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Ecosystem and Socio-economic Resilience Analysis and Mapping (ESRAM)

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Developing Ecosystem-based Solutions for Managing Biodiversity Landscapes in Bhutan

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The project focuses on developing ecosystem-based solutions for managing biodiversity landscapes, with a special focus on establishing approaches and tools for protecting and managing White-bellied Heron (WBH) habitats along Punatsangchhu and Mangdechhu basins in Bhutan.

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01 INTRODUCTION

1.1 About the ESRAM Manual

This Ecosystem and Socio-economic Resilience Analysis and Mapping (ESRAM) manual is intended to serve as a handbook of the Royal Society for Protection of Nature (RSPN) for designing and implementing Ecosystem based Adaptation (EbA) interventions in its programme/ project areas in Bhutan. EbA is a concept that encompass approaches to address the threats to ecosystems and ecosystem services from unsustainable development practices aggravated further by climate change. With global efforts falling short of the mitigation measures required to bring climate change under control, adaptation has become a major global challenge as people, livelihoods, and ecosystems become more vulnerable to the adverse effects of climate change. Adaptation by enhancing resilience or addressing the vulnerability of communities, livelihoods and ecosystems is therefore a key component of global responses to climate change. The Paris Agreement calls for countries to integrate adaptation into relevant socioeconomic and environmental policies and actions (UN, 2015).[1] The concept of EbA is widely recognized and embraced by countries to respond to this call.

ESRAM is essentially a part of the EbA process. A good understanding of the concept of EbA is, therefore, a prerequisite for a better understanding and application of ESRAM. With this understanding of ESRAM as a terminology associated with the EbA process, this manual covers the following aspects of EbA:

- Social-ecological Systems and context of human livelihoods and ecosystems vulnerability to climate change
- EbA framework and associated concepts and theories
- ESRAM, its components and processes
- Assessment methods and protocols

Within the context of the overall EbA framework, the manual focuses on the widely accepted approaches and processes leading up to identification and design of EbA interventions. The manual begins with an introduction to human livelihoods and ecosystems vulnerability to climate change. Chapter 2 focuses on EbA framework and associated concepts and theories. Chapter 3 deals with those components of EbA ESRAM components and processes. The subsequent chapters 4, 5, 6, and 7 deal with assessment methodologies associated with each of the components of ESRAM. The methodologies and protocols adopted in the first ESRAM exercise fielded by RSPN under its project 'Developing ecosystem-based solutions for managing biodiversity landscapes in Bhutan'.

1 See Article 7.2 and 7.5 of Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T.I.A.S. No. 16-1104.

The users of the manual must be cognizant of the availability of various approaches, methods, and protocols for assessing the geophysical, environmental, and socio-economic conditions of an area. Considering that these methodologies and approaches are constantly evolving and being updated, the manual will need to be updated and improved upon to suit the context and changing needs of the organization. Hