Food	0.1883	0.2105	0.1982	0.1888	0.1882	0.1892
Water	0.0650	0.0671	0.0780	0.0775	0.0412	0.0774
Natural Disaster & Climate variability	0.2552	0.2535	0.2609	0.2141	0.1689	0.1667

Among the six districts, indices show variable adaptive capacity while smaller differences in terms of exposure. This means that climate change variables are affecting different districts in a similar manner (Figure 3.18). There is also variation concerning sensitivity among districts as the access to food and food production, water availability and health facilities appear to differ.

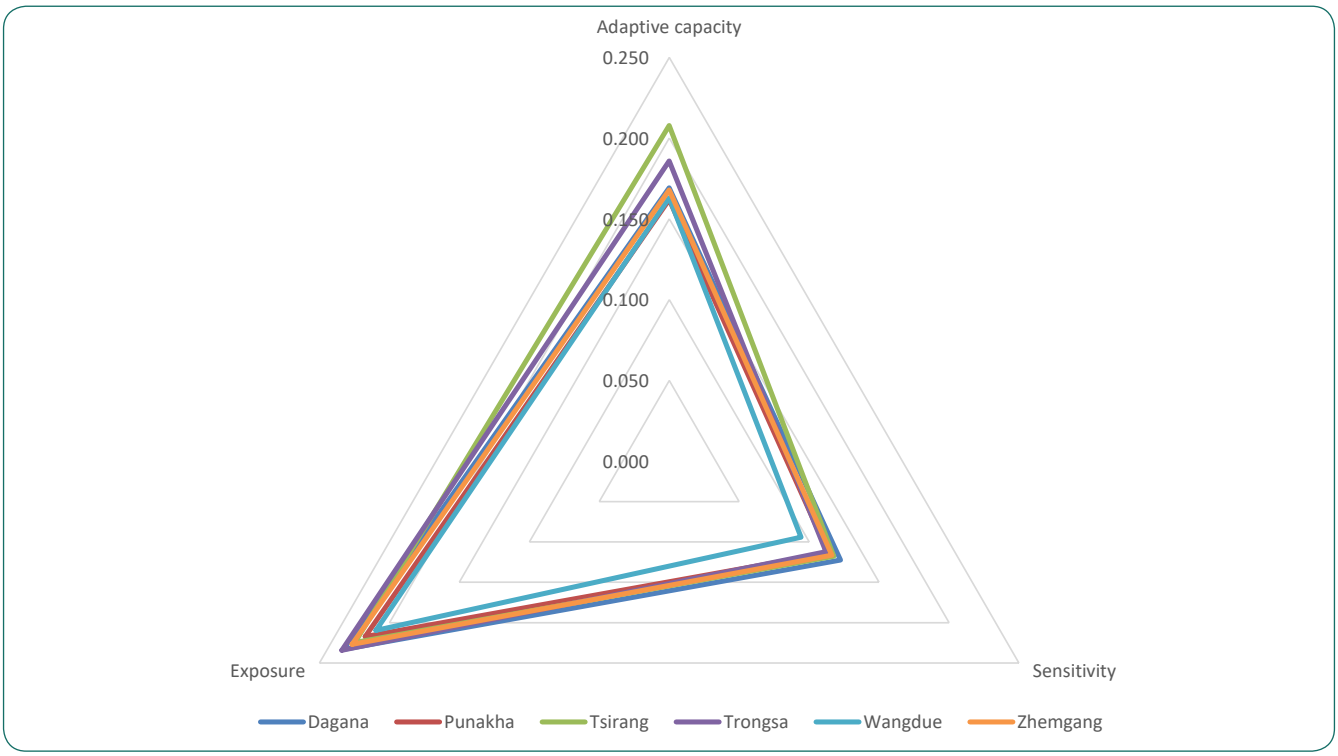


Figure 3.18: Components of Vulnerability for the six Dzongkhags

Among the major components of vulnerability within the study area, Socio-demographic profile is found to be relatively the major issue, followed by Natural disasters and climate variability, food production and social network (Figure 3.19). Trongsa district is relatively more vulnerable concerning socio-demographic profile, while Tsirang district shows relatively higher vulnerability concerning natural disasters and climate variability. All the district shows high vulnerability concerning food production while Punakha district show relatively higher vulnerability than other district. Zhemgang district reflects relatively higher vulnerability concerning social network.

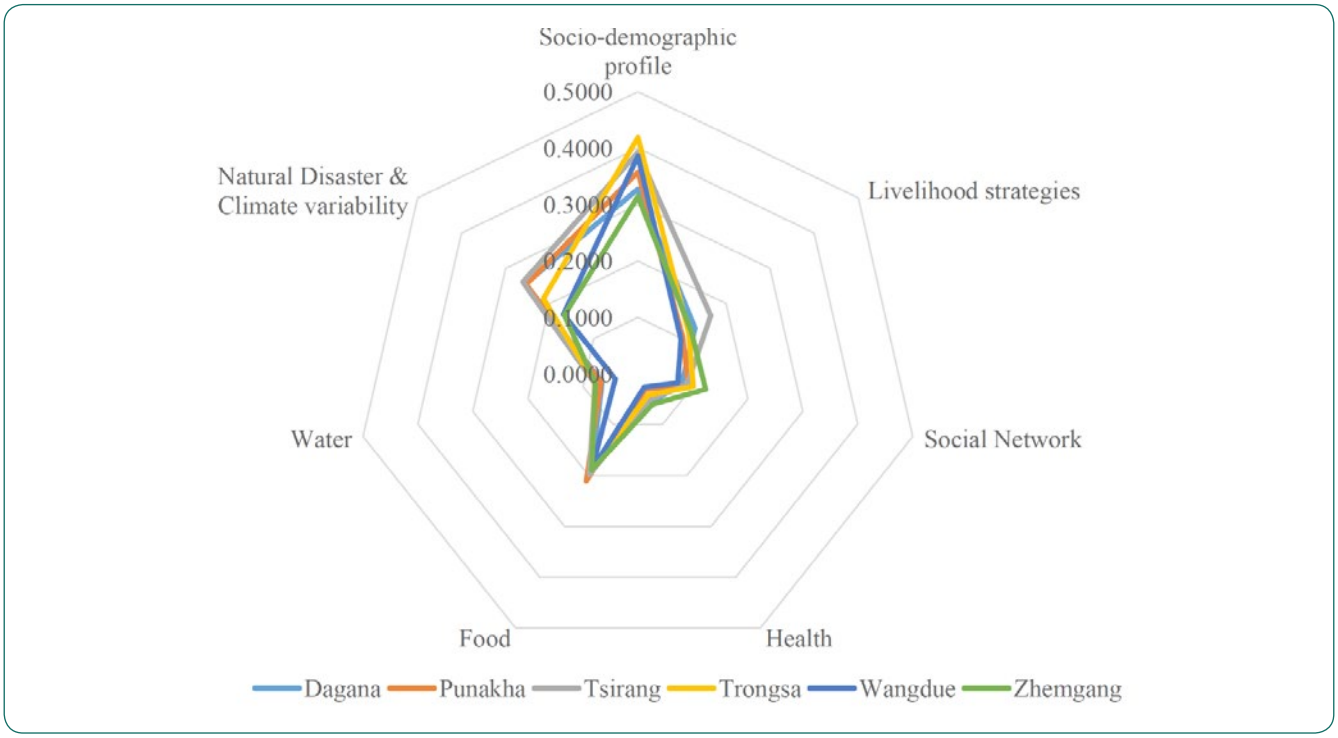


Figure 3.19: District wise Major Components of Vulnerability

While Trongsa district shows higher vulnerability concerning livelihood but Dagana district appear as the most vulnerable district concerning Climate Change Vulnerability, followed by Zhemgang and Punakha. The most resilient district within the study area is found to be Tsirang (Figure 3.20).

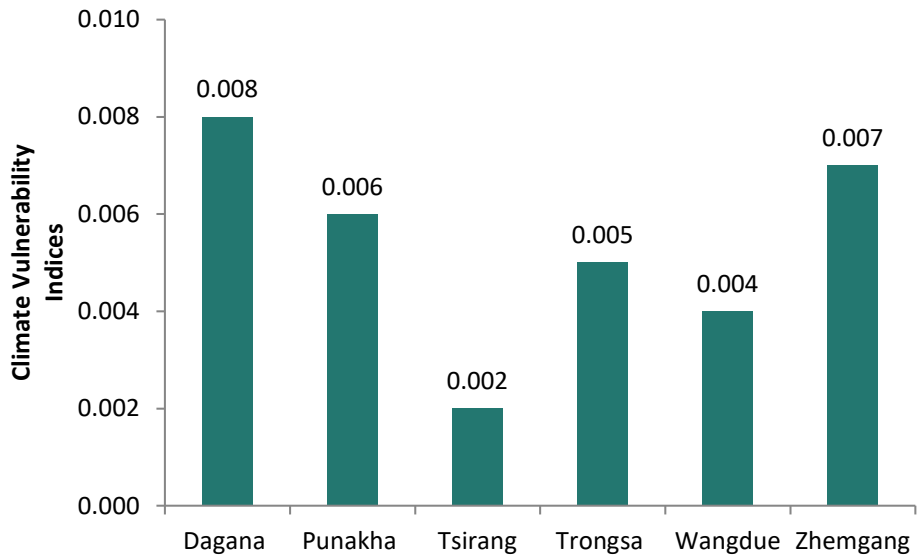


Figure 3.20: Climate Vulnerability Indices by Dzongkhags

In Punakha district, Chhubu Gewog reflects higher vulnerability concerning adaptive capacity while Guma Gewog is more vulnerable concerning sensitivity. With regard to Exposure Shengana Gewog is most vulnerable followed by Toedwang, Talo, Limbukha and Kabesa. In Wangduephodrang, Ruebesa Gewog reflects higher vulnerability concerning adaptive capacity while in Tsirang (Rangthaling Gewog) shows a higher index. With regard to Sensitivity, Ada Gewog in Wangdue and Tsirangtoe in Tsirang show higher indices. In Dagana (Tsangkha), Trongsa (Langthel) and Zhemgang (Nangkor) show higher indices. With regard to sensitivity, Tsandagang in Dagana, Langthel in Trongsa, and Nangkor in Zhemgang and show higher indices and concerning Exposure Tashiding in Dagana, Korphu in Trongsa and Trong in Zhemgang show higher indices (Table 3.19).

Table 3.19: Vulnerability components among study Gewogs

Distrit	Punakha										
Gewog	Barp	Chhu-bu	Dzomi	Goen-shari	Guma	Kabesa	Lim-bukha	Shengana	Tala	Toed-wang	
Adaptive capacity	0.0958	0.1939	0.1429	0.1718	0.1717	0.1616	0.1692	0.1742	0.1781	0.1601	
Sensitivity	0.1066	0.1097	0.1136	0.0988	0.1752	0.0965	0.1113	0.1029	0.1090	0.1144	
Exposure	0.1972	0.1693	0.2065	0.2129	0.2036	O.2150	0.2287	0.2612	0.2386	0.2401	

District	Wangdue										
Gewog	Ada	Daga	Gaset-shogom	Gaset-shoom	Rubesa	Theodt-sho	Bar-shong	Rangthaling	Sergithang	Shol-ingkha	Tsirangtoe
Adaptive capacity	0.1878	0.1314	0.1486	0.1687	0.1926	0.1488	0.1989	0.301	0.1920	0.1617	0.1851
Sensitivity	0.1201	0.0245	0.093	0.1002	0.1109	0.1169	0.1253	0.1119	0.0985	0.1016	0.1512
Exposure	0.237	0.1827	0.1841	0.1911	0.2279	0.2352	0.1693	0.2373	0.2276	0.2276	0.2611
District	Dagana						Trongsa		Zhemgang		
Gewog	Kana	Kheb-isa	Laja	Tashid-ing	Tsang-kha	Tsena-gang	korphu	langthel	Nangkhor	Trong	
Adaptive capacity	0.1468	0.1817	0.1774	0.1683	0.1821	0.1586	0.1832	0.1886	0.1774	0.1584	
Sensitivity	0.991	0.1231	0.1389	0.1214	0.0933	0.1586	0.1024	0.1217	0.1271	0.1054	
Exposure	0.2288	0.2282	0.2404	0.2471	0.2283	0.2254	0.2411	0.2269	0.2255	0.2279	

Rangthaling Gewog in Tsirang showed higher vulnerability concerning adaptive capacity, similarly, Shangana Gewog in Punakha and Tsirangtoe Gewog in Tsirang reflect higher vulnerability concerning exposure to climate variability and change while Guma Gewog in Punakha showed higher sensitivity that includes food and food production, access to water and access to health facilities (Figure 3.21). Among all the major components, access to health appears to have no issues in all the study Gewogs.

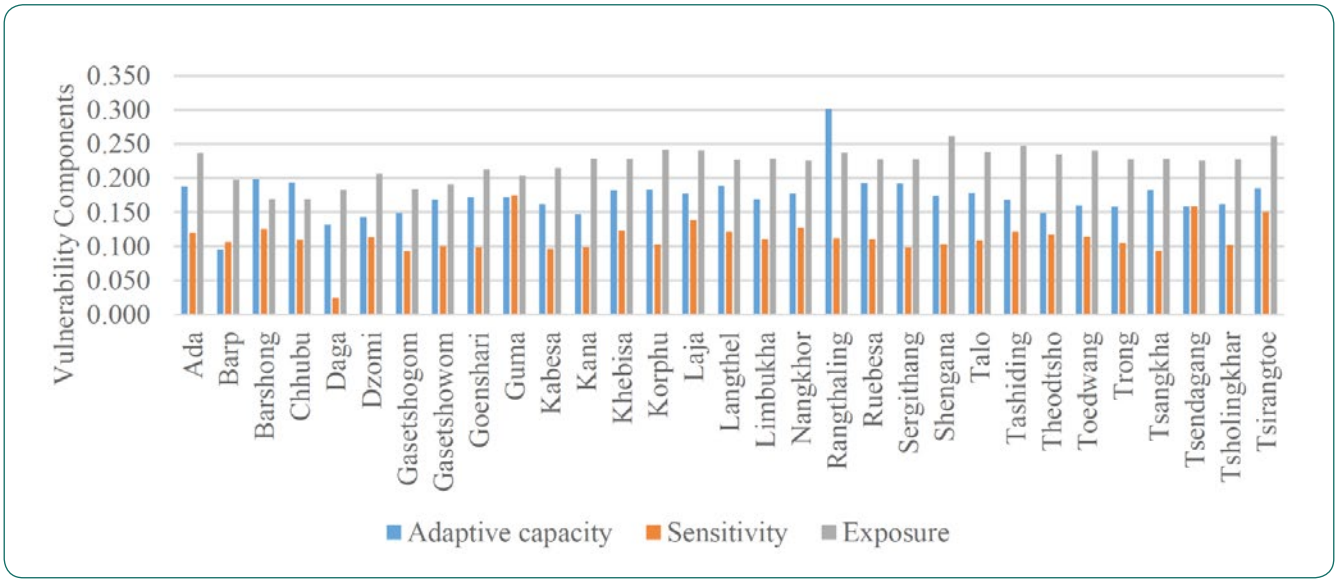


Figure 3.21: Gewog wise Components of Vulnerability

3.4.2 Climate vulnerability of Gewogs

The results from the climate vulnerability assessment are presented in Table 3.20. Among the 31 Gewogs, relatively nine Gewogs have been assessed as '*highly vulnerable*' of which Tsirangtoe Gewog under Tsirang district is most highly vulnerable. The other highly vulnerable Gewogs are Tsendagang, Tashiding, Laja, and Kana under Dagana district, Toedwang, Barp, and Shelngana Gewogs under Punakha district, and Thoedtsho Gewog under Wangduephodrang district.

15 Gewogs were assessed as 'vulnerable' while 7 Gewogs were *'less vulnerable'*.

Table 3.20: Category of Climate Vulnerable Gewogs

District	Gewogs	CVI	Category
Dagana	Tshendagang	0.0106	Highly Vulnerable
	Tashiding	0.0096	Highly Vulnerable
	Laja	0.0087	Highly Vulnerable
	Kana	0.0081	Highly Vulnerable
Punakha	Toedwang	0.0092	Highly Vulnerable
	Barp	0.0108	Highly Vulnerable
	Shengana	0.009	Highly Vulnerable
Tsirang	Tsirangtoe	0.0115	Highly Vulnerable
Wangduephodrang	Thoedtsho	0.0101	Highly Vulnerable
Dagana	Khebisa	0.0057	Vulnerable
	Tshangkha	0.0043	Vulnerable
Punakha	Dzomi	0.0072	Vulnerable
	Limbukha	0.0066	Vulnerable
	Talo	0.0066	Vulnerable
	Guma	0.0056	Vulnerable
	Kabesa	0.0052	Vulnerable
	Goenshari	0.0041	Vulnerable
Tsirang	Tsholingkhar	0.0067	Vulnerable
Trongsa	Korphu	0.0059	Vulnerable
	Langthel	0.0047	Vulnerable
Zhemgang	Nangkhor	0.0061	Vulnerable
	Trong	0.0073	Vulnerable
Wangduephodrang	Ada	0.0059	Vulnerable
	Ruebesa	0.0039	Vulnerable
Tsirang	Sergithang	0.0035	Less vulnerable
Wangduephodrang	Gasetshogom	0.0033	Less vulnerable
	Gasetshowom	0.0022	Less vulnerable
	Daga	0.0013	Less vulnerable
Punakha	Chhubu	-0.0027	Less vulnerable
Tsirang	Barshong	-0.0037	Less vulnerable
	Rangthaling	-0.0071	Less vulnerable

3.4.3 Contributing factors to 'Highly Vulnerable' Gewogs

Between the two river basins, PRB (0.1275) reflects more vulnerability to climate change impacts than MRB (0.1488). This could be because the former is relatively more exposed than the latter. Although concerning livelihoods, communities living in the MRB are more vulnerable than PRB but with regard to the access to forest resources, quality of ecosystems and the level of ecosystem services that local people depend on are contributing to vulnerability.

Both at the basin and the Gewog level, the data indicates that most of the highly vulnerable Gewogs have a high level of exposure to climate extreme events such as droughts, occurrence of invasive plant species and the variation in temperature and precipitation. Based on the architecture of the landscape, the study areas in PRB receive relatively less rainfall than other regions. The details of contributing factors associated with the vulnerable gewogs are presented in Table 3.21.

Table 3.21: Contributing factors associated with highly vulnerable Gewogs

District/Gewogs	Contributing factors to vulnerability
DAGANA	
Tsendagang	1. Impacts of climate change with extreme events such as soil erosion and landslide.
	2. Increase of invasive species
	3. Scarcity of water for farming
	4. Increasing number of extreme hot days
Tashiding	1. Exposure to extreme climate events such as erosion and landslide, storms, and high intensity of rains with high variability
	2. Human-wildlife conflicts
	3. Low crop yield
	4. Labor shortage
Laja	1. Climate change impacts with extreme events such as storms, floods, erosion and landslides
	2. Occurrence and increase of invasive species
	3. Limited income to support families, small land holding size, etc.
	4. Labour shortage as members migrated out of the community
	5. Low crop yield
	6. High level of human and wildlife conflicts
Kana	1. Climate change impacts extreme events such as storms, floods, erosion, and landslides
	2. Occurrence and increase of invasive species
	3. Limited income to support families, small land holding size, etc.
	4. High level of human-wildlife conflicts
PUNAKHA	
Barp	1. Impacts of climate change with extreme events
	2. Scarcity of water for farming and drinking
	3. Occurrence of invasive species
	4. Low food production

Toedwang	1. Impacts of climate change with extreme events such high variation in temperature and precipitation
	2. Occurrence and increase of invasive species
	3. Scarcity of water for drinking
	4. Low food production due to scarcity of water
Shengana	1. Food production due to water scarcity
	2. Human-wildlife conflicts
	3. Low adaptive capacity due to limited source of income
	4. High exposure to extremely hot days and high intensity of rains
	5. Limited access to ecosystem services such as forest resources
TSIRANG	
Tsirangtoe	1. Climate variability such as maximum and minimum average temperature and precipitation
	2. Water scarcity results in low food production
	3. Human-wildlife conflicts affecting livelihoods
	4. Labour shortage as household members and available to work in the farm are relatively less
WANGDUEPHODRANG	
Thedtsho	1. Impacts of climate change with extreme events such high variation in temperature and precipitation
	2. Occurrence and increase of invasive species
	3. Scarcity of water for farming and drinking
	4. Shortage of labour for farming

3.5 WBH habitat suitability assessment

This chapter supplements the ESRAM study with additional information on the suitability of the study area as a WBH habitat. There are two sub-components of this habitat suitability assessment. First, the study employed MaxEnt modelling to assess the suitability of existing WBH habitat areas and attempts to identify potential WBH habitat under changing climate. Second, the study employed GIS analysis to identify degraded areas in the study area with the view to explore possible areas for habitat restoration.

3.5.1 Suitability of existing WBH habitat areas

The sighting data since early 2000 show that the occurrence of WBH shifted gradually from the upper zone of Punatsangchhu to the lower basin and to the MRB. Based on the existing data on WBH occurrence (sightings), forest types, dam location, road network, settlements, the level of disturbance and others, it is found that the habitat in the Punakha, Wangduephodrang and Trongsa areas is highly disturbed and appears that the habitat is shrinking. Currently, lower basin areas of Punatsangchhu such as Tsirang and Dagana and other lower basin areas of Bertichhu in Mangdechhu appear more suitable than upper basins in both the rivers (Figure 3.22).

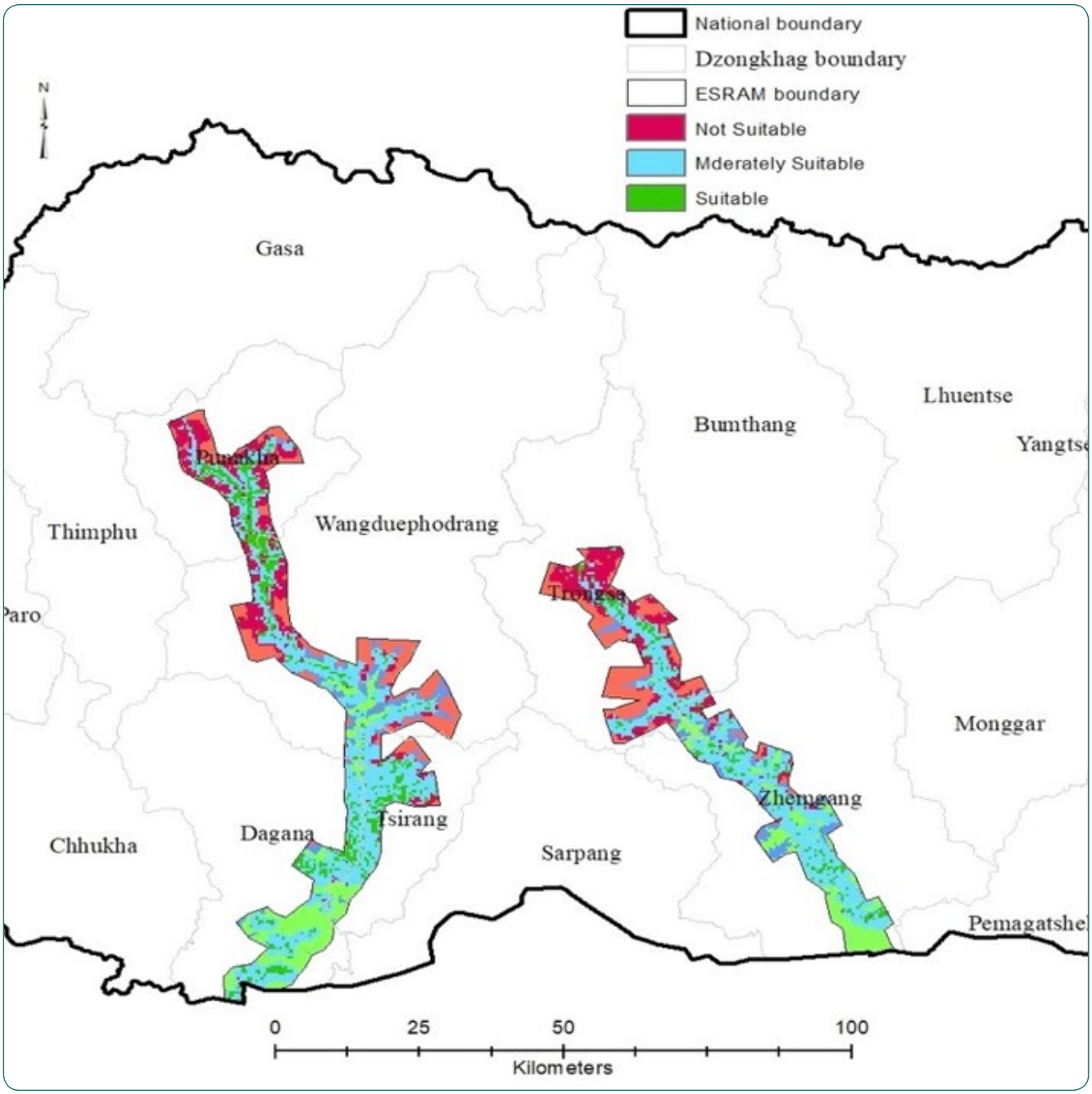


Figure 3.22: Habitat Suitability of the ESRAM Study Area

3.5.2 Habitat suitability under different climate projection scenarios

Employing the WBH habitat distribution modeling methodology the habitat suitability assessment was carried out. The MaxEnt model was built using 73 presence data, six climatic variables, three topographic variables, and land-use land-cover data. This model depicts the spatial distribution of potentially suitable habitats for WBH across Bhutan. The bioclimatic and topographic variables selected for the study were uploaded to MaxEnt software and the current and future distribution of WBH was modeled. In order to test the accuracy of the model, theArea under Curve (AUC) values of training data and test data were analyzed. The calibration of the model for WBH was satisfactory (AUC=0.906 for 10 replicates (Figure 3.23). The findings indicated that WBH's current and future distribution characterized by the selected variables is excellent.

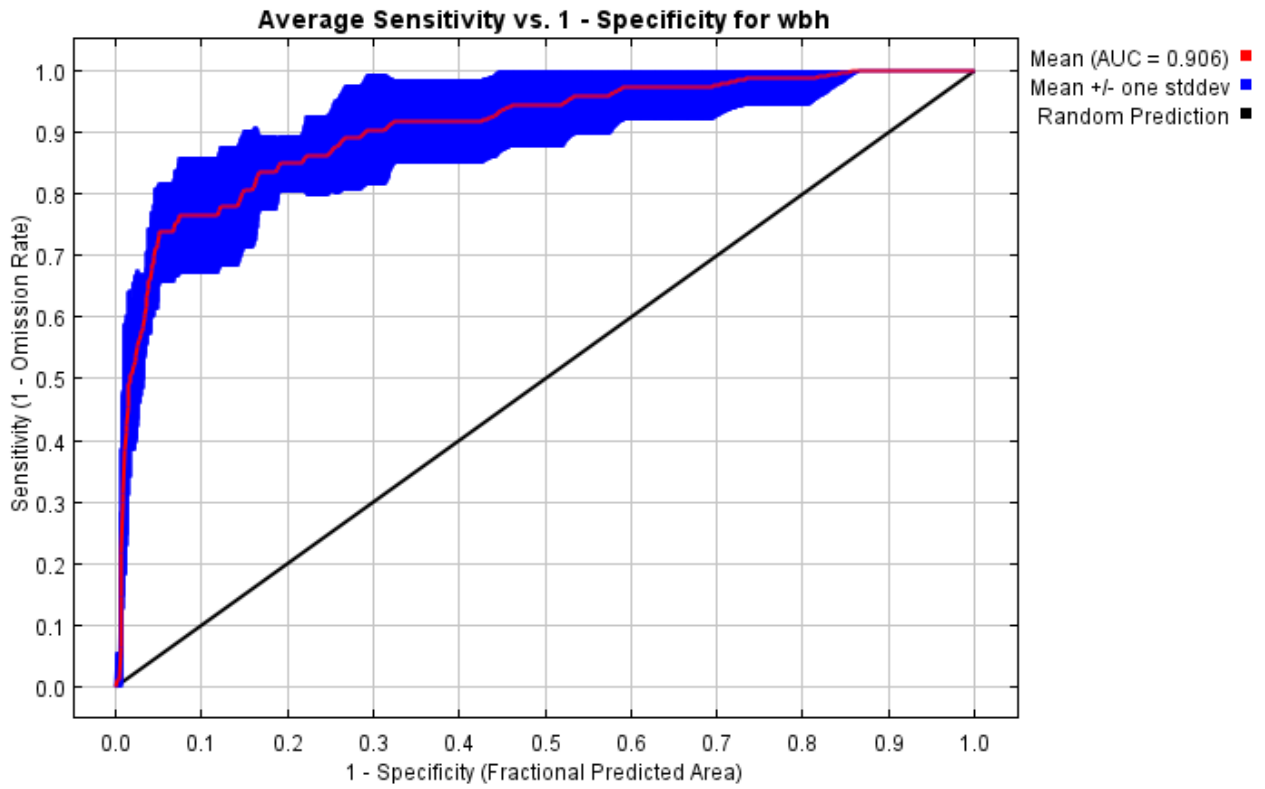


Figure 3.23: Receiver operating characteristic curve and AUC value under the current period

The relative percentage contribution and permutation importance of environmental and topographic variables were generated by the MaxEnt model (Table 3.22).

From all the variables, land-use land-cover has the highest percentage contribution followed by isothermality with 38% and 23% respectively. Slope, elevation, precipitation seasonality and mean diurnal range temperature have less than 1% contribution individually. In consideration of the permutation importance, mean annual temperature, precipitation of wettest month, and precipitation of driest month has the highest impact on the habitat model and contributed around 80% in together. Isothermality and slope have negligible contributions with less than 1% each for the distribution of WBH.

Table 3.22: Analysis of variable contributions

Variable	Percent contribution	Permutation importance
Land-use land-cover	38	6.8
Isothermality	23	0.5
Precipitation of driest month	16	23.2
Mean annual temperature	10.2	28.8
Precipitation of wettest month	7.6	27.3
Aspect	1.9	1.6
Slope	0.8	0.4
Elevation	0.7	1.3
Precipitation seasonality	0.7	7.9
Mean Diurnal Range	0.5	2.2

Response curves show the quantitative relationship between environmental variables and probability of presence (also known as habitat suitability), and they deepen the understanding of the ecological niche of the species. The response to the digital elevation model showed that the species was highly favored at the altitude between 800 masl–2000 masl with the maximum at 1000 masl. The elevation is not a key eco-factor for WBH distribution. The most suitable slope for WBH was 0-20 degrees and prefers all facing aspects.

Furthermore, the model predicts that WBH prefers an annual mean temperature of 18-23°C, and precipitation in the wettest month is in between 300 – 600mm. This indicates that WBH normally lives in moderate temperature and rainfall habitats. Precipitation seasonality represented the variability of precipitation and showed a good probability of WBH presence between 80-100mm. There is a sharp rise in presence of WBH between the isothermality of 45-50°C. Isothermality is the ratio between the mean diurnal range in temperature and the annual temperature range. Land-use land-cover is one dominant variable that affects the distribution of WBH in Bhutan. Chirpine forest and agricultural land is the major habitat preferred by WBH followed by Broadleaf, Fir, and Mixed Conifer forest.

The response curves of 10 environmental variables (Figure 3.24) in White-bellied Heron habitat distribution model pertain to i) Landuse-landcover, ii) Elevation (m), iii) Aspect (Degree), iv) Slope (Degree), v) Annual Mean Temperature (°C) vi) Mean Diurnal Temperature Range (Mean of monthly (max temp-min temp) in °C, vii) Isothermality (°C), viii) Precipitation of wettest month (mm), ix) Precipitation of Driest Month (mm), and x) Precipitation Seasonality (mm).

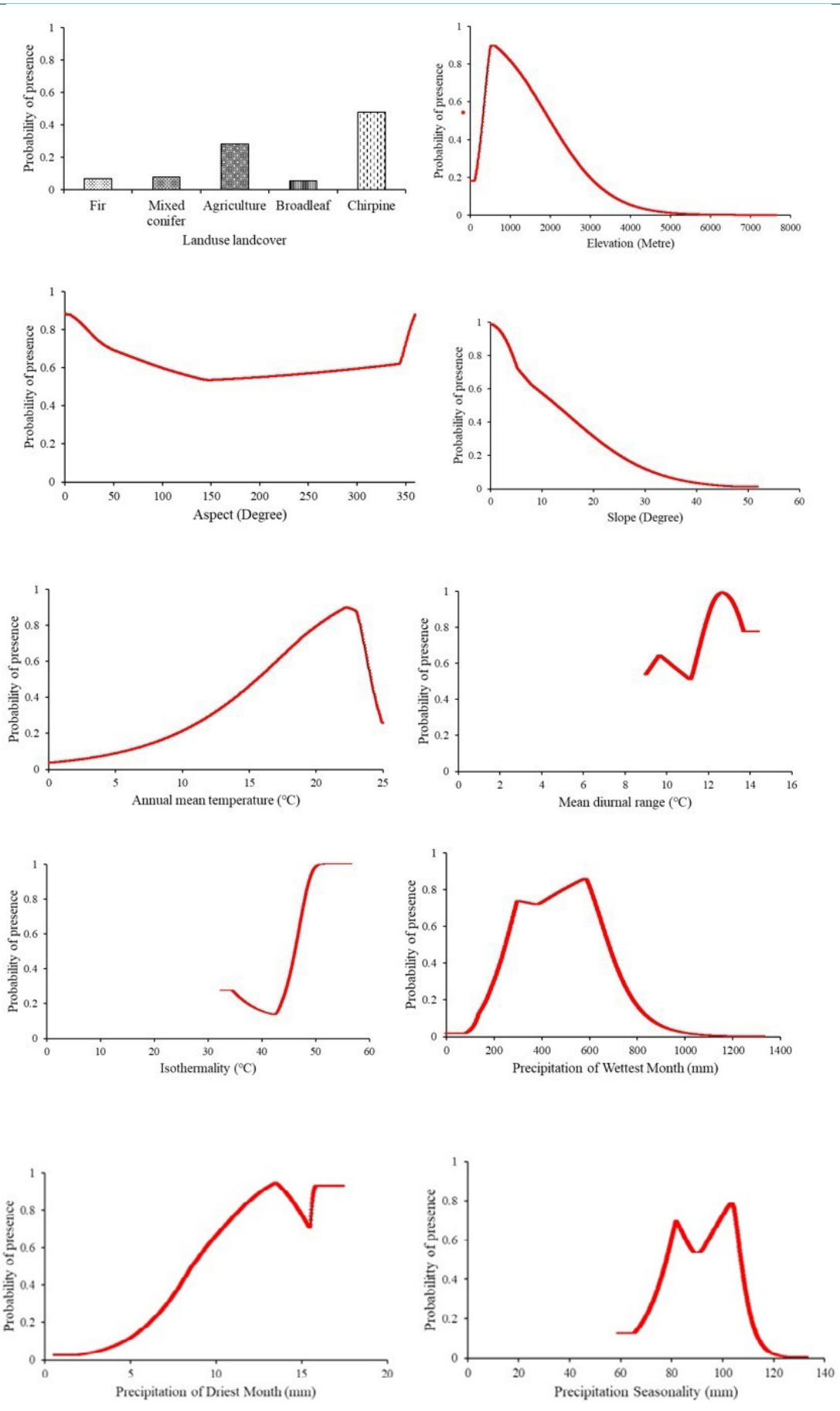


Figure 3.24: Response curves of 10 environmental variables in WBH habitats distribution model

We retrieved the alternative estimation of variable importance to the models via the jackknife test (Figure 3.24). The results depicted that the highest environmental variable with the highest training gain, when used in isolation, is land-use land-cover. This means that this single variable appeared to have the most useful information by itself and proved to have the highest importance. The jackknife test indicated the distribution of WBH was mainly influenced by isothermality, annual mean temperature, and elevation (Figure 3.25).

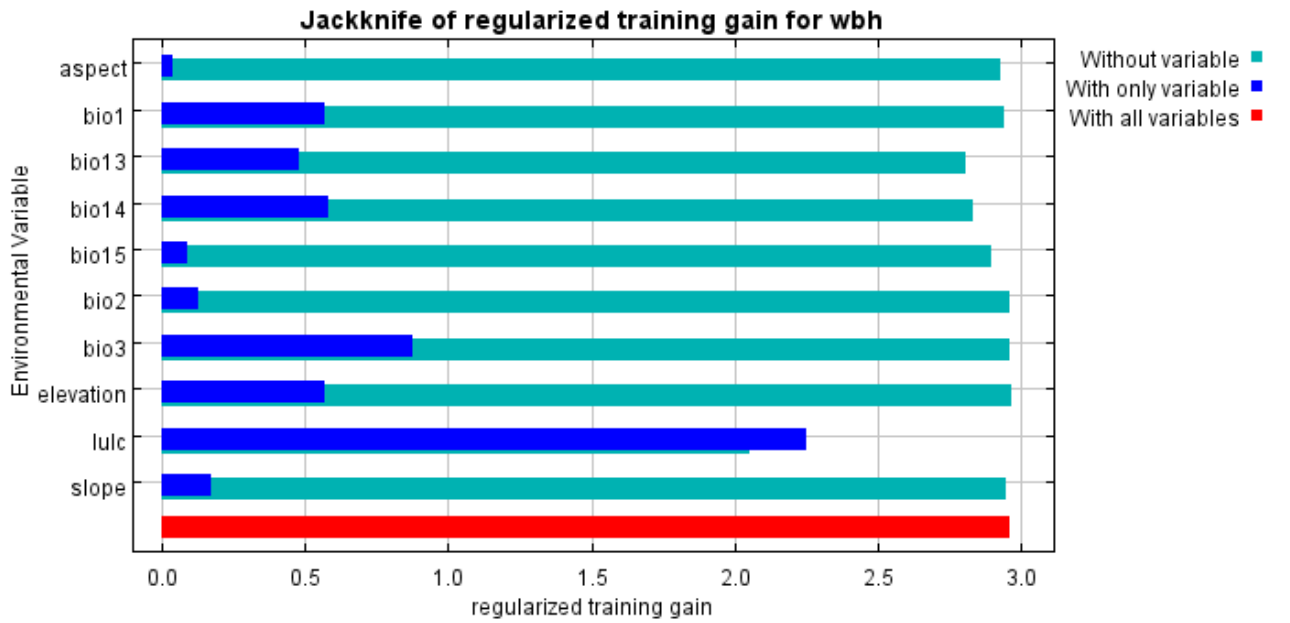


Figure 3.25: Relative predictive power of different environmental variables based on the jackknife of regularized training gain in MaxEnt models for WBH

Based on "presence only" data of 73 coordinates, the model for the current and future scenarios is generated by using MaxEnt software. The MaxEnt generated output for future scenarios of Representative Concentration Pathway (RCP) (RCP 2.6, RCP 4.5, and RCP 8.5) for the years 2041-4060 and current scenario using historical data of the year 1970-2000. The current predicted suitable area for WBH habitat in Bhutan is 786.81 sq.km. It is predicted that Wangduephodrang, Punakha, and Zhemgang districts account for the highly suitable area (Table 3.23; Figure 3.26).

Table 3.23: Distribution changes of WBH habitat under climatic scenario (2041-2060)

	RCP2.6 (km^2/%)	RCP4.5 (km^2/%)	RCP8.5 (km^2/%)
Range expansion	403.45 (1.04)	436.02 (1.13)	531.64 (1.38)
No occupancy	37191.72 (96.65)	37159.15 (96.57)	37063.54 (96.32)
No Change	660.87 (1.71)	646.16 (1.67)	676.63 (1.75)
Range contraction	216.43 (0.56)	231.14 (0.60)	200.67 (0.52)

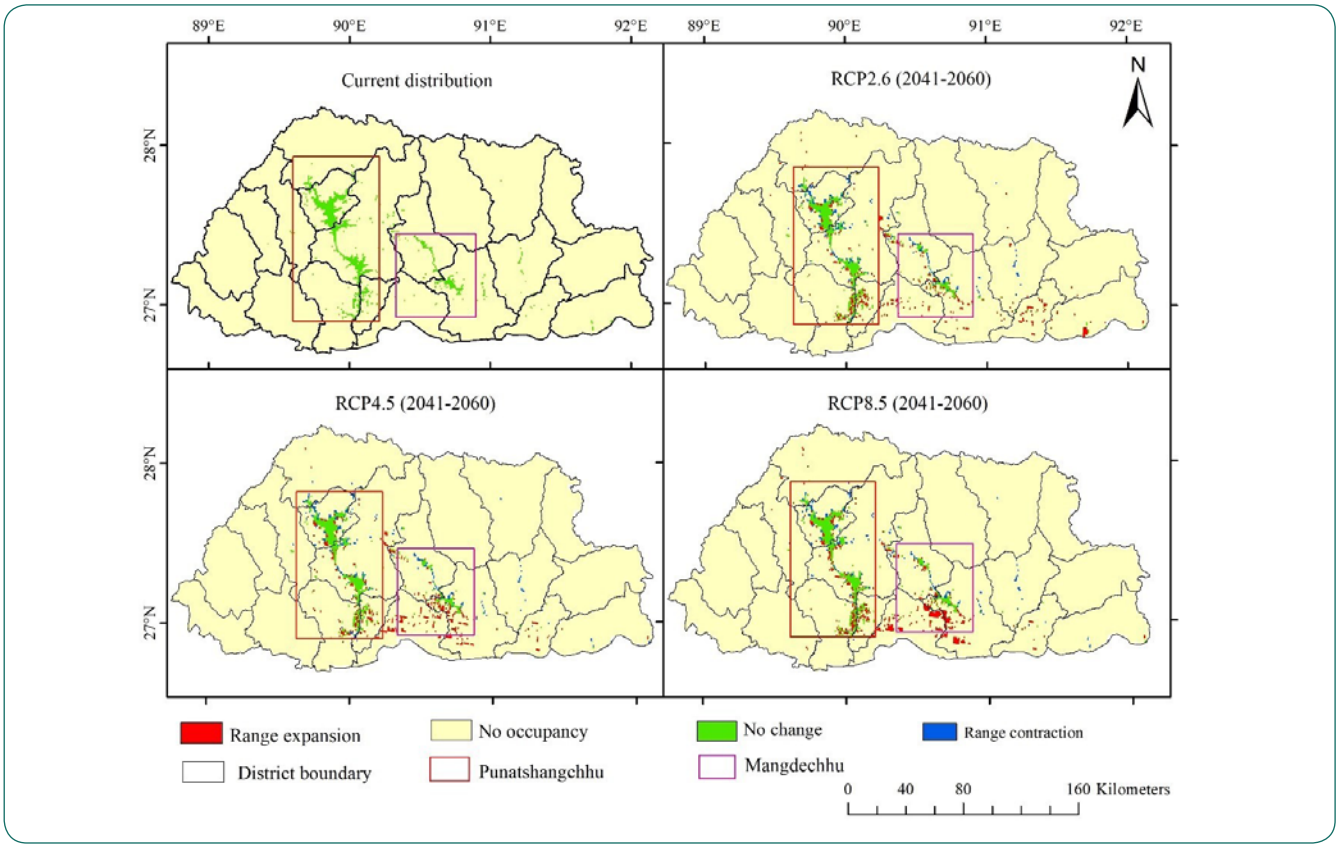


Figure 3.26: MaxEnt generated output for future scenarios under RCP 2.6, RCP 4.5 and RCP 8.5) for the years 2041- 4060

The predicted suitable areas were classified into four classes namely; range expansion, no occupancy, no change, and range contraction using distribution changes between binary SDM. The distribution changes between binary SDM showed expansion of suitable area from (1.04%) in RCP2.6 to (1.38%) in RCP 8.5 for the years 2041-2060. The study depicts constriction of 0.6% of a suitable area in RCP 2.6 to 0.52% in RCP 8.5 for the year 2041-2060. The suitable range will be expanded more towards Zhemgang and Sarpang districts in RCP8.5 for the year 2041-2060 (Figure 3.26). In other words, there will be a shift of preferred WBH habitat towards Zhemgang and Sarpang under worsening climate scenarios.

3.6 Mapping of degraded and potential habitat restoration sites

The term 'degrade' literally is to lower, spoil or destroy the quality of something and 'degradation' is the process leading to lowering, spoiling, or destroying the quality of something. Forest degradation is therefore the process that leads to the deterioration of the quality of forests. The result of this process is 'degraded forest'. However, the perceptions of what constitutes a 'degraded forest' vary greatly. In this case, 'degraded forest' are those areas with no trees or vegetation that are identified as having been under natural vegetation in the past. Degraded forest in the ESRAM study area were identified by analyzing time series satellite images over the period of last one to two decades. The drivers of forest degradation in the study area are:

3.6.1 Hydro-power projects and their components

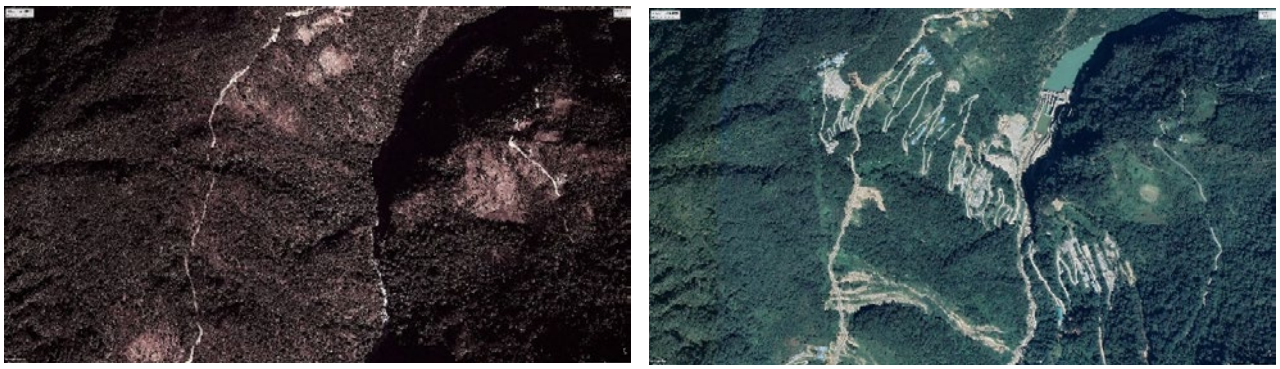
The development of mega hydropower projects in both the basin namely Punatsanchhu-I, Punatsangchhu-II and Mangdechhu hydroelectric power projects have required large areas of forest cover to be removed for the construction of various project components like the dam site and its

complex, powerhouse and its complex, access road construction to various project sites and adits. And some of these sites are very close or to the river itself and within the buffer of the WBH roosting. Observations are outlined based on the interpretation of satellite imagery available for different time series and illustrated below.

3.6.2 Road and power transmission lines

New road construction

With the advent of development activities for increased economic activity and connectivity to villages in the country numerous farm roads have been constructed. And the alignment of these roads has been through the forest covered region only, whereby the forest covers have been removed and excavated soil and debris dumped on the slopes further leading to erosion and soil slides (Figure 3.27).

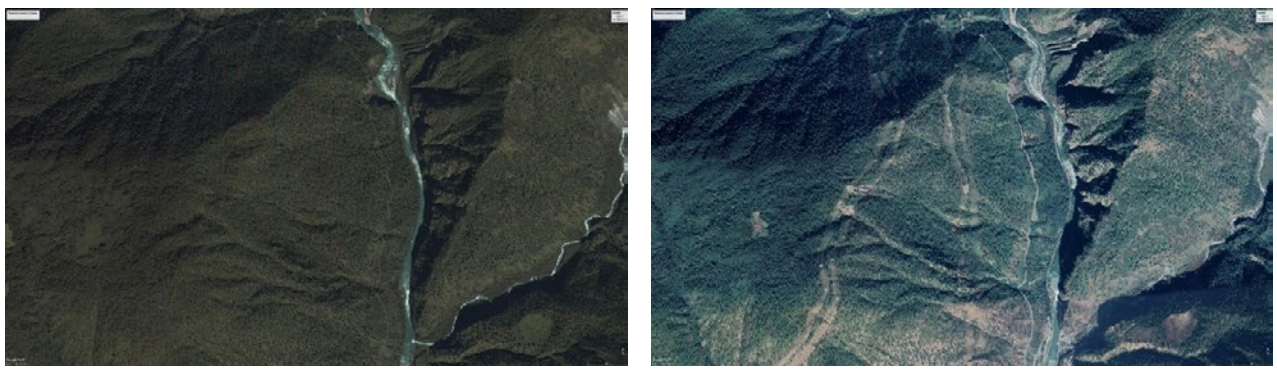


Mangdechhu & Nikachhu Hydropower-2010 | Mangdechhu & Nikachhu Hydropower-2020

Figure 3.27: *Satellite photos of Mangdechhu and Nikachhu depicting degraded forests*

Installation and laying of high-tension power transmission lines

With the commission of HEP projects, the most economic grid system related to power export from the hydropower projects needs to be installed. This happens with the development of a transmission system from the extremely steep valleys and high mountains in Bhutan to the plains of Assam in India. Numerous high voltage transmission lines have been installed in both the river basin and this too all through the vegetated areas only. The laying of transmission lines have led to the clearing and felling of trees along its pathway with buffers depending on the carrying capacity (voltage) of the transmission lines (Figure 3.28).



PRB 2003 | PRB 2017 with Transmission Lines

Figure 3.28: *Degradation of forests in PRB due to high tension power transmission lines between 2003 and 2017*

3.6.3 Quarry and mining activities

The establishment of quarries and mines in the basins has also led to the removal of tree covers and scarring the landscape. As illustrated below (Figure 3.29) over a period the area has been scarred and removed of vegetation.

Taksha Mines-2003

Taksha Mines-2020

Figure 3.29: *Forest degradation in PRB due to mining*

3.6.4 Landslides

Landslide is one of the major classes in the DoFPS LULC 2016 report and is defined as the class that 'includes mass movement of soil debris due to gravitational force triggered by other factors such as rainfall and earthquakes' (LULC 2016).

Several landslides have occurred in both the basin and the area extent captured. Several major landslides exist in the basin like the Reotala slide in Zhemgang.

04 RECOMMENDATIONS

Balwani, Tsirang/Damcho Yonten

4.1 EbA priority area

Before venturing into defining the EbA options, it is important to define the priority areas for the implementation of EbA interventions. For the purpose of optimal use of limited financial resources, it is recommended that the implementation of the EbA options be prioritized for those areas that are identified as 'highly vulnerable' to climate change. To narrow it down further for the sake of focusing interventions in WBH habitat areas, an overlay of a vulnerability index map with WBH siting records makes the perfect site for prioritizing interventions. District wise GIS maps overlaying the three levels of climate vulnerability with WBH sighting records are given in Appendix 3.1.

Table 4.1: Highly vulnerable' and 'vulnerable' parts of Gewogs that fall in the WBH habitat areas in Punatsangchhu and Mangdechhu basins

DAGANA	PUNAKHA	TSIRANG	WANGDUE P	TRONGSA	ZHEMGANG
Kana	Barp	Tsirangtoe	Toedtsho	Korphu	Nangkhor
Laja	Shengana	Tsholingkhar	Ada	Langthil	Trong
Tashiding	Toedwang		Ruebesa		
Tshendagang	Dzomi				
Khebisa	Goenshari				
Tsangkha	Guma				
	Kabesa				
	Limbukha				
	Talo				

Highly vulnerable

Vulnerable

For ease of identifying the Chiwogs that fall under 'Highly vulnerable' and 'vulnerable' Gewogs, climate vulnerability maps of the ESRAM areas under each district are provided in Appendix 3.1.

4.2 Proposed EbA options

Having known the priority areas for implementation of the EbA, specific measures are proposed in the framework below.

Table 4.2: Framework for Ecosystem-based Adaptation options: Ecosystems, Adaptation Options, and proposed location

Ecosystems	Adaptation options	Proposed location
Forest	Maintain and manage provisional and regulatory services of forest ecosystem	1. Dagana: Chiwogs falling in WBH habitat areas of i) Kana, ii) Laja, iii) Tashiding, and iv) Tshendagang (see Dagana map in Appendix 3.1) 2. Punakha: Chiwogs falling in WBH habitat areas of i) Barp, ii) Shelnganang, and iii) Toedwang (see Punakha map in Appendix 31) 3. Tsirang: Chiwogs falling under Tsirangtoed (see Tsirang map in Appendix 3.1 4. Wangduephodrang: Chiwogs falling under Thoedtsho Gewog (see Wangduephodrang map in Appendix 3.1)
	• Initiate enrichment of community forests for timber and fuelwood	
	• Watershed management and restoration of degraded forests » Initiate and establish community-based integrated forest and horticultural nurseries » Plant local and indigenous species around water sources and water bodies (streams, rivers and lakes) » Initiate plantation in barren and unstable slopes	
Agriculture	Enhance agricultural productivity	
	• Address Human-wildlife interface » Promote and support crop protection from wildlife (eg. electric fencing) » Introduce innovative local level institutional mechanism for management of HWC	
	• Improve access to water for household use and irrigation » Support repair and maintenance of irrigation and drinking water supply schemes on a cost sharing basis » Research on low risk water retention and storage systems » Strengthen the functional capacity of water user groups in management of water resources	
	• Support climate smart inputs to agriculture production and marketing » Promote irrigation efficiency » Facilitate subsidized inputs to farm production » Support for labor saving farm equipment	

Riverine	• Promote Agroforestry and horticulture » Initiate locally relevant agroforestry models for specific areas » Make agroforestry and horticultural seedling and saplings locally available through the community based integrated nurseries (with forest nurseries).	
	Conserve and protect WBHs, their habitat, and food base	WBH habitat areas of Punatsangchhu and Mangdechhu basins
	• Monitor WBH population and habitat conditions	
	• Ensure adequate food base for WBH » Support community based fishery » Prevent illegal fishing through enhanced patrolling by authorized government agencies » Support conservation and protection of important water bodies for fish breeding	Berti chhu and the small stream at Berti Eco camp
Generic, applicable to all ecosystems within WBH habtat	• Strengthen collective action and cooperation with major stakeholders (Department of Forest and Park Services, Divisional Forest Offices, Local governments agencies, hydropower authorities and community groups) » Support formation of platform for cooperation and coordination at local level	Project areas In highly vulnerable and vulnerable Gewogs
	• promote education and advocacy on the environment, climate change and WBH conservation » Carry out awareness and education programs on ecosystem services and conservation including WBH conservation » Advocate for protection of WBH habitats	WBH habitat areas of Punatsangchhu and Mangdechhu basins
	• Develop and promote ecotourism/ nature-based tourism » Develop tourism product around WBH for wildlife and bird enthusiasts » Identify local community tourism products that bring unique culture, high conservation values, and livelihood experiences » Package the above tourism products into a tourism itinerary for tour operators to promote at national, regional, and international tourists.	Communities falling in WBH habitat areas
	• Invasive plant species management » Conduct detailed study on invasive species and their effects » Prepare management strategy for the invasive species in the project area	WBH habitat areas of Punatsangchhu and Mangdechhu basins

4.3 Description of EBA measures

The EbA measures proposed in Table 4.2 are further described below, each supported by adaptation functions and expected environmental, social, and economic benefits from implementation.

4.3.1 Maintain and manage provisional and regulatory services of forest ecosystem

Provisioning ecosystem services are most exploited by the local people. Although many respondents report that the provisioning services, in general, have not changed, timber, fuelwood, and water are most appropriate for daily needs. Increasing appropriation without safeguarding and sustaining the resource will induce degradation of the ecosystem resulting in diminished provisioning and regulating services. EbA measures to maintain and manage the provisioning and regulatory services of the forest ecosystem are recommended to derive the benefits specified in Table 4.3 below:

Table 4.3: EbA measures and benefits: Maintain and manage provisional and regulatory services of forest ecosystem

EbA Measures	Climate change Adaptation function	Environmental benefits	Social benefits	Economic benefits
Afforestation: Initiate enrichment of community forests for timber and fuelwood	Carbon sequestration; offset emissions from fuelwood consumption	Slope stability; soil erosion control	Enhances collective action of the community forest group	Addresses local needs for timber and fuel
Watershed management and restoration of degraded forests	Helps stabilize slopes and control erosion during intense rainfall	Slope stability; soil erosion control	Improved water availability; reduced risks of floods and landslides	Sustained source of timber, fuelwood, and water

The recommended EbA measures are:

a. Afforestation: Initiate enrichment of community forests for timber and fuelwood

The degradation of forests in the study area is attributed to large-scale infrastructure development projects and from communities continuously accessing various ecosystem services. If unaddressed, the cumulative effects over a period of time will result in destabilization of slopes from erosion and landslides and dwindling of provisioning ecosystem services. To mitigate the existing degraded forest areas in the project area, an afforestation program comprising the following is recommended:

i) Initiate decentralized afforestation program at community levels to cater to the local level restoration of vegetation. Some crucial aspects of afforestation are:

- Identification of plantation areas at the local level
- Development of nurseries for an adequate supply of seedlings
- Timely group plantation events organized
- Institute local level mechanisms with human and financial resources to ensure maximum survival of plantations through protection, timely watering, and maintenance of plantations

This will not only help to address local needs for ecosystem services but also contribute to carbon sequestration thereby contributing to national and global objectives of fostering a low carbon economy.

b. Watershed management and restoration of degraded forests

Water supply, fuelwood, and timber are most valued by all communities in the study area. However, the sustainability of such ecosystem services is dependent on the extent to which the integrity of the provisioning ecosystems is maintained. Keeping the exploitation of natural resources within their regeneration capacity is extremely important to enable communities to avail the services sustainably. For this, the following initiatives are recommended:

i) Promote watershed management

All communities in the project area are located in one or the other watershed that serves as a source of water for drinking as well as irrigation. Given that forest areas are common pool resources that on one hand are vulnerable to exploitation from free riding while on the other hand, individual users have minimal interest to contribute to the maintenance of the service. To address this issue at the local level, initiatives to mobilize and support community groups and collective action for the identification, protection, and restoration of water sources will contribute immensely to sustained access to ecosystem services, especially water supply. Proposed activities are:

- Initiate and establish community based integrated forest and horticultural nurseries
- Plant local and indigenous species around water sources and water bodies (streams, rivers and lakes)
- Initiate plantation on barren and unstable slopes

ii) Advocate with Hydropower and mining industries for rehabilitation and restoration of degraded areas.

Based on the degraded areas identified in the hydropower project areas and mining sites in the WBH habitat areas, the conservation of WBH and its habitats will benefit from the enhanced restoration. Initiatives must be taken to advocate with hydroelectric power project authorities on afforestation and greening of degraded areas along roads, residential, and open areas within the jurisdiction of the projects.

4.3.2 Enhance agriculture productivity

Mixed farming (crop and livestock) is the main livelihood activity pursued by the majority of the respondents, but these two sectors are confronted by a number of constraints like labour shortage, wildlife damage, irrigation shortage, and unavailability of inputs on time. The consequences of these challenges are felt in different fields and scales like the abandonment of farming, reduction of production areas, increasing fallow land, etc. Therefore, development interventions must be focused on minimizing the different constraints. EbA measures to enhance agricultural productivity, climate change adaptation function, and associated environmental and socio-economic benefits are given in Table 4.4.

Table 4.4: EbA measures and benefits: Enhance agricultural productivity

EbA Measures	Climate change Adaptation function	Environmental benefits	Social benefits	Economic benefits
Address human-wildlife interface	Helps reduce dependence on forest resources through enhanced farm productivity; Reduced appropriation of forest ecosystem goods and services making forest ecosystem more resilient to adverse effects of climate change	Reduced appropriation of provisioning services and products from the forest; Enhanced co-benefits from human-wildlife systems	Reduced time and efforts of farmers in crop protection and more time available for social activities	Enhanced agriculture productivity resulting in food self-sufficiency and income generation
Enhance access to water for household use and irrigation	Addresses seasonal fluctuation of water availability under changing climate through high-efficiency water delivery technology and infrastructure	Enhanced availability of water enables communities to transform open space and barren agricultural land into the plantation and productive crop areas. Enhanced green areas help prevent dust pollution, soil erosion, and landslides.	Improves health and sanitation of households; better nutrition from enhanced farm productivity; helps reduce rural urban migration thereby addressing farm labour shortage.	Enhanced agriculture productivity resulting in food self-sufficiency and income generation; optimizes off-season use of cropland.
Support climate smart inputs to agriculture production and marketing	Enables communities to orient traditional crops and farming systems to suit changing climate	Improved agriculture productivity is expected to reduce the appropriation of forest products resulting in enhanced biodiversity and ecosystem integrity	Reduces drudgery and exposure to crop failures	Increased income and food self-sufficiency
Promote agro-forestry and horticulture	Improves the adaptive capacity of farmers by diversifying the farming risks from changing climate;	Soil erosion control and slope stability; carbon sequestration; and reduced dependency on forests for fodder, timber, and fuel wood.	Diversified sources of livelihood; reduced travel time for fodder, timber, and fuelwood	Food self-sufficiency and diversified income sources

The following areas of intervention will help build resilient communities:

a. Enhance co-benefits from the human-wildlife interface

Wildlife crop damage has been reported in almost all agriculture-based communities. Considering that the majority of the farmers reported crop damage as a serious to a very serious issue, it is important to explore effective, well-planned management and a holistic and integrated approach that will enhance mutual coexistence.

Two interventions are proposed under this EbA measure:

i) Promote and support crop protection from wildlife (eg. electric fencing)

It was learned from the survey that farmers have experienced immense relief from interventions like electric fencing. 49% of the respondents reported electric fencing as very effective in protecting crops from wildlife infiltration. Such interventions have not only enabled the reduction of crop loss to wildlife but also reduced the time required for crop protection from wildlife enabling them to invest time for other priorities. Since 66% of the respondents reported investing time in the physical guarding of crops, this intervention will deliver environmental, social, and economic benefits.

Interventions to mitigate HWC could be implemented in the Chiwogs in the highly vulnerable Gewogs (Table 4.5).

Table 4.5: *Chiwogs in the highly vulnerable Gewogs faced with wildlife crop damage*

DISTRICTS	DAGANA						TSIRANG
Gewogs	Laja	Tashiding	Tsendagang				Tsirangtoe
Chiwogs	Thasa	Norbuling	Gangzor	Lower Gangzor	Lower Tsendang	Tsend-agang	Kapazhing

Resources permitting, the HWC challenged Chiwogs in the WBH habitat areas under 'vulnerable' Gewogs will also benefit from such schemes. For detailed information on HWC affected Chiwogs and to identify location for interventions, refer Appendix 3.2.

ii) Introduce an innovative local level institutional mechanism for management of HWC

Schemes for compensation or insurance against production loss from wildlife damage needs to be institutionalized at the local level. This recommendation follows from the fact that centrally controlled and disbursed compensation schemes have not been sustained under lack of local level monitoring, verification, and mechanisms to control ineligible claims. This calls for the development, piloting, and institutionalization of decentralized locally operated mechanisms for insurance and or compensation schemes. Such schemes should i) ensure monitoring and verification of damages by wildlife to avoid false claims, ii) ensure insurance or compensation does not incentivize farmers to not protect their crops. An initiative to develop, pilot, and institutionalize a robust mechanism that harnesses the co-benefits of the human-wildlife interface is proposed. One or more of the Chiwogs in the 'highly vulnerable' Gewogs are proposed for this intervention.

b. Improve access to water for household use and irrigation

Over 51% of the household respondents in PRB reported having faced irrigation water problems in the last 12 months. Likewise, around 45% experienced irrigation water problems in the last twelve months. Likewise, although over 97% of the respondents revealed households had piped drinking water supply, over 50% of the respondents reported having experienced problems of inadequate supply especially in the form of inconsistent supply (about 54%) and decreased quantity (58% reported decrease in water quantity over last 10 years). To address this decline in water quantity as well as consistency in access, the following measures are proposed:

i) Support repair and maintenance of irrigation and drinking water supply schemes on a cost sharing basis.

ii) Research on low risk water retention and storage systems: This will allow communities to adapt to the projected 'too much rain when not needed and too little when needed'.

iii) Strengthen the functional capacity of water user groups in the management of water resources

Sources of water for drinking and irrigation are not differentiable in rural agriculture communities of Bhutan. Hence, it makes economic sense to integrate the drinking water supply with initiatives for access to irrigation.

Interventions related to improving drinking water and irrigation could be implemented in Chiwogs under 'Highly vulnerable' and 'Vulnerable' Gewogs facing irrigation issues. (Table 4.6).

Table 4.6: *Highly vulnerable and Vulnerable Gewogs that have Chiwogs in which more than 50% of respondents reported having faced drinking and irrigation water issues*

PUNTSANGCHHU				MANGDECHHU	
DAGANA	**PUNAKHA**	**TSIRANG**	**WANGDUE P**	**TRONGSA**	**ZHEMGANG**
Kana	Barp	Tsholingkhar	Thoedtsho	Korphu	Nangkhor
Khebisa	Shengana		Athang	Langthil	Trong
Tsangkha	Toedwang				
	Dzomi				
	Talo				

Highly vulnerable

Vulnerable

For the purpose of identifying locations for interventions, Chiwogs with drinking water and irrigation issues in WBH habitat areas that fall under 'Highly Vulnerable' and 'Vulnerable' Gewogs are reflected in given Appendix 3.3.

c. Support climate smart inputs to agriculture production and marketing

Abandonment of cultivated land and effective pursuance of agriculture is often affected by the absence or difficulty of irrigation facilities, and farm labour shortage are crucial for agriculture. Some of the factors contributing to the vulnerability of the Gewogs are scarcity of water for drinking and irrigation and labour shortage. While the increased supply of water is one option, the other option is to efficiently utilize the available resources (water and labour).

The following interventions are proposed:

i) Promote irrigation efficiency

Irrigation is a critical issue for the Gewogs under Punakha and Tsirang districts covered by the study. Improvement of existing irrigation systems or water supply services will be useful in helping farmers in increasing productivity and continue the cultivation of land. Activities under this intervention may include:

a. Irrigation needs assessment: This will allow RSPN to determine the type of irrigation required (rainwater harvesting, drip irrigation, etc) for specific communities or beneficiaries.

b. Provision of targeted interventions to reduce water problems irrigation efficiency: The above activity should be followed by actual field implementation which may include but not limited to:

- Rehabilitation of irrigation systems
- Rainwater harvesting and drip irrigation systems in water-scarce areas and

c. Drip irrigation systems could be effective leading to agricultural productivity.

ii) Facilitate subsidized inputs to farm production

The farming communities should be accessible quality inputs on time to effectively pursue their farming. Respondents in the study areas especially under Dagana and Tsirang dzongkhags have a strong interest to undertake piggery but the unavailability of piglets is a constraint raised by them. Liaising with the concerned authority to facilitate the supply of piglets and other agricultural inputs essential for farmers will be beneficial for the farmers.

iii) Support for labor saving farm equipment

Dependency on natural resources, associated exploitation, and decline in ecosystem services can be partially addressed through interventions that help farmers enhance on-farm productivity. Labor being a major constraint to agricultural productivity, any efforts to supplement labor shortage with efficient and appropriate labor saving machinery and equipment will help communities divert economic activities away from exploitation of natural resources to on-farm production activities.

- Promote efficient farming methods and technology, especially in the area of :
    a) Irrigation
    b) Labour saving farm machinery and equipment

d.Promote Agroforestry and Horticulture

Farmers in the study area are mainly constrained by the limited source of income and livelihood diversification options. Agro-forestry is known worldwide for the socio-economic, environmental, climate benefits, and reduction in vulnerability to climate change impacts. Similar opportunities exist in the WBH habitat areas, especially in terms of diversifying livelihood and income sources.

Development of agro-forestry with nutritional fodder trees and forage species by communities will not only provide land management benefits to farmers but also diversity nutrition to both humans and livestock. Further, the promotion of horticulture, especially orchards (fruits) will also help to further diversify livelihood and income sources while enhancing carbon sequestration benefits. The following activities are proposed:

i) Initiate locally relevant agro-forestry models for specific areas
ii) Make agro-forestry and horticultural tree species seedling and saplings locally available through the community based integrated nurseries (with forest nurseries).

4.3.3 Conserve and protect WBHs, their habitat, and food base

Considering that the primary mandate of RSPN is environmental conservation with specific areas of interest in the protection of the critically endangered WBH, it is important to ensure that the conservation of the WBH and its habitats are monitored on a continuous ongoing basis. This essentially entails safeguarding the integrity of the riverine ecosystem as a habitat of WBH. The proposed EbA measures and benefits under this intervention are given in Table 4.7

Table 4.7: *EbA measures and benefits: Conserve and protect WBHs, their habitat, and food base*

EbA Measures	Climate change Adaptation function	Environmental benefits	Social benefits	Economic benefits
Maintain WBH population and habitat conditions	WBH requires pristine undisturbed riverine ecosystems for survival. Their presence indicates resilient ecosystems	WBH as critically endangered species and its habitat preserved; pristine rivers and intact riverine forest ecosystems	The aesthetic value of the presence of WBH; good living environment	Abundant provisioning services of intact riverine ecosystems - fish, timber; Project support for local livelihood enhancement
Ensure adequate food base for WBH	Resilient riverine ecosystem	Fish and aquatic biodiversity maintained; survival of WBH as critically endangered species;	The aesthetic value of the presence of WBH	Availability of fish to local communities

The proposed measures are described below:

a. Monitor WBH population and habitat conditions

Keeping in mind the ultimate objective of protecting the current population of WBH from dwindling, it is important to maintain a constant vigil over the population of the species and the condition of its habitats in the country. The proposed activities under this EbA measure are:

i) Annual WBH population surveys

This will help track the status of the species. This is fundamental to ensuring the ultimate goal of ensuring the survival of WBH on an ongoing basis.

ii) Research potential habitat
In the light of findings from habitat suitability assessment, it is equally important to study the condition of the habitat. Under the changing climate scenario and habitat infringement from infrastructure development projects, especially hydropower projects along Punatsangchhu, the need to identify suitable alternative habitats for the reintroduction of the species will be a priority. Following the results from MaxEnt habitat, it is recommended that suitable habitats are explored to facilitate reintroduction, if opted for.

b. Ensure adequate food base for WBH

Ensuring sustained availability of food base for WBH is another important element of WBH conservation. Hence, measures to ensure the maintenance of aquatic biodiversity and fish availability need to be pursued especially in the context of increasing disturbance from infrastructure development, urbanization, and associated illegal fishing. Proposed activities under this measure include:

i) Support community based fishery:
This will help to supplement community needs for fish thereby reducing pressure on fish in rivers.

ii) Prevent illegal fishing through enhanced patrolling by authorized government agencies:
This entails working closely with and supporting the Department of Forests and Park Services and its Divisional Forest Offices for regular patrolling and control of illegal fishing along critical WBH feeding areas.

iii) support conservation and protection of important water bodies for fish breeding
During the ESRAM biodiversity survey, Bertichhu and the stream in Berti eco-camp (in Zhemgang district) were found to be important fish breeding sites that need to be protected and preserved for propagation and maintenance of the freshwater fish population. This will directly or indirectly help to maintain the food base for the WBH.

4.3.4 Generic and crosscutting interventions

Interventions proposed are related to all ecosystems and are applicable to the entire WBH habitat areas. The benefits of the proposed cross-cutting measures are given in Table 4.8 below:

Table 4.8: *Generic EbA measures and benefits*

EbA Measures	Climate change Adaptation function	Environmental benefits	Social benefits	Economic benefits
Develop and promote eco-tourism/ nature-based tourism to harness the cultural services of WBH habitat areas.	Eco-tourism as a diversified source of income and livelihood option to supplement agriculture under changing climate	Species and habitats preserved	Wider appreciation and support for nature and WBH as a source of livelihood and	WBH conservation is sustained through tourism revenue; Diversified income source of local people

Promote education and advocacy on the environment, climate change and WBH conservation	Enables farmers to understand and better appreciate the need to safeguard ecosystems for sustained services and products	Improved ecosystem conditions from positive human attitude and actions	An environmentally conscious community provides platform for collective action	Sustained ecosystem services
Invasive plant species management	The resilience of ecosystems and communities enhanced through elimination or reduction of invasive species	Enhances the habitat for native flora and fauna.		Avoided cost of damage from invasive species
Strengthen collective action and cooperation with major stakeholders	Empowers stakeholders and groups on shared efforts to adapt to climate change	Multiple	Enhanced Cooperation and coordination	Sustained ecosystem services

The proposed interventions are:

a. Develop and promote ecotourism/ nature-based tourism

The need to incentivize local communities to partner in the protection of the WBH, its habitat, and biodiversity conservation, in general, is not just a conservation agenda but also important for the promulgation of sustainable livelihoods through non-exploitative nature-based enterprises. The study revealed that the cultural ecosystem services are less harnessed thereby presenting immense opportunity for the development and promotion of nature-based ecotourism in the WBH habitat areas. Hence, it is recommended that the project initiate an ecotourism program that is built around the i) high conservation values of WBH as a critically endangered species, and ii) the natural, cultural, and high conservation values of different communities in the project area. This initiative should lead to:

- Sustained financial support for WBH and its habitat conservation
- Alternative income for local communities

In pursuit of the above objectives, the following activities are proposed:

i) Development of tourism products based on fulfilling WBH enthusiasts to learn about and experience sightings of WBH in the wild and in captivity. The product should preferably be centered around the WBH Centre in Changchey, Tsirang with guided tours to explore sightings of WBH in the wild.

ii) Identify local community tourism products that bring unique culture, high conservation values, and livelihood experiences.

iii) Package the above tourism products into a number of days of tourism itinerary with fee structures that cater to national, regional and international tourists.

b. Promote education and advocacy on the environment, climate change, and WBH conservation

The extent to which communities, households, and individuals cooperate, contribute, and participate in addressing challenges and issues is determined by the level of awareness and understanding of the challenges or issues. Empowered communities and individuals with the appropriate knowledge, skills, and attitude are, therefore, an essential foundation for local level capacity to cope with and address emerging challenges and issues.

Education for sustainability is therefore an overarching initiative that must be promoted as the forerunner of the programmes and interventions recommended in the preceding sections. Specific areas to be taken up under education for sustainability include:

i) General environmental education and awareness programmes
ii) Education and communication support during implementation of recommended interventions.

c. Invasive plant species management

Invasive species are known to cause the extinction of native plants and animals often causing a reduction in biodiversity. The biodiversity assessment revealed the presence of the invasive species in WBH habitat in both the river basins. Leaving these invasive species unattended or unmanaged would possibly mean leaving them to compete with native species for limited resources. The resulting alteration to habitats and ecosystem disruptions could inflict social inconveniences and economic losses. As a precaution, the following interventions are proposed:

i) Conduct a detailed study on invasive species and their effects
ii) Prepare a management strategy for the invasive species in the project area

d. Strengthen collective action and cooperation with major stakeholders

Ecosystems being essentially Common Pool Resources (CPRs) are vulnerable to exploitation by individuals whose economic rationality would drive them to maximize benefits from provisioning services while contributing least to the upkeep of the ecosystem integrity essential in sustaining the ecosystem services. For this, it is essential to build on and strengthen existing platforms and mechanisms for collective action and cooperation. As much as it is important for collective action at the community level, it is equally important to create similar mechanisms at the policy and administrative levels. The proposed activities are:

i) Strengthen collective action at community level

The farmers' groups provide avenues for marginal farmers to strengthen their existence and functioning through collective actions. Since 83.3% of the respondents feel that farmers now understand the need and benefits of cooperation and collective action. 76.2% of the respondents were positive about forming groups. Institutional mechanisms that provide a platform for people to act collectively will contribute immensely to enhancing resilience.

Social network indicators for sharing resources are critically important for reducing vulnerabilities and or strengthening resilience. From the climate vulnerability assessment, social networks appear to be strong in all the districts, i.e., in the surveyed Gewogs but strengthening social capital in forms such as water and forest user groups provide a necessary enabling environment for collective action.

Based on the above, forming new or engaging the existing social networks and farmers' groups should be further explored especially in areas related to livelihood enhancement activities and WBH

conservation programs. Interventions towards strengthening local level collective actions include:

i) Facilitating formation and/ or strengthening of community groups

Existing farmers' groups as permissible under existing laws, rules and regulations as well as informal self help groups are excellent platforms for promoting collective action at a community level. Groups being promoted by the different government agencies include i) Forest User Groups, ii) Water User Associations (WUA), iii) Agriculture Cooperatives. In addition, there are informal associations and self-help groups including the Local Conservation Support Groups (LCSGs), the strengthening of which will go a long way in the successful implementation of EbA interventions.

ii) Foster collaboration with and support major stakeholders

For the successful implementation of EbA interventions for WBH conservation, the cooperation and support of concerned government authorities and agencies need to be harnessed. Necessary mechanisms must be put in place to optimize cooperation, support, and participation of the following government authorities and agencies such as the DoFPS, Divisional Forest Offices, District administrations and Local Governments authorities, hydropower authorities, etc.

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Appendices 1: Socio-economic status of the study area

Appendix 1.1: Demography of the respondents for each district

Demographic characteristics	Gender, N (%)						
	Zhemgang	Trongsa	Dagana	Tsirang	Wangdue	Punakha	Total
Male	54 (4.4)	10 (0.8)	41 (3.3)	59 (4.8)	79 (6.4)	221 (17.9)	464 (37.5)
Female	86 (7.0)	25 (2.0)	51 (4.1)	61 (4.9)	117 (9.5)	433 (35.0)	773 (62.5)
	Age, N (%)						
Below 20	0 (0.0)	0 (0.0)	1 (0.1)	4 (0.3)	2 (0.2)	2 (0.2)	9 (0.7)
21 - 40 years	63 (5.1)	11 (0.9)	37 (3.0)	51 (4.1)	74 (6.0)	209 (16.9)	445 (36.0)
41 - 60 years	46 (3.7)	16 (1.3)	40 (3.2)	42 (3.4)	76 (6.1)	258 (20.9)	478 (38.6)
Above 61 years	31 (2.5)	8 (0.6)	14 (1.1)	23 (1.9)	44 (3.6)	185 (15.0)	305 (24.7)
	Education level, N (%)						
None	87 (7.0)	30 (2.4)	54 (4.4)	76 (6.1)	126 (10.2)	455 (36.8)	828 (66.9)
Primary	12 (1.0)	1 (0.1)	15 (1.2)	18 (1.5)	17 (1.4)	67 (5.4)	130 (10.5)
Middle secondary	13 (1.1)	0 (0.0)	14 (1.1)	14 (1.1)	20 (1.6)	40 (3.2)	101 (8.2)
High school	7 (0.6)	1 (0.1)	4 (0.3)	8 (0.6)	12 (1.0)	36 (2.9)	68 (5.5)
Undergraduate	9 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.2)	10 (0.8)	22 (1.8)
Master	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.2)	3 (0.2)
Others	12 (1.0)	3 (0.2)	5 (0.4)	4 (0.3)	18 (1.5)	43 (3.5)	85 (6.9)
	Ethnic group, N (%)						
Ngalop	4 (0.3)	0 (0.0)	14 (1.1)	30 (2.4)	176 (14.3)	615 (49.8)	839 (67.9)
Sharchop	9 (0.7)	0 (0.0)	1 (0.1)	4 (0.3)	10 (0.8)	17 (1.4)	41 (3.3)
Lhotshampa	4 (0.3)	1 (0.1)	74 (6.0)	79 (6.4)	6 (0.5)	1 (0.1)	165 (13.4)
Khengpa	121 (9.8)	9 (0.7)	2 (0.2)	4 (0.3)	2 (0.2)	9 (0.7)	147 (11.9)
Mangdep	2 (0.2)	25 (2.0)	0 (0.0)	3 (0.2)	1 (0.1)	2 (0.2)	33 (2.7)
Others	0 (0.0)	0 (0.0)	1 (0.1)	0 (0.0)	1 (0.1)	8 (0.6)	10 (0.8)
	Gender of the household head, N (%)						
Female	95 (7.7)	27 (2.2)	33 (2.7)	43 (3.5)	128 (10.3)	508 (41.1)	834 (67.4)
Male	45 (3.6)	8 (0.6)	59 (4.8)	77 (6.2)	68 (5.5)	146 (11.8)	403 (32.6)
	Occupation, N (%)						
Business	9 (0.7)	0 (0.0)	8 (0.6)	17 (1.4)	16 (1.3)	28 (2.3)	78 (6.3)
Employed	4 (0.3)	0 (0.0)	2 (0.2)	0 (0.0)	9 (0.7)	7 (0.6)	22 (1.8)
Farmer	125 (10.1)	35 (2.8)	82 (6.6)	103 (8.3)	170 (13.7)	612 (49.5)	1127 (91.1)
Others	2 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	7 (0.6)	10 (0.8)

Appendix 1.2: Head of household, income, and occupation of the respondents for each district

	Gender of the household head, N (%)						
	Zhemgang	**Trongsa**	**Dagana**	**Tsirang**	**Wangdue**	**Punakha**	**Total**
Female	95 (7.7)	27 (2.2)	33 (2.7)	43 (3.5)	128 (10.3)	508 (41.1)	834 (67.4)
Male	45 (3.6)	8 (0.6)	59 (4.8)	77 (6.2)	68 (5.5)	146 (11.8)	403 (32.6)
	Occupation, N (%)						
Business	9 (0.7)	0 (0.0)	8 (0.6)	17 (1.4)	16 (1.3)	28 (2.3)	78 (6.3)
Employed	4 (0.3)	0 (0.0)	2 (0.2)	0 (0.0)	9 (0.7)	7 (0.6)	22 (1.8)
Farmer	125 (10.1)	35 (2.8)	82 (6.6)	103 (8.3)	170 (13.7)	612 (49.5)	1127 (91.1)
Others	2 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	7 (0.6)	10 (0.8)
	Source of income, N (%)						
< Nu. 50000	81 (6.6)	28 (2.3)	45 (3.7)	59 (4.8)	104 (8.5)	231 (18.8)	548 (44.7)
Nu. 51000-100000	40 (3.3)	6 (0.5)	31 (2.5)	34 (2.8)	53 (4.3)	207 (16.9)	371 (30.3)
Nu. 101000-200000	11 (0.9)	0 (0.0)	12 (1.0)	22 (1.8)	19 (1.5)	128 (10.4)	192 (15.7)
Nu. 201000-500000	6 (0.5)	1 (0.1)	3 (0.2)	3 (0.2)	16 (1.3)	61 (5.0)	90 (7.3)
Nu. > 500000	2 (0.2)	0 (0.0)	1 (0.1)	2 (0.2)	3 (0.2)	17 (1.4)	25 (2.0)

Appendix 1.3: Livelihood of the respondents

	Agriculture, N (%)						
	Zhemgang	**Trongsa**	**Dagana**	**Tsirang**	**Wangdue**	**Punakha**	**Total**
Very important	113 (9.3)	27 (2.2)	65 (5.4)	93 (7.7)	147 (12.1)	598 (49.3)	1043 (85.9)
Important	13 (1.1)	5 (0.4)	15 (1.2)	15 (1.2)	12 (1.0)	23 (1.9)	83 (6.8)
Medium	4 (0.3)	2 (0.2)	3 (0.2)	1 (0.1)	5 (0.4)	3 (0.2)	18 (1.5)
Not Important	1 (0.1)	1 (0.1)	1 (0.1)	2 (0.2)	0 (0.0)	1 (0.1)	6 (0.5)
Not at all	3 (0.2)	0 (0.0)	7 (0.6)	8 (0.7)	25 (2.1)	21 (1.7)	64 (5.3)
	Livestock, N (%)						
Very important	21 (1.7)	2 (0.2)	16 (1.3)	24 (2.0)	25 (2.1)	42 (3.5)	130 (10.7)
Important	53 (4.4)	19 (1.6)	44 (3.6)	65 (5.4)	86 (7.1)	281 (23.1)	548 (45.1)
Medium	29 (2.4)	5 (0.4)	11 (0.9)	12 (1.0)	13 (1.1)	79 (6.5)	149 (12.3)
Not Important	2 (0.2)	0 (0.0)	3 (0.2)	4 (0.3)	3 (0.2)	42 (3.5)	54 (4.4)
Not at all	29 (2.4)	9 (0.7)	17 (1.4)	14 (1.2)	62 (5.1)	202 (16.6)	333 (27.4)
	Trade/Business, N (%)						
Very important	11 (0.9)	0 (0.0)	11 (0.9)	22 (1.8)	20 (1.6)	40 (3.3)	104 (8.6)
Important	13 (1.1)	0 (0.0)	4 (0.3)	2 (0.2)	11 (0.9)	82 (6.8)	112 (9.2)
Medium	6 (0.5)	0 (0.0)	2 (0.2)	5 (0.4)	7 (0.6)	51 (4.2)	71 (5.8)
Not Important	7 (0.6)	0 (0.0)	1 (0.1)	3 (0.2)	7 (0.6)	39 (3.2)	57 (4.7)
Not at all	99 (8.2)	35 (2.9)	71 (5.8)	86 (7.1)	146 (12.0)	432 (35.6)	869 (71.6)
	Off-farm labour, N (%)						
Very important	10 (0.8)	8 (0.7)	4 (0.3)	6 (0.5)	12 (1.0)	14 (1.2)	54 (4.5)
Important	50 (4.1)	7 (0.6)	30 (2.5)	27 (2.2)	34 (2.8)	147 (12.1)	295 (24.3)
Medium	26 (2.1)	8 (0.7)	14 (1.2)	30 (2.5)	36 (3.0)	104 (8.6)	218 (18)
Not Important	11 (0.9)	1 (0.1)	6 (0.5)	5 (0.4)	6 (0.5)	42 (3.5)	71 (5.9)
Not at all	37 (3.1)	11 (0.9)	36 (3.0)	51 (4.2)	101 (8.3)	338 (27.9)	574 (47.4)

Appendix 1.4: No. of households reporting damages by different wildlife

	Wild pigs							
	Zhemgang	**Trongsa**	**Dagana**	**Tsirang**	**Wangdue**	**Punakha**	**Total**	**Percent**
Most destructive	115	27	26	50	101	494	813	74.6
Destructive	6	3	21	30	24	28	112	10.3
Neutral	4	0	7	1	9	14	35	3.2
Not destructive	5	3	25	26	21	50	130	11.9
	Monkeys							
Most destructive	32	10	60	60	67	54	283	26.8
Destructive	35	18	9	23	25	58	168	15.9
Neutral	10	1	5	6	4	19	45	4.3
Not destructive	53	4	8	18	56	422	561	53.1
	Barking deer							
Most destructive	56	5	33	33	28	132	287	26.8
Destructive	52	20	20	35	45	160	332	31.1
Neutral	10	3	8	7	15	49	92	8.6
Not destructive	11	5	22	30	59	231	358	33.5
	Bear							
Most destructive	12	4	3	7	1	5	32	3.2
Destructive	40	5	6	7	8	30	96	9.6
Neutral	21	6	6	6	4	21	64	6.4
Not destructive	55	17	63	79	117	482	813	80.9
	Birds							
Most destructive	30	3	22	24	24	41	144	13.8
Destructive	48	16	24	37	48	116	289	27.8
Neutral	22	4	7	14	22	73	142	13.7
Not destructive	28	10	27	25	50	325	465	44.7
	Sambar							
Most destructive	35	2	7	9	8	39	100	9.8
Destructive	32	15	11	18	26	96	198	19.4
Neutral	13	3	1	5	11	48	81	7.9
Not destructive	46	13	59	66	89	370	643	62.9
	Tigers							
Most destructive	4	0	1	0	1	7	13	1.3
Destructive	7	1	0	0	2	12	22	2.2
Neutral	9	3	2	0	2	7	23	2.3
Not destructive	104	27	70	93	123	511	928	94.1
	Wild dogs							
Most destructive	12	0	2	0	9	16	39	3.9
Destructive	21	3	2	4	25	38	93	9.3
Neutral	17	1	4	1	11	31	65	6.5
Not destructive	74	27	64	88	86	460	799	80.2

Appendix 1.5: Impacts of Human-wildlife conflicts

	Changes in cropping pattern							
	Zhemgang	**Trongsa**	**Dagana**	**Tsirang**	**Wangdue**	**Punakha**	**Total**	**Percent**
Very frequently	5	1	4	3	4	8	25	2.3
Frequently	19	7	13	14	16	50	119	11.1
Occasionally	23	5	11	16	20	57	132	12.3
Rarely	14	5	8	25	20	86	158	14.7
Never	69	16	46	51	98	361	641	59.6
Total	130	34	82	109	158	562	1075	100
Percent	12.1	3.2	7.6	10.1	14.7	52.3	100	
	Reduction in crop yield							
Very frequently	66	16	38	47	56	178	401	37.1
Frequently	34	7	17	29	45	161	293	27.1
Occasionally	14	6	13	21	35	107	196	18.1
Rarely	4	3	8	5	6	38	64	5.9
Never	11	2	8	7	18	81	127	11.7
Total	129	34	84	109	160	565	1081	100
Percent	11.9	3.1	7.8	10.1	14.8	52.3	100	
	Abandonment of land							
Very frequently	11	4	3	4	3	8	33	3.1
Frequently	9	5	5	7	11	35	72	6.8
Occasionally	13	4	2	7	9	17	52	4.9
Rarely	10	3	7	17	11	39	87	8.2
Never	86	18	65	72	124	451	816	77
Total	129	34	82	107	158	550	1060	100
Percent	12.2	3.2	7.7	10.1	14.9	51.9	100	
	Shift in livelihood activities							
Very frequently	10	3	4	8	12	43	80	7.4
Frequently	10	7	15	27	11	71	141	13.1
Occasionally	12	3	10	12	13	35	85	7.9
Rarely	9	2	6	8	16	51	92	8.5
Never	89	19	49	53	107	362	679	63.1
Total	130	34	84	108	159	562	1077	100
Percent	12.1	3.2	7.8	10	14.8	52.2	100	
	Reduction in cultivation area							
Very frequently	18	4	3	3	4	5	37	3.5
Frequently	27	14	12	14	22	47	136	12.9
Occasionally	14	2	15	10	14	25	80	7.6
Rarely	12	1	7	15	15	50	100	9.5
Never	58	13	46	65	98	420	700	66.5
Total	129	34	83	107	153	547	1053	100
Percent	12.3	3.2	7.9	10.2	14.5	51.9	100	

Appendix 1.6: Benefits from conservation

	Benefits from afforestation							
	Zhemgang	**Trongsa**	**Dagana**	**Tsirang**	**Wangdue**	**Punakha**	**Total**	**Percent**
Yes	63	7	34	87	91	214	496	58.6
No	32	14	27	20	33	224	350	41.4
Total	95	21	61	107	124	438	846	100
Percent	11.2	2.5	7.2	12.6	14.7	51.8	100	
	Benefits from checking illegal activities							
Yes	29	8	15	51	38	178	319	40.8
No	43	14	39	45	68	254	463	59.2
Total	72	22	54	96	106	432	782	100
Percent	9.2	2.8	6.9	12.3	13.6	55.2	100	
	Benefits from community awareness and trainings							
Yes	62	11	27	69	55	274	498	60.4
No	25	12	27	24	54	185	327	39.6
Total	87	23	54	93	109	459	825	100
Percent	10.5	2.8	6.5	11.3	13.2	55.6	100	
	Benefits from changes in agricultural practices							
Yes	34	9	18	34	45	142	282	36.6
No	40	12	35	52	57	293	489	63.4
Total	74	21	53	86	102	435	771	100
Percent	9.6	2.7	6.9	11.2	13.2	56.4	100	
	Benefits from new protection measures							
Yes	29	8	12	28	36	89	202	26.8
No	45	11	37	60	63	337	553	73.2
Total	74	19	49	88	99	426	755	100
Percent	9.8	2.5	6.5	11.7	13.1	56.4	100	

Appendices 2: Ecosystem services valuation

Appendix 2.1: Ecosystem Services availed by local communities in WBH habitat areas of Bhutan

Provisioning	
Ecosystem services	**Count (HHs)**
Fresh water	1,494
Timber	1,401
Fuel Wood	1,397
NWFP	1,158
Wild Fruits and Vegetables	1,117
Fresh air	1,072
Flag Pole	1,057
Bamboo	1,053
Construction stones	1,039

Regulating	
Ecosystem services	**Count (HHs)**
Land productivity	1,173
Improved vegetation	857
Wind break	554
Carbon sequestration	542
Soil erosion protection	531
Reduced forest fire	524
Groundwater recharge	466
Pollution Control	360
Local weather regulation	342

Fodder trees	976
Fodder	954
Betel nut paan	868
Sand and clay	713
Incense materials	621
Fish	578
Leaf Litter	569
Tea leaves	505
Medicinal/Holy sprin	489
Medicinal plant	454
Fibre (pulb for paper)	406
Dye plants	394
Bush meat	352
Edible insects	341
Essential oil (lemon)	331
Wood burr	165
Limestone	128

Cultural	
Ecosystem services	**Count (HHs)**
Seat of guardian dieties	1,016
Spiritual sites	985
Traditional Monument	934
Pilgrimage site	717
Tourism/ Recreation	652
Recreation	410
Picnic Spot	347
Asthetic value	196

Biological reproducti	316
Flood regulation	239
Waste water treatment	79
Pollination	14

Supporting	
Ecosystem services	**Count (HHs)**
Soil productivity	984
Wildlife and plant habitat	797
Biodiversity	762
Wild animal diversity	672
Pollination	494
Nutrient cycling	401
Maintain genetic dive	344
Improved vegetation c	23
Reduced forest fire	16
Soil erosion protection	3
Spiritual sites	3
others	3

Appendix 2.2: Household perceptions on trends in Ecosystem services

Provisioning Services

Provisioning services	Trend in Provisioning Services						
	Decrease		No change		Increase		Total
	HH Count	%	HH Count	%	HH Count	%	Count HH
Timber	788	56.29	400	28.57	212	15.14	1400
NWFP	604	52.20	374	32.32	179	15.47	1157
Bush meat	176	50.14	154	43.87	21	5.98	351
Edible insects	168	49.41	160	47.06	12	3.53	340
Fuel Wood	647	46.35	440	31.52	309	22.13	1396
Fish	248	42.98	249	43.15	80	13.86	577
Fodder	377	39.56	346	36.31	230	24.13	953
Construction stones	407	39.21	393	37.86	238	22.93	1038
Bamboo	411	39.07	404	38.4	237	22.53	1052
Wood burr	62	37.80	62	37.80	40	24.39	164

Wild Fruits and veget	421	37.72	510	45.70	185	16.58	1116
Betel nut paan	325	37.49	316	36.45	226	26.07	867
Fresh water	525	35.16	625	41.86	343	22.97	1493
Leaf Litter	199	35.04	237	41.73	132	23.24	568
Limestone	42	33.07	61	48.03	24	18.90	127
Incense materials	197	31.77	339	54.68	84	13.55	620
Flag Pole	335	31.72	592	56.06	129	12.22	1056
Tea leaves	156	30.95	203	40.28	145	28.77	504
Essential oil (lemon)	95	28.79	175	53.03	60	18.18	330
Fodder trees	267	27.38	411	42.15	297	30.46	975
Sand and clay	192	26.97	351	49.30	169	23.74	712
Medicinal plant	118	26.05	270	59.60	65	14.35	453
Fibre (pulb for paper)	105	25.93	199	49.14	101	24.94	405
Dye plants	87	22.14	202	51.40	104	26.46	393
Medicinal /Holy Sprin	97	19.88	377	77.25	14	2.87	488
Fresh air	175	16.34	738	68.91	158	14.75	1071

Regulating Services trend

Regulating Services	Trend in Regulating Services						
	Decrease		No change		Increase		Total
	HH Count	%	HH Count	%	HH Count	%	Count HH
Land productivity	476	40.61	464	39.59	232	19.80	1172
Groundwater recharge	123	26.45	271	58.28	71	15.27	465
Nutrient cycling	72	18.00	224	56.00	104	26.00	400
Carbon sequestration	95	17.56	310	57.30	136	25.14	541
Maintain genetic diversity	60	17.44	161	46.80	123	35.76	344
Reduced forest fire	83	15.40	220	40.82	236	43.78	539
Soil erosion protection	62	11.63	260	48.78	211	39.59	533
Improved vegetation cover	84	9.59	283	32.31	509	58.11	876
Wind break	48	8.68	234	42.31	271	49.01	553
Waste water treatment	6	7.69	59	75.64	13	16.67	78
Flood regulation	18	7.56	173	72.69	47	19.75	238
Pollution Control	26	7.24	179	49.86	154	42.90	359
Local weather regulat	22	6.45	281	82.40	38	11.14	341
Others	0	0.00	4	100.00	0	0.00	4

Supporting Services trend

Supporting Services	Trend in Regulating Services						
	Decrease		No change		Increase		Total
	HH Count	%	HH Count	%	HH Count	%	Count HH
Soil productivity	378	38.45	387	39.37	218	22.18	983
Wildlife and plant habitat	201	25.25	275	34.55	320	40.20	796
Biodiversity	209	27.46	251	32.98	301	39.55	761
Wild animal diversity	212	31.64	218	32.54	240	35.82	670
Pollination	116	22.88	283	55.82	108	21.30	507
Biological reproducti	49	15.56	188	59.68	78	24.76	315

Trend in Cultural Services

Cultural Services	Trend in Regulating Services						
	Decrease		No change		Increase		Total
	HH Count	%	HH Count	%	HH Count	%	Count HH
Tourism	472	72.50	141	21.66	38	5.84	651
Asthetic	9	4.62	160	82.05	26	13.33	195
Picnic Spot	14	4.05	284	82.08	48	13.87	346
Pilgrimage site	20	2.79	640	89.39	56	7.82	716
Recreation	9	2.20	365	89.24	35	8.56	409
Traditional Monument	20	2.14	862	92.39	51	5.47	933
Spiritual sites	18	1.82	894	90.58	75	7.60	987
Seat of guardian diet	11	1.08	966	95.17	38	3.74	1015

Appendix 2.3: Comparison of ecosystem trends between Mangdechhu and Punatsangchhu Basin

	Mangdechhu Basin	Punatsangchhu Basin	Total
Provisioning Service			
Increase	2.5	17.46	19.96
No Change	2.72	19.44	22.16
Decrease	1.11	9.16	10.28
Total	**6.33**	**46.07**	**52.4**
Regulating Services			
Increase	0.5	3.54	3.54
No Change	1.45	10.3	10.3
Decrease	0.65	6.25	6.25
Total	**2.6**	**20.1**	**20.1**
Supporting Services			
Increase	0.55	3.55	3.55
No Change	0.77	5.13	5.13
Decrease	0.38	4.06	4.06
Total	**1.7**	**12.7**	**12.7**
Cultural Services			
Increase	0.18	1.61	1.61
No Change	0.86	12.1	12.11
Decrease	0.27	1.04	1.04
Total	**1.32**	**14.77**	**14.77**

Appendix 2.4: Comparison of ecosystem trends among different WBH sites

	WBH Area	Potential WBH Area	Total
Provisioning Service			
Increase	18.26	1.7	19.96
No Change	19.99	2.17	22.16
Decrease	9.62	0.66	10.27
Total	**47.87**	**4.53**	**52.39**
Regulating Services			
Increase	3.13	0.42	3.55
No Change	9.49	0.81	10.3
Decrease	5.72	0.53	6.25
Total	**18.33**	**1.77**	**20.1**
Supporting Services			
Increase	3.12	4.43	3.55
No Change	4.67	0.46	5.13
Decrease	3.76	0.3	4.06
Total	**11.55**	**1.18**	**12.73**
Cultural Services			
Increase	1.47	0.14	1.61
No Change	11.24	0.87	12.11
Decrease	0.92	0.12	1.04
Total	**13.63**	**1.13**	**14.77**

Appendix 2.5: Trends of ecosystem services among different districts

	Zhemgang	Trongsa	Dagana	Tsirang	Wangdue	Punakha	Gasa	Total
Provisioning Service								
Increase	2.04	0.46	0.9	1.2	3.34	12.02	0.01	19.96
No Change	2.17	0.55	1.92	1.67	3.76	12.04	0.05	22.16
Decrease	0.93	0.18	0.49	1.03	1.56	6.07	0.02	10.28
Total	**5.14**	**1.19**	**3.3**	**3.9**	**8.66**	**30.12**	**0.08**	**52.4**
Regulating Services								
Increase	0.38	0.12	0.19	0.31	0.55	1.99	0	3.54
No Change	1.2	0.25	0.84	0.68	1.75	5.57	0	10.3
Decrease	0.56	0.09	0.48	0.7	1.02	3.39	0.01	6.25
Total	**2.14**	**0.46**	**1.51**	**1.69**	**3.33**	**10.96**	**0.01**	**20.1**
Supporting Services								
Increase	0.44	0.1	0.38	0.33	0.5	1.79	0	3.55
No Change	0.61	0.16	0.43	0.33	0.94	2.66	0	5.13
Decrease	0.29	0.09	0.17	0.4	0.67	2.43	0	4.06
Total	**1.34**	**0.36**	**0.98**	**1.07**	**2.1**	**6.88**	**0.01**	**12.73**
Cultural Services								
Increase	0.11	0.07	0.02	0.33	0.23	1.15	0	1.61
No Change	0.67	0.19	0.32	0.33	1.98	8.61	0.02	12.11
Decrease	0.25	0.02	0.04	0.1	0.1	0.53	0	1.04
Total	**1.04**	**0.28**	**0.38**	**0.46**	**2.31**	**10.28**	**0.02**	**14.77**

Appendix 2.6: Estimates of demand for ecosystem services using conditional logit model

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	**Membership Fee**	**Labour Contribution**	**WBH-Area**	**Potential WBH-Area**	**Mangdechu Basin**	**Punatsangchu Basin**
ASC	-2.451***	-0.617***	-1.394***	-0.488***	-0.880***	-1.390***
	(0.169)	(0.16)	(0.0627)	(0.17)	(0.142)	(0.0645)
Drinking Water	0.0156***	0.0008*	0.0057***	0.0049***	0.0065***	0.0053***
	(0.0007)	(0.0004)	(0.0003)	(0.0009)	(0.0008)	(0.0003)
Irrigation Water	0.147***	-0.0189***	0.0272***	0.0536***	0.0621***	0.0226***
	(0.0111)	(0.007)	(0.0056)	(0.0162)	(0.0131)	(0.0058)
Fuelwood Collection	0.0003	0.0033***	0.0025***	0.0013	0.001	0.0028***
	(0.0005)	(0.0004)	(0.0003)	(0.001)	(0.0007)	(0.0003)
Animal Fodder and Bedding	0.0255	-0.351***	-0.169***	-0.147	-0.172**	-0.182***
	(0.0603)	(0.0426)	(0.0337)	(0.0972)	(0.0769)	(0.035)
Timber	0.0035***	-1.34e-05	0.0013***	0.0001	0.0028***	0.0006*
	(0.0006)	(0.0004)	(0.0003)	(0.001)	(0.0008)	(0.0003)
Fishing	-0.0148***	0.0241***	0.0108***	0.0217**	0.0065	0.0111***
	(0.0057)	(0.0044)	(0.0035)	(0.0099)	(0.0079)	(0.0036)
NWFP	0.0682	-0.0883**	-0.013	0.111	-0.0534	0.0157
	(0.0534)	(0.0411)	(0.0329)	(0.0991)	(0.075)	(0.0344)
WBH	0.260***	0.556***	0.434***	0.437***	0.712***	0.379***
	(0.0759)	(0.0692)	(0.0503)	(0.142)	(0.11)	(0.0524)
Labour-Fee	-9.86E-05	0.0002	-0.0002***	0.0001	0.0001**	-0.0003***
	(0.0001)	(0.0001)	(3.62e-05)	(0.0001)	(8.51e-05)	(3.80e-05)
Observations	6,251	7,956	12,911	1,296	2,268	11,890

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Appendix 2.7: Comparative estimates of demand for ecosystem services among different socioeconomic conditions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	**Gender**		**Particip. in Conservation**		**TV Connection**		**HWC**	
	Female	Male	Yes	No	Yes	No	Yes	No
ASC	-1.238***	-1.509***	-1.503***	-1.117***	-1.211***	-1.488***	-1.291***	-1.465***
	(0.0708)	(0.107)	(0.0815)	(0.0902)	(0.0728)	(0.105)	(0.0634)	(0.153)
Drinking Water	0.0050***	0.0074***	0.0069***	0.0037***	0.0048***	0.0071***	0.0058***	0.0038***
	(0.0004)	(0.0006)	(0.0004)	(0.0005)	(0.0004)	(0.0006)	(0.0003)	(0.0009)
Irrigation Water	0.0242***	0.0401***	0.0360***	0.0325***	0.0196***	0.0543***	0.0365***	-0.0134
	(0.0065)	(0.0096)	(0.0073)	(0.0086)	(0.0066)	(0.0095)	(0.0057)	(0.0147)
Fuelwood Collection	0.0022***	0.0032***	0.0030***	0.00134**	0.0030***	0.0017***	0.0023***	0.0029***
	(0.0003)	(0.0005)	(0.0004)	(0.0005)	(0.0004)	(0.0005)	(0.0003)	(0.0009)
Animal Fodder	-0.133***	-0.259***	-0.142***	-0.184***	-0.216***	-0.0633	-0.178***	-0.215**
	(0.0388)	(0.0562)	(0.0427)	(0.0514)	(0.0403)	(0.0553)	(0.0341)	(0.0881)
Timber	0.0006	0.0020***	0.0015***	0.0012**	0.0001	0.0028***	0.0010***	0.0015*
	(0.0004)	(0.0005)	(0.0004)	(0.0005)	(0.0004)	(0.0005)	(0.0003)	(0.0009)
Fishing	0.0085**	0.0162***	0.0063	0.0165***	0.0114***	0.0062	0.0139***	0.0015

	(0.004)	(0.0059)	(0.0045)	(0.0053)	(0.0042)	(0.0057)	(0.0035)	(0.0091)
NWFP	0.0118	-0.05	0.0668	-0.0948*	0.0016	0.0439	0.0212	-0.116
	(0.0382)	(0.0548)	(0.0424)	(0.0505)	(0.0396)	(0.0543)	(0.0335)	(0.086)
WBH	0.420***	0.506***	0.391***	0.544***	0.349***	0.568***	0.459***	0.258**
	(0.0579)	(0.083)	(0.0655)	(0.0756)	(0.0593)	(0.0824)	(0.0507)	(0.13)
Labour Fee	-0.0002***	-0.0002***	-0.0001***	-0.0002***	-0.0003***	8.23E-05	-0.0002***	-0.0005***
	(4.24e-05)	(5.97e-05)	(4.39e-05)	(6.32e-05)	(4.37e-05)	(5.92e-05)	(3.66e-05)	(0.0001)
Observations	9,382	4,655	8,208	5,447	8,915	4,644	12,214	1,968

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Appendix 2.8: Willingness to pay for ecosystem services

VARIABLES	WTP	Confidence Interval		WTP	Confidence Interval	
DrinkingWater	157.84	-1166.5	1559.19	-3.36	-29.57	23.47
IrrigationWater	1493.56	-11489.48	15018.59	77.41	-432.54	623.26
FuelwoodCollection	4.05	-51.05	55.61	-13.52	-104.89	85.86
AnimalFodder	258.40	-5226.74	5207.07	1435.39	-8490.87	10976.87
Timber	36.15	-283.58	370.58	0.05	-11.97	10.58
Fishing	-150.11	-1603.22	1112.23	-98.67	-783.28	573.52
NWFP	691.27	-5136.25	6966.70	360.72	-2170.38	2769.26
WBH	2636.84	-20323.12	27360.58	-2273.99	-18406.66	13590.47

	Mangdechhu Basin			Punatsangchhu Basin		
	WTP	Confidence Interval		WTP	Confidence Interval	
Drinking Water	9.03	-46.46	51.83	15.34	12.00	20.00
Irrigation Water	-54.42	-511.70	583.29	64.54	32.06	106.47
Fuelwood Collection	24.49	-114.11	105.90	8.03	5.65	11.35
Animal Fodder	-3725.61	-15245.86	17336.72	-518.93	-776.64	-314.45
Timber	4.51	-40.01	30.11	1.82	-0.19	4.08
Fishing	147.52	-750.49	583.03	31.81	10.90	55.45
NWFP	-1151.42	-4475.30	5273.20	44.75	-147.94	238.21
WBH	3194.20	-16066.10	13784.96	1082.81	738.50	1572.56

	WBH Area			Potential WBH Area		
VARIABLES	WTP	Confidence Interval		WTP	Confidence Interval	
Drinking Water	20.19	15.60	27.32	-40.79	-399.24	392.46
Irrigation Water	95.00	55.63	149.07	-441.96	-4607.22	3849.66
Fuelwood Collection	8.96	6.10	13.27	-11.01	-105.05	92.16
Animal Fodder	-589.38	-916.26	-346.05	1209.66	-10322.12	10317.34
Timber	4.52	2.11	7.80	-0.87	-56.11	71.56
Fishing	37.77	12.99	66.91	-179.00	-2041.18	1568.47
NWFP	-45.45	-281.56	175.55	-917.52	-9341.93	7802.74
WBH	1515.06	1052.27	2221.06	-3602.67	-41570.45	31480.61

Appendix 2.9: Estimated value of Ecosystem Services by types of ecosystem and ecosystem services

	Total area (ha)	US $ per hectare per year Kubiszewski et al. (2013)				US $ per hectare per year (ESRAM Area)			Household Mean Value		Percentage contribution
		Ref	Min	Max	Mean	Min	Max	Mean	$US/year	Nu/year	
A. Cropland	**1313.25**	**17**	**1100.44**	**3949.46**	**2524.95**	**1445155.46**	**5186623.09**	**3315889.27**	**2812.46**	**206012.63**	**28.75**
Provisioning services			199.96	249.60	224.78	262590.90	327785.89	295188.40	250.37	18339.74	
Food		2	97.91	146.17	122.73	128578.99	191963.01	161176.49	136.71	10013.72	
Raw materials		1			15.17			19920.69	16.90	1237.65	
Water		1			88.26			115902.19	98.31	7200.88	
Regulating services			897.73	3652.97	2275.35	1178942.61	4797264.17	2988103.39	2534.44	185647.64	
Air quality		1			73.09			95981.50	81.41	5963.23	
Biodiversity protection		2	104.80	2661.47	1383.14	137633.85	3495175.48	1816404.67	1540.63	112851.27	
Biological control		1			38.61			50707.21	43.01	3150.38	
Climate regulation		1			131.01			172042.32	145.92	10688.80	
Erosion prevention		2	70.33	186.17	128.25	92359.56	244481.19	168420.37	142.85	10463.78	
Pollination		1			26.20			34408.46	29.18	2137.76	
Soil formation		2	213.75	295.11	255.12	280700.62	387547.95	335029.77	284.16	20815.04	
Water purification		1			241.33			316920.06	268.80	19689.90	
Cultural services			1.38	48.27	24.82	1810.97	63384.01	32597.49	27.65	2025.25	
Recreation		2	1.38	48.27	24.82	1810.97	63384.01	32597.49	27.65	2025.25	
B. Orchard	**119.88**	**9**			**2134.69**			**255906.88**	**217.05**	**15899.22**	**2.22**
Provisioning services					517.13			61992.95	52.58	3851.55	
Food		1			28.96			3471.60	2.94	215.69	
Raw materials		1			194.44			23309.35	19.77	1448.18	
Water		1			293.73			35211.99	29.87	2187.68	
Regulating services					1521.04			182341.92	154.66	11328.71	
Air quality		1			315.79			37857.03	32.11	2352.02	
Biodiversity protection		1			319.93			38352.97	32.53	2382.83	
Climate regulation		1			264.77			31740.39	26.92	1972.00	
Soil formation		1			428.87			51412.82	43.61	3194.22	
Water purification		1			191.68			22978.72	19.49	1427.64	
Cultural Services					96.53			11572.02	9.82	718.96	
Recreation		1			96.53			11572.02	9.82	718.96	

C. Forest	**1119.42**	**63**	**1839.59**	**29944.99**	**6950.16**	**2059269.36**	**33521015.11**	**7780148.11**	**6598.94**	**483372.22**	**67.45**
Provisioning Services			92.39	1224.55	655.03	103426.57	1370788.00	733248.09	621.92	45555.91	
Bioprospecting		1			11.03			12349.44	10.47	767.26	
Food		4		595.73	333.72		666869.84	373570.60	316.85	23209.54	
Genetic resources		1			26.20			29329.92	24.88	1822.24	
Timber		2	53.78	68.95	60.68	60203.53	77184.01	67921.93	57.61	4219.92	
Water		5		522.64	223.40		585054.79	250076.19	212.11	15536.96	
Regulating Services			1743.06		4859.60	1951211.75		5439928.95	4614.02	337976.93	
Air quality		1			1174.91			1315215.51	1115.53	81712.92	
Biodiversity protection		8	9.65	7159.77	1336.25	10805.76	8014787.49	1495826.09	1268.72	92934.06	
Biological control		2	6.90	19.31	12.41	7718.40	21611.52	13893.12	11.78	863.16	
Climate regulation		15	2.76	9651.62	1682.38	3087.36	10804217.58	1883289.82	1597.36	117006.77	
Erosion prevention		2	2.76	158.59	79.98	3087.36	177523.22	89533.45	75.94	5562.62	
Pollination		1			518.50			580423.75	492.30	36061.10	
Soil formation		1			15.17			16980.48	14.40	1054.98	
Water purification		5		140.66	38.61		157455.38	43223.05	36.66	2685.40	
Cultural Services			4.14	9866.75	1435.54	4631.04	11045031.69	1606971.07	1362.99	99839.38	
Cultural values		1			2.76			3087.36	2.62	191.81	
Tourism/Recreation		11			1432.78			1603883.71	1360.38	99647.57	
D. Lakes/Rivers	**27.55**	**29**	**1599.64**	**21429.66**	**6656.43**	**44070.08**	**590387.13**	**183384.73**	**155.54**	**11393.50**	**1.59**
Provisioning services			681.23	16348.05	4219.74	18767.78	450388.64	116253.84	98.60	7222.73	
Energy		4	77.22	9010.39	2376.02	2127.52	248236.13	65459.27	55.52	4066.91	
Food		3	17.93	73.09	52.40	493.89	2013.55	1443.68	1.22	89.69	
Raw materials		1			1.38			37.99	0.03	2.36	
Water		10	46.89	3566.09	1788.56	1291.71	98245.89	49274.91	41.79	3061.40	
Regulating Services			537.81	3697.10	1624.46	14816.67	101855.08	44753.93	37.96	2780.51	
Biodiversity protection		1			435.76			12005.30	10.18	745.88	
Climate regulation		1			79.98			2203.50	1.87	136.90	
Water purification		3	22.06	3181.35	1108.72	607.86	87646.28	30545.13	25.91	1897.74	
Cultural Services			380.60	1383.14	810.85	10485.64	38105.42	22338.97	18.95	1387.90	
Recreation		6	380.60	1383.14	810.85	10485.64	38105.42	22338.97	18.95	1387.90	
Total (A+B+C+D)	**2580.10**	**118**	**4539.67**	**55324.10**	**18266.23**	**3548494.90**	**39298025.33**	**11535328.99**	**9783.99**	**716677.56**	**100.00**

Appendix 2.10: Value of Ecosystem Services by District, Gewog, and Chiwog based on Benefit transfer method and DCE (in Ngultrum).

DAGANA

GEOG	CHIWOG	HH_COUNT	Benefit Transfer	DCE
Drugyel Gang	AMBITHANG_PANGSERPO	140	1369759.17	48834.23618
Drugyel Gang	BUDEPANG_ PANGNA	166	1624143.01	57903.45147
Lhamoy Zingkha	CHONGSAMLING	8	78271.95	2790.52778
Nichula	DANGREYBOOG	20	195679.88	6976.31945
Nichula	DRAMZE-KESA	39	381575.77	13603.82294
Tashiding	GANG-GYAB	30	293519.82	10464.47918
Nichula	GANGTOGKHA	23	225031.86	8022.76737
Tsenda Gang	GANGZUR-MAED	120	1174079.29	41857.91672
Tsenda Gang	GANGZUR-TOED	94	919695.44	32788.70143
Tsangkha	GELEGCHHU	76	743583.55	26510.01392
Khebisa	GIBSA	41	401143.76	14301.45488
Tsangkha	GOONGPA-SOOMCHU	18	176111.89	6278.68751
Goshi	GOZHI	10	97839.94	3488.15973
Goshi	GOZHI-MAED	60	587039.64	20928.95836
Karmaling	JEMATHANG	27	264167.84	9418.03126
Karmaling	KARMALING	101	988183.40	35230.41324
Lhamoy Zingkha	KUENDREL THANG	55	538119.67	19184.87850
Lhamoy Zingkha	LHAMOI DZINGKHA	121	1183863.28	42206.73270
Lhamoy Zingkha	LOONGSILSA	100	978399.41	34881.59727
Tashiding	NAMCHAGLA	240	2348158.57	83715.83345
Tsenda Gang	NORBU-ZHINGKHA	34	332655.80	11859.74307
Tashiding	NORBULING	106	1037103.37	36974.49311
Karmaling	OMCHHU	63	616391.63	21975.40628
Drugyel Gang	PANGNA_PATALA	34	332655.80	11859.74307
Drugyel Gang	PANGSERPO	188	1839390.88	65577.40287
Tsangkha	PATEYKHA	146	1428463.13	50927.13201
Tsenda Gang	SAMARCHHU	84	821855.50	29300.54171
Karmaling	SENCHUMTHANG	86	841423.49	29998.17365
Tashiding	SHAMDOLAY	105	1027319.38	36625.67713
Tashiding	TASHIDING	246	2406862.54	85808.72928
Drugyel Gang	THANGNA	26	254383.85	9069.21529
Lajab	THASA	46	450063.73	16045.53474
Khebisa	THOMGANG	1	9783.99	348.81597
Tsangkha	TSANGKHA	36	352223.79	12557.37502
Tsenda Gang	TSENDA-GANG	214	2093774.73	74646.61816
Dorona	TSHALAMJI	18	176111.89	6278.68751
Nichula	YARPHELLING	11	107623.93	3836.97570
Tsangkha	ZINCHILA	8	78271.95	2790.52778

PUNAKHA

GEOG	CHIWOG	HH_COUNT	Benefit Transfer	DCE
Kabisa	AGONANG_ZARBISA	28	273951.83	9766.84724
Chhubu	BALI	31	303303.82	10813.29515
Guma	BAYMENANG_PHULINGSOOM_WANG-WAKHA	11	107623.93	3836.97570
Chhubu	BUMTAKHA_TENPAKHA	55	538119.67	19184.87850
Guma	CHANGYUL_LOONGSILGANG_TASHIJONG	278	2719950.35	96970.84041
Kabisa	CHHOETEN NYINGPO_UESARKHA	97	949047.42	33835.14935
Toewang	DAWAKHA	23	225031.86	8022.76737
Guma	DOCHHUKHA_DZOMLINGTHANG_RITSA	63	616391.63	21975.40628
Lingmukha	DOMPALA	15	146759.91	5232.23959
Talo	DONGKOKHAR_YONGGU	48	469631.71	16743.16669
Goenshari	DRAAGCHHUKHA	4	39135.98	1395.26389
Dzome	DZOMISA_MENDAGANG	69	675095.59	24068.30212
Talo	GANGTHRAMO_LABTSAKHA_SOELW-DRANGSA	66	645743.61	23021.85420
Dzome	GUBJI_TSEYKAKHA	30	293519.82	10464.47918
Guma	GUMA_WOLAKHA	121	1183863.28	42206.73270
Lingmukha	GUMKARMO	22	215247.87	7673.95140
Chhubu	JANGWAKHA_SEWALA	51	498983.70	17789.61461
Toewang	JIBJO_YUESAKHA	54	528335.68	18836.06253
Dzome	JIMITHANG	35	342439.79	12208.55904
Toewang	KEWANANG_TSHACHHUPHU	23	225031.86	8022.76737
Dzome	KHILIKHAR_LOONGKHA	30	293519.82	10464.47918
Shengana	KHUBJI_TSHOSA	8	78271.95	2790.52778
Guma	LAKHU_TSHOWOGM	47	459847.72	16394.35072
Talo	LOONGNANGKHA	2	19567.99	697.63195
Chhubu	NGOE-DROOB-CHHU	18	176111.89	6278.68751
Kabisa	PELTARI	41	401143.76	14301.45488
Goenshari	SECHAED-NANG	56	547903.67	19533.69447
Kabisa	SIRIGANG_WAKOO DAMCHHI	194	1898094.85	67670.29870
Toewang	TAMIGDAMCHHU_THANGBJI	41	401143.76	14301.45488
Dzome	TANAG_USA	40	391359.76	13952.63891
Toewang	TSEPHUG_KHAWAKHA	46	450063.73	16045.53474
Chhubu	YEBISA	107	1046887.36	37323.30908
Goenshari	ZHELNGOESA	32	313087.81	11162.11113
Barp	CHAGSA	4	39135.98	1395.26389
Barp	GAMAKHA_SEBTOKHA	168	1643711.00	58601.08341
Lingmukha	OOMTEKHA	80	782719.52	27905.27782
Barp	SOBSOKHA_YUWAKHA_ZHIKHA	82	802287.51	28602.90976
Barp	TSHOGKORNA	164	1604575.02	57205.81952
Barp	USAKHA	196	1917662.83	68367.93065

TSIRANG

GEOG	CHIWOG	HH_COUNT	Benefit Transfer	DCE
Barshong	BARSHONG MAED	49	479415.71	17091.98266
Barshong	BARSHONG TOED	7	68487.96	2441.71181
Rangthangling	CHARINGMA_RANGTHANGLING	10	97839.94	3488.15973
Barshong	CHUNYIKHANG	32	313087.81	11162.11113
Semjong	DEKIDLING	9	88055.95	3139.34375
Tsholingkhar	DROOBCHHUGANG	14	136975.92	4883.42362
Goseling	DZAMLING ZOR	40	391359.76	13952.63891
Rangthangling	GAGALING_NYIMAZOR	45	440279.73	15696.71877
Barshong	GANGTOGKHA	24	234815.86	8371.58334
Phutenchhu	GOENTEG-KHA_TONGSHINGGANG	41	401143.76	14301.45488
Tsholingkhar	GOMSOOM	55	538119.67	19184.87850
Tsirang toe	KABELZHING	55	538119.67	19184.87850
Tsholingkhar	KAPAZHING	29	283735.83	10115.66321
Sergithang	NORBOOGANG	77	753367.54	26858.82990
Phutenchhu	NORBUTHANG	46	450063.73	16045.53474
Phutenchhu	PELJORLING	59	577255.65	20580.14239
Mendrelgang	PEMASHONG_SAMSHING GADEN	6	58703.96	2092.89584
Goseling	PHUENSOOMGANG	7	68487.96	2441.71181
Sergithang	SEMDENJONG	41	401143.76	14301.45488
Sergithang	SERGITHANG MAED	62	606607.63	21626.59031
Sergithang	SERGITHANG TOED	34	332655.80	11859.74307
Phutenchhu	SERZHONG	25	244599.85	8720.39932
Tsirang toe	SOENTABSA	61	596823.64	21277.77433
Rangthangling	SOONKOSH	24	234815.86	8371.58334
Tsirang toe	TAGTHANG_WANGPHOO	59	577255.65	20580.14239
Phutenchhu	TASHICHHOELING	86	841423.49	29998.17365
Sergithang	TASHITHANG	86	841423.49	29998.17365
Barshong	TOED-SANG	32	313087.81	11162.11113
Tsirang toe	TONGSHINGNANG	6	58703.96	2092.89584
Tsholingkhar	TSHOLINGKHAR MAED	282	2759086.32	98366.10430
Tsholingkhar	TSHOLINGKHAR TOED	87	851207.48	30346.98962
Tsirang toe	TSIRANG TOED	80	782719.52	27905.27782

WANGDUEPHODRANG

GEOG	CHIWOG	HH_COUNT	Benefit Transfer	DCE
Rubesa	BANGTOEDKHA	157	1536087.07	54764.10771
Rubesa	BJAGPHOOG	26	254383.85	9069.21529
Gasetshogom	CHANGCHE_MATHSIGPOGTO	193	1888310.85	67321.48273
Gasetshogom	CHANGKHA	53	518551.68	18487.24655
Gasetshogom	DABCHHAYKHA_MATSHIGKHA	192	1878526.86	66972.66676
Thedtsho	DZONGKHAG THROMDE	122	1193647.27	42555.54867
Rubesa	GYALA	76	743583.55	26510.01392
Daga	GYAPAKHA	21	205463.88	7325.13543
Gasetsho Wom	HAEBISA	72	704447.57	25114.75003
Gasetsho Wom	HAETSHOKHA	20	195679.88	6976.31945
Athang	JAROGGANG_DZAWA	54	528335.68	18836.06253
Daga	KAMICHHU_UMA KHAMAED	86	841423.49	29998.17365
Daga	KAMINA WOGYAL	5	48919.97	1744.07986
Gasetshogom	KHAMAEDNA	39	381575.77	13603.82294
Gasetshogom	KHATOEDKHA	26	254383.85	9069.21529
Nahi	KHOORJOONGLA_LANGMIZI	7	68487.96	2441.71181
Phangyul	KOOMCHHI_PHANGYUEL	23	225031.86	8022.76737
Athang	LAWA_LAMGA	25	244599.85	8720.39932
Thedtsho	LHO RINCHHENGANG	143	1399111.15	49880.68410
Athang	LOMTSHOKHA	17	166327.90	5929.87154
Athang	LOPHOKHA_PHAGTAKHA	48	469631.71	16743.16669
Thedtsho	MARTALOONGCHU	37	362007.78	12906.19099
Gasetsho Wom	MEDPISA_TAABCHHAEKHA	37	362007.78	12906.19099
Rubesa	OOLA	37	362007.78	12906.19099
Athang	ROOKHA	45	440279.73	15696.71877
Gasetsho Wom	SHINGKHEY KHAMAED	50	489199.70	17440.79863
Daga	SILI_TAAGSHA	37	362007.78	12906.19099
Thedtsho	THANGOO	55	538119.67	19184.87850
Thedtsho	TSHOGKORNA	2	19567.99	697.63195
Daga	UMA KHATOED	45	440279.73	15696.71877
Thedtsho	WANGJOKHA	43	420711.74	14999.08683
Rubesa	ZAMDING	2	19567.99	697.63195

MANGDECHHU BASIN

TRONGSA

Geog	CHIWOG	HH_COUNT	Benefit Transfer	DCE
Dragten	KUENGA RABTEN	159	1555655.05	55461.73966
Dragten	SAMLING KHAMAED	146	1428463.13	50927.13201
Dragten	SAMLING KHATOED	88	860991.48	30695.80560
Dragten	TAGTSE_TASHIDINGKHA	113	1105591.33	39416.20491
Dragten	UESAR	33	322871.80	11510.92710
Korphu	KORPHOOG MAED	75	733799.55	26161.19795
Korphu	KORPHOOG TOED	29	283735.83	10115.66321
Korphu	NABI	92	900127.45	32091.06949

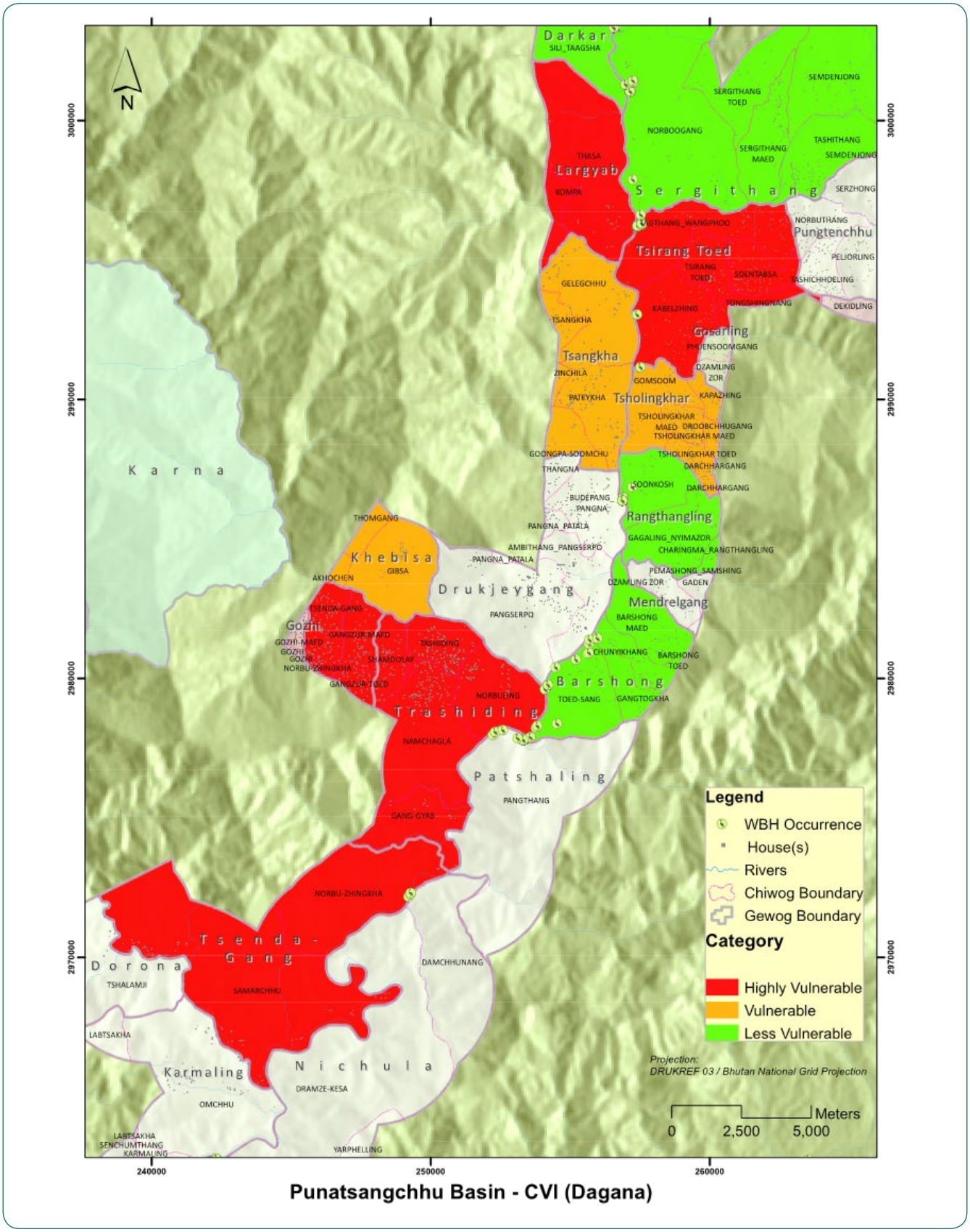
Korphu	NYIMZHONG MAED	101	988183.40	35230.41324
Korphu	NYIMZHONG TOED	46	450063.73	16045.53474
Langthe	BALING	120	1174079.29	41857.91672
Langthe	DANGDOONG	172	1682846.98	59996.34730
Langthe	JANGBI	44	430495.74	15347.90280
Langthe	LANGTHIL	109	1066455.35	38020.94102
Langthe	YUEDROONGCHHOELING	199	1947014.82	69414.37857
Nubi	BAGOCHEN_BOOLINGPANG_UELING	36	352223.79	12557.37502
Nubi	BJI_SENGM-BJI	6	58703.96	2092.89584
Tangsibji	KELA	74	724015.56	25812.38198
Tangsibji	NYALA DRANGLA	10	97839.94	3488.15973
Tangsibji	TANGSIBJI	163	1594791.03	56857.00355
Tangsibji	TSHANGKHA	55	538119.67	19184.87850

ZHEMGANG

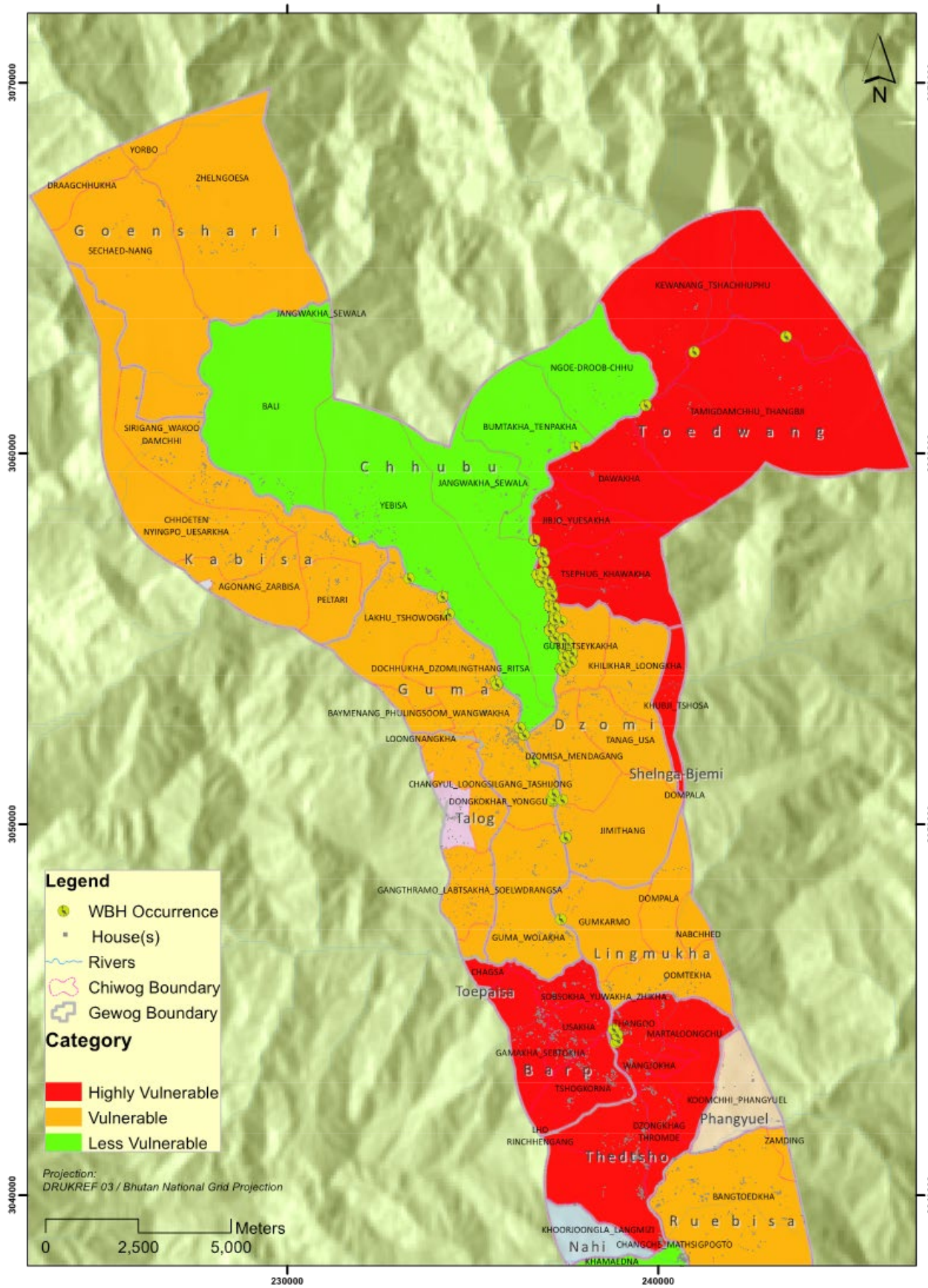
Geog	CHIWOG	HH_COUNT	Benefit Transfer	DCE
Bardo	DIGALA	64	626175.62	22324.22225
Goshing	BUDHASHI	82	802287.51	28602.90976
Goshing	LAMTHANG	58	567471.66	20231.32642
Goshing	LICHIBI	45	440279.73	15696.71877
Goshing	LINGMAPONG_SAMCHHOELING	104	1017535.38	36276.86116
Nangkhor	BULI	7	68487.96	2441.71181
Nangkhor	DAKPHEL_TALI	27	264167.84	9418.03126
Nangkhor	DUENMANG	83	812071.51	28951.72573
Nangkhor	GOLENG	102	997967.39	35579.22922
Nangkhor	NYAKHA	97	949047.42	33835.14935
Ngangla	MARANGDUED	81	792503.52	28254.09379
Ngangla	PANBANG_SONAMTHANG	289	2827574.28	100807.81611
Ngangla	RIBATI	82	802287.51	28602.90976
Pangkhar	MAMONG TRONG_PANTANG	85	831639.49	29649.35768
Goshing	BUDHASHI	1	9783.99	348.81597
Phangkhar	CHAG-NGAR-ZAM	10	97839.94	3488.15973
Phangkhar	PANABI	37	362007.78	12906.19099
Phangkhar	SHALINGTOED_TASHIBI	68	665311.60	23719.48614
Trong	BERTI_TAGMA	235	2299238.60	81971.75358
Nangkhor	DAKPHEL_TALI	3	29351.98	1046.44792
Trong	DANGKHAR_TRONG	170	1663278.99	59298.71536
Nangkhor	GOLENG	13	127191.92	4534.60765
Trong	GONGPHU	133	1301271.21	46392.52437
Trong	SOOBDRANG	10	97839.94	3488.15973
Trong	TSHANGLAJONG_ZURPHEL	83	812071.51	28951.72573

Appendices 3: Climate change vulnerability assessment

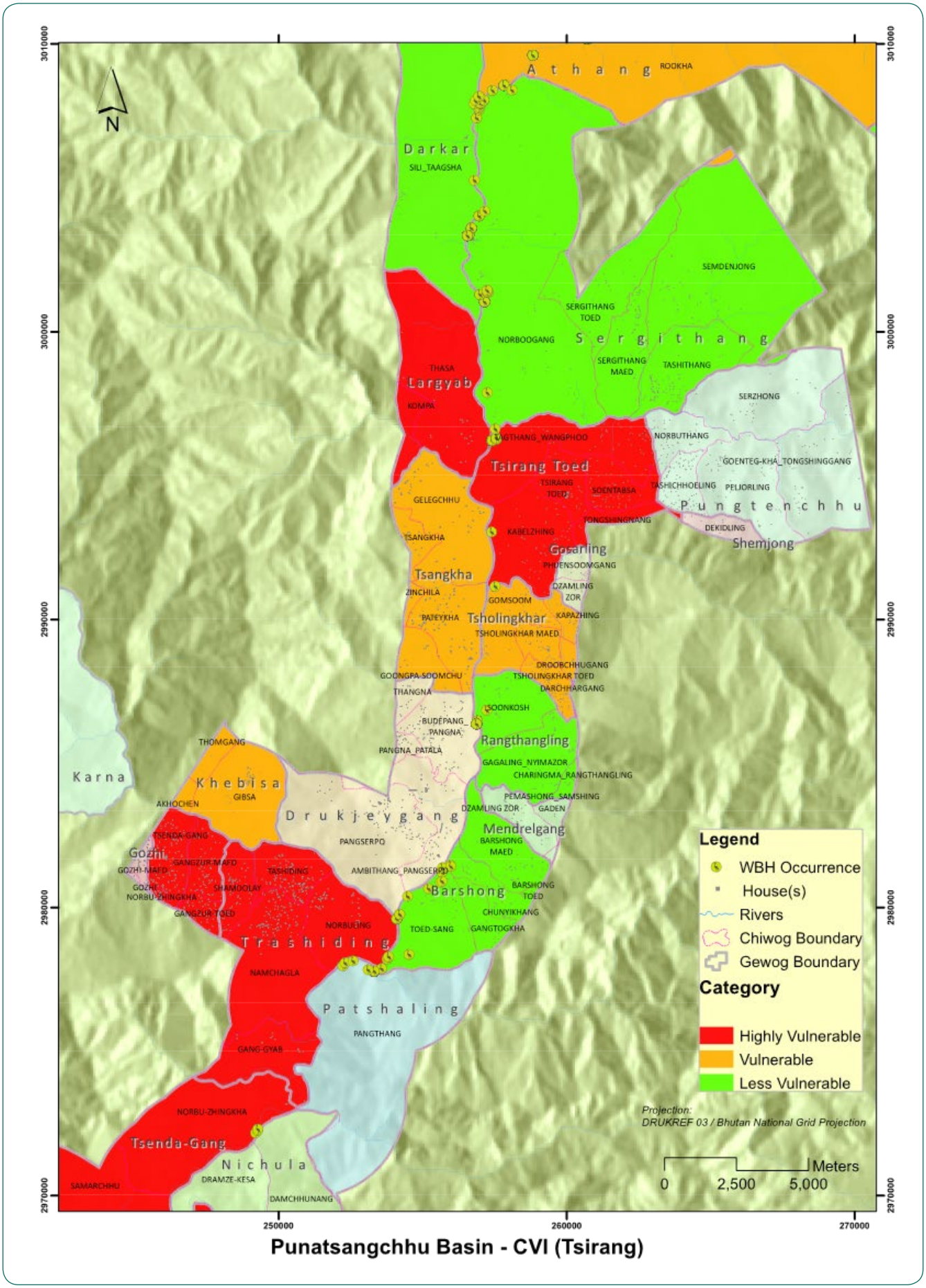
Appendix 3.1: District wise maps overlaying highly vulnerable Gewogs (Highly vulnerable - shaded red; Vulnerable – shaded yellow) with WBH sitings.



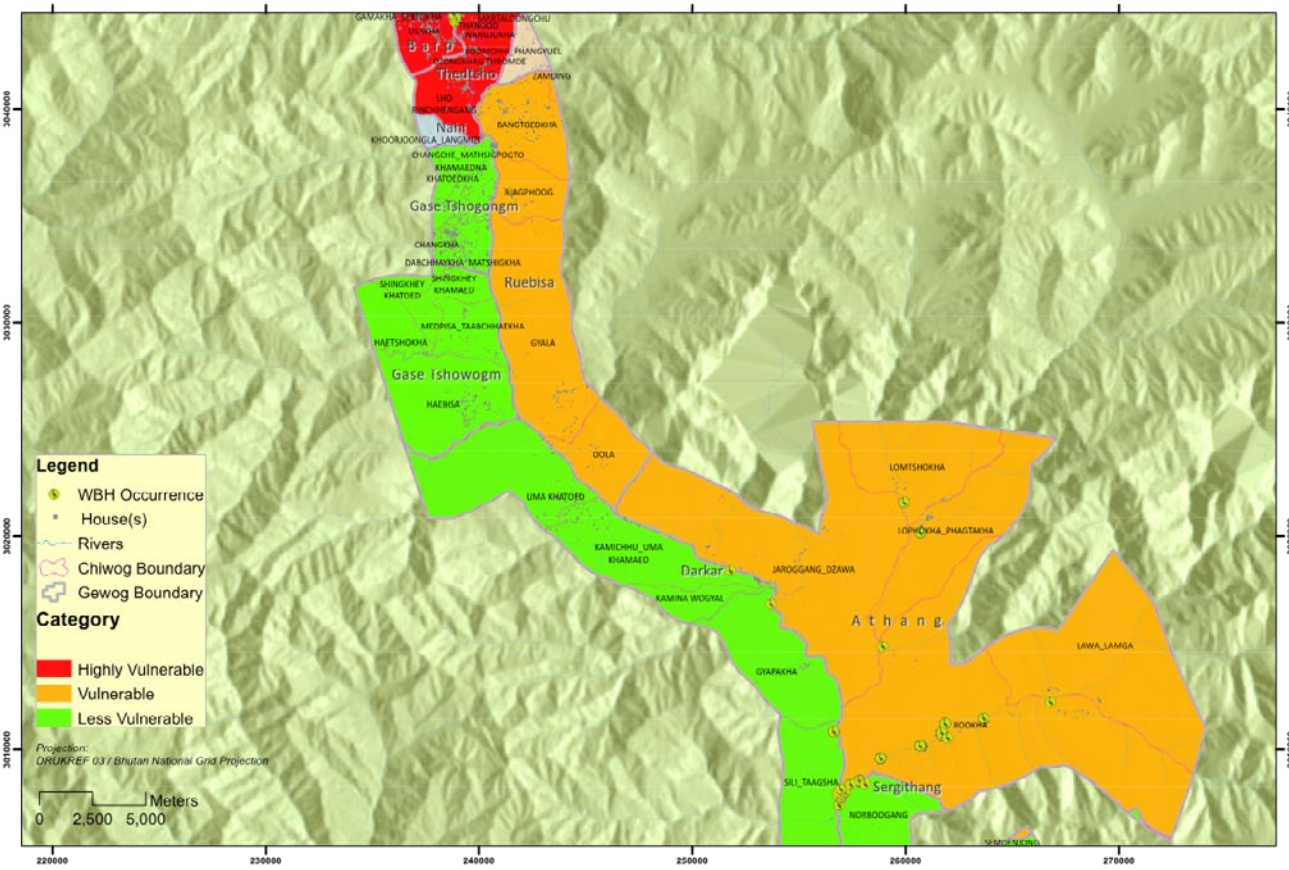
Punatsangchhu Basin - CVI (Dagana)



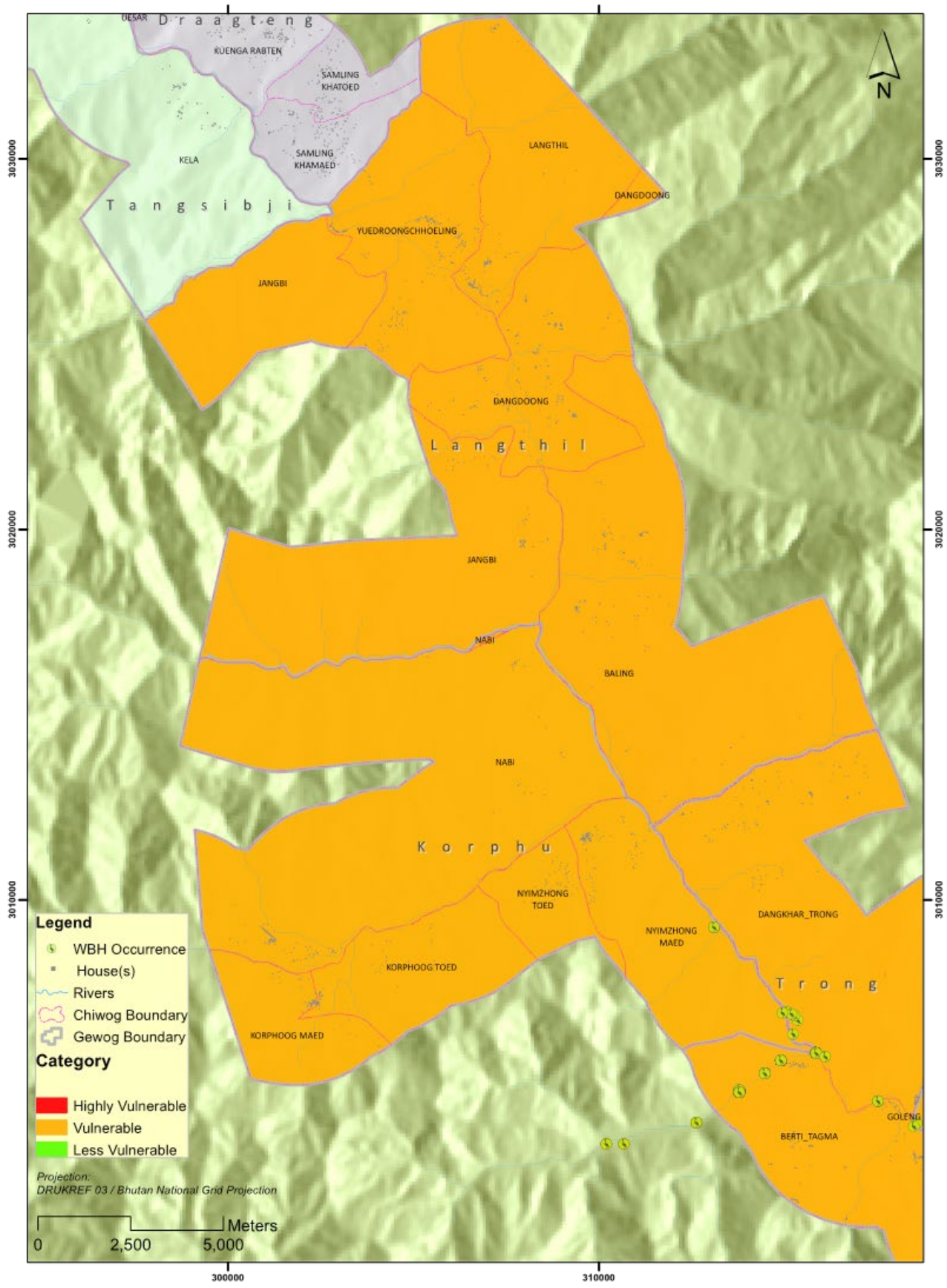
Punatsangchhu Basin - CVI (Punakha)



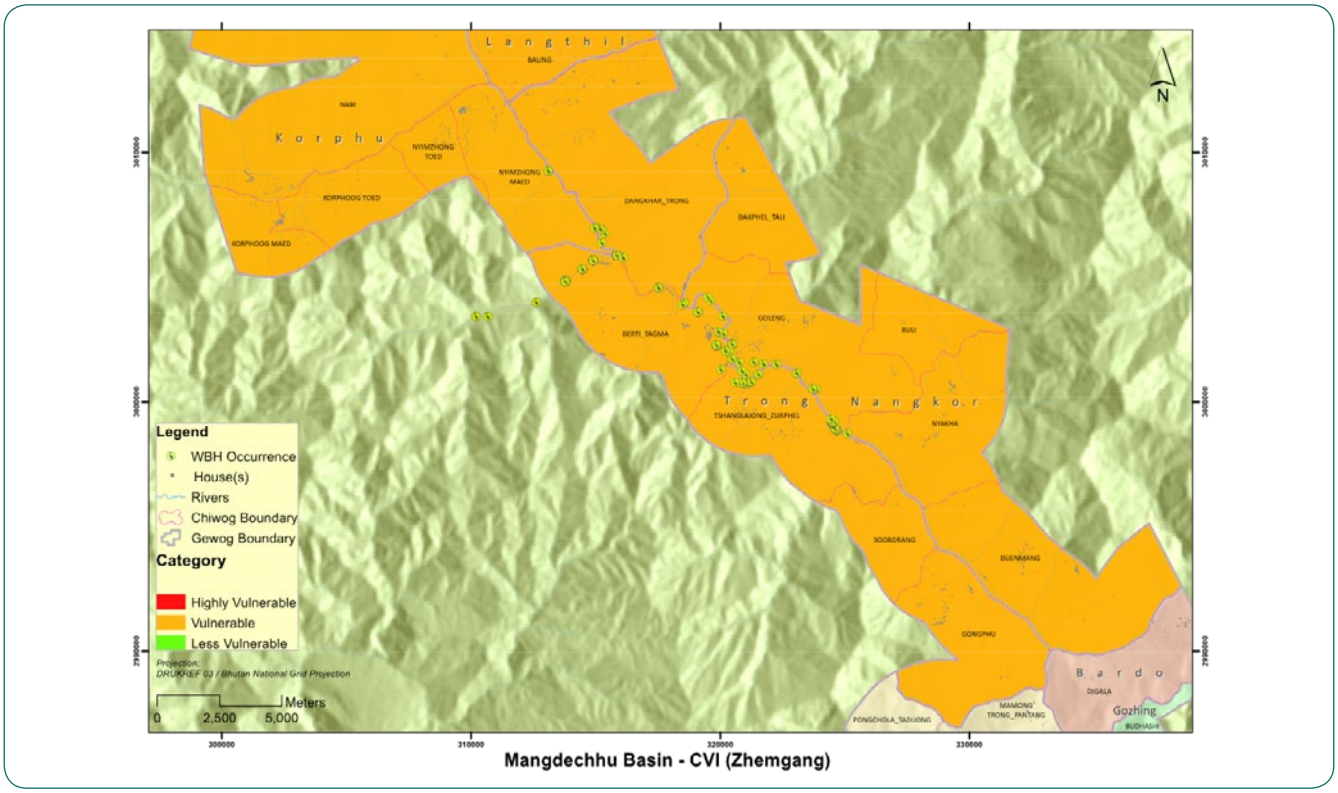
Punatsangchhu Basin - CVI (Tsirang)



Punatsangchhu Basin - CVI (Wangdue Phodrang)



Mangdechhu Basin - CVI (Trongsa)



Mangdechhu Basin - CVI (Zhemgang)

Appendix 3.2: HWC challenged Chiwogs under 'highly vulnerable' and 'vulnerable' Gewogs in WBH habitat areas (by District)

DAGANA	
GEWOG	**CHIWOG**
Tashiding	Norbuling
Tsendagang	Gangzor
Tsendagang	Lower Gangzor
Tsendagang	Lower Tsendang
Tsendagang	Tsendagang
Tsangkha	Galeychu
Tsangkha	Salambji
Tsangkha	Tshangkha
Laja	Thasa
Kana	Chinathang
Kana	Gewthang
Kana	Khagochi
Kana	Laling
Kana	Nindhukh
Kana	Tanabji
Khebisa	Pogto
Khebisa	Gumla

PUNAKHA	
GEWOG	**CHIWOG**
Barp	Barp
Barp	Chagsa
Barp	Chimipang
Barp	Eutshokh
Barp	Gamakha
Barp	Mesina
Barp	Sobsokha
Barp	Tshogkor
Barp	Tshokorn
Dzome	Changjok
Dzome	Dzombesa
Dzome	Dzome
Dzome	Dzomisa
Dzome	Gubji Ts
Dzome	Jemithan
Dzome	Jubji
Dzome	Khilikho
Dzome	Lukha
Dzome	Tana
Dzome	Tshekha

GEWOG	**CHIWOG**
Shelnga-Bjemi	Khubji
Shelnga-Bjemi	Tshosa
Talog	Dangkhok
Talog	Dongkokh
Talog	Gangthra
Talog	Labtsakha
Talog	Yungu-Do
Toedwang	Bjijokha
Toedwang	Damwom
Toedwang	Khawajar
Toedwang	Nyakha
Toedwang	Sambaykha
Toedwang	Samdingkha
Toedwang	Samdingkha
Toedwang	Tshephu
Toedwang	Tama Dam
Toedwang	Thambjee
Toedwang	Toed Wang
Toedwang	Tsachhuphu
Toedwang	Tsephu
Toedwang	Tsiphuja

TSIRANG	
GEWOG	CHIWOG
Tsirangtoe	Kapazhing
Rangthaling	Sunkosh
Tsholingkhar	Tsholing
Tsholingkhar	Kapasay

WANGDUEPHODRANG	
GEWOG	CHIWOG
Athang	Ada
Athang	Jarigang
Athang	Lamga
Athang	Lawa
Athang	Lawa Lam
Athang	Lhangba
Athang	Lhobakha
Athang	Lophukha
Athang	Miktona
Athang	Rukha

GEWOG	CHIWOG
Athang	Rukha-Sa
Athang	Zawa
Rukha	Thangna
Thedtsho	Matalong
Thedtsho	Thango
Tshedtsho	Thedtsho
Thedtsho	Thragom
Tshedtsho	Tshedtsh
Thedtsho	Wanjuhuk

ZHEMGANG	
GEWOG	CHIWOG
Trong	Berti
Trong	Dangkar
Trong	Takabi
Trong	Tama Berti
Trong	Tangkhar
Trong	Tingtibi
Trong	Trong
Trong	Tshangla
Trong	Wangdigang
Trong	Zurphel

TRONGSA	
GEWOG	CHIWOG
Korphu	Nimshong
Langthil	Dangdung
Langthil	Ngormey
Nangkhor	Goling
Nangkhor	Wangdar

Appendix 3.3: Chiwogs faced with drinking water and irrigation issues in WBH habitat areas that fall under 'highly vulnerable' and 'vulnerable' Gewogs (by District)

		DAGANA							DAGANA					
		KHEBISA GEWOG		TSANGKHA GEWOG					KANA GEWOG					
		Pogto	Gumla	Babithang	Galeychu	Pedakha	Salambji	Sunkosh	Chinathang	Gewthang	Khagochi	Laling	Nindhukh	Tanabji
Drinking water problem in the last 12 months	Yes	2	2	3	4	4	8	1	7	0	0	0	0	2
	No	0	0	0	0	0	0	0	0	2	2	10	5	2
Irrigation water problem in the last 12 months	Yes	2	2	3	4	4	8	1	0	2	2	6	0	0
	No	0	0	0	0	0	0	0	7	0	0	4	5	3
Consistent water supply	Yes	2	2	0	0	0	0	0	1	2	2	9	3	2
	No	0	0	3	4	4	8	1	6	0	0	1	2	2
House with piped drinking water	Yes	2	2	3	4	4	8	1	7	2	2	8	5	4
	No	0	0	0	0	0	0	0	0	0	0	2	0	0
Water quantity has decreased in the last 10 years	Yes	2	2	1	3	2	6	1	4	1	0	4	5	1
	No	0	0	2	1	2	2	0	3	1	2	6	0	2
Did the house-hold observe drying up of spring water	Yes	2	2	0	0	0	0	0	7	2	2	10	5	4
	No	0	0	3	4	4	8	1	0	0	0	0	0	0

		PUNAKHA											
		BARP GEWOG										SHELNGA BJEMI GEWOG	
		Barp	Chagsa	Chimipang	Eutshokh	Gamakha	Mesina	Sibjikha	Sobsokha	Tshogkor	Tshokorn	Khubji	Tshosa
Drinking water problem in the last 12 months	Yes	4	10	3	11	5	3	1	10	8	8	0	2
	No	0	0	0	8	0	0	0	0	0	0	3	2
Irrigation water problem in the last 12 months	Yes	4	7	0	32	5	3	1	10	4	0	0	1
	No	0	3	3	5	0	0	0	0	4	8	3	3
Consistent water supply	Yes	1	1	0	18	0	0	0	0	4	1	3	1
	No	3	9	3	21	5	3	1	10	4	7	0	3
House with piped drinking water	Yes	3	9	3	39	5	3	1	10	7	8	3	4
	No	1	1	0	0	0	0	0	0	1	0	0	0
Water quantity has decreased in the last 10 years	Yes	2	7	1	27	5	2	0	7	6	6	2	2
	No	2	3	2	11	0	1	1	3	2	2	1	2
Did the household observe drying up of spring water	Yes	4	10	3	39	5	3	1	10	8	8	3	4
	No	0	0	0	0	0	0	0	0	0	0	0	0

		PUNAKHA														
		TOEDWANG GEWOG														
		Tshephu	Samdingkha	Bjijokha	Damwom	Jibjo Eu	Khawajar	Nyakha	Sambaykha	Samdingkha	Tama Dam	Thambjee	Toed Wang	Tshachhuphu	Tsephu	Tsiphuja
Drinking water problem in the last 12 months	Yes	2	1	5	1	1	5	0	0	0	0	0	0	0	0	0
	No	0	0	0	0	0	2	1	1	3	11	20	5	9	13	1
Irrigation water problem in the last 12 months	Yes	0	1	0	0	0	0	1	1	3	11	5	0	0	0	0
	No	2	0	5	1	1	5	0	0	0	0	15	5	9	13	1
Consistent water supply	Yes	0	0	5	1	0	1	0	1	3	10	15	5	9	13	1
	No	2	1	0	0	1	5	0	0	0	1	5	0	0	0	0
House with piped drinking water	Yes	2	1	4	1	1	7	1	0	3	10	20	5	9	13	0
	No	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0
Water quantity has decreased in the last 10 years	Yes	2	0	3	0	0	5	0	1	1	6	5	1	0	2	0
	No	0	1	2	1	1	1	1	0	2	5	14	4	9	11	1
Did the household observe drying up of spring water	Yes	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	No	0	0	5	1	1	7	1	1	3	11	20	5	9	13	1

		PUNAKHA														
		DZOME GEWOG										TALOG GEWOG				
		Changjok	Dzomesa	Dzome	Gubji Ts	Jemithan	Jubji	Khilikho	Lukha	Tana	Tshekha	Dangkhok	Dongkokh	Gangthra	Labtsakha	Yungu-Do
Drinking water problem in the last 12 months	Yes	1	7	6	2	20	2	4	14	6	10	4	8	0	11	0
	No	0	12	33	9	0	0	0	0	0	0	0	6	1	10	2
Irrigation water problem in the last 12 months	Yes	0	0	23	1	20	2	4	14	5	0	3	8	0	12	2
	No	1	19	16	9	0	0	0	0	1	10	1	6	0	9	0
Consistent water supply	Yes	0	12	24	2	15	0	0	0	1	4	1	7	1	12	1
	No	1	7	15	9	5	2	4	14	5	6	3	7	0	9	1
House with piped drinking water	Yes	1	19	39	11	20	2	4	12	6	9	3	14	1	21	2
	No	0	0	0	0	0	0	0	2	0	1	1	0	0	0	0
Water quantity has decreased in the last 10 years	Yes	1	10	29	3	14	2	3	12	5	9	3	6	1	12	1
	No	0	9	10	8	6	0	1	2	1	1	1	8	0	9	1
Did the household observe drying up of spring water	Yes	1	19	39	11	20	2	4	14	6	10	4	14	1	17	0
	No	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2

		WANGDUEPHODRANG								
		THEDTSHO GEWOG								
		Bajothang	Matalong	Rincheng	Thango	Thedtsho	Thragom	Tshedtsh	Wanjukha	TOTAL
Drinking water problem in the last 12 months	Yes	0	3	10	6	2	1	5	4	31
	No	1	8	0	0	0	0	0	0	9
Irrigation water problem in the last 12 months	Yes	0	0	9	6	2	1	5	1	24
	No	1	8	0	0	0	0	0	3	12
Consistent water supply	Yes	1	5	9	3	0	0	1	4	23
	No	0	6	1	3	2	1	4	0	17
House with piped drinking water	Yes	1	10	10	5	2	1	4	4	37
	No	0	1	0	1	0	0	1	0	3
Water quantity has decreased in the last 10 years	Yes	1	8	5	3	2	1	1	1	22
	No	0	3	5	3	0	0	4	2	17
Did the household observe drying up of spring water	Yes	0	0	0	0	0	0	0	0	0
	No	1	11	10	6	2	1	5	4	40

		TSIRANG		
		TSHOLINGKHAR GEWOG		
		Kapasay	Gomsoom	Tsholing
Drinking water problem in the last 12 months	Yes	6	14	4
	No	0	0	0
Irrigation water problem in the last 12 months	Yes	6	14	4
	No	0	0	0
Consistent water supply	Yes	4	0	0
	No	2	14	4
House with piped drinking water	Yes	6	14	4
	No	0	0	0
Water quantity has decreased in the last 10 years	Yes	5	10	4
	No	1	3	0
Did the household observe drying up of spring water	Yes	6	0	0
	No	0	14	4

		WANGDUEPHODRANG												
		ATHANG GEWOG												
		Ada	Jarigang	Lamga	Lawa	Lawa Lam	Lhangba	Lhobakha	Lophukha	Miktona	Rukha	Rukha-Sa	Rukha (Thangna)	Zawa
Drinking water problem in the last 12 months	Yes	0	5	4	1	0	1	2	5	0	2	2	1	6
	No	0	4	0	4	1	0	0	5	1	21	0	0	2
Irrigation water problem in the last 12 months	Yes	0	1	0	0	0	1	2	6	1	10	0	1	7
	No	0	6	4	4	1	0	0	3	0	13	2	0	0
Consistent water supply	Yes	3	3	1	2	6	1	2	5	1	18	0	0	5
	No	0	6	3	3	1	1	0	5	0	5	2	1	3
House with piped drinking water	Yes	0	4	0	0	12	1	2	10	1	23	2	1	6
	No	0	0	0	0	1	0	0	0	0	0	0	0	1
Water quantity has decreased in the last 10 years	Yes	0	2	0	0	3	1	2	7	1	9	2	1	3
	No	0	1	0	0	3	1	0	2	0	13	0	0	4
Did the household observe drying up of spring water	Yes	0	4	0	0	0	0	0	0	0	2	2	0	8
	No	0	3	4	5	1	0	0	0	0	0	0	1	0

		TRONGSA		
		KORPHU	LANGHIL GEWOG	
		Nimshong	Dangdung	Ngormey
Drinking water problem in the last 12 months	Yes	2	17	0
	No	0	6	1
Irrigation water problem in the last 12 months	Yes	2	19	0
	No	0	4	1
Consistent water supply	Yes	0	5	1
	No	2	18	0
House with piped drinking water	Yes	2	23	1
	No	0	0	0
Water quantity has decreased in the last 10 years	Yes	2	17	1
	No	0	5	0
Did the household observe drying up of spring water	Yes	2	23	1
	No	0	0	0

		ZHEMGANG												
		NANGKHOR GEWOG			TRONG GEWOG									
		Goling	Wangdar	TOTAL	Berti	Dangkar	Takabi	Tama Berti	Tangkhar	Tingtibi	Trong	Tshangla	Wangdigang	Zurphel
Drinking water problem in the last 12 months	Yes	20	0	20	5	8	2	28	2	7	3	27	1	7
	No	12	2	14	15	0	0	0	0	0	0	0	0	0
Irrigation water problem in the last 12 months	Yes	20	0	20	0	4	2	28	2	7	3	27	1	7
	No	12	2	14	15	2	0	0	0	0	0	0	0	0
Consistent water supply	Yes	19	2	21	8	5	2	28	2	7	3	0	0	0
	No	13	0	13	12	3	0	0	0	0	0	27	1	7
House with piped drinking water	Yes	31	2	33	19	8	2	27	2	6	2	26	1	7
	No	1	0	1	0	0	0	1	0	1	1	1	0	0
Water quantity has decreased in the last 10 years	Yes	18	1	19	3	7	1	25	1	4	2	24	1	4
	No	13	1	14	17	1	1	3	1	3	1	3	0	3
Did the household observe drying up of spring water	Yes	32	2	34	0	0	0	0	0	0	0	0	0	0
	No	0	0	0	20	8	2	28	2	7	3	27	1	7

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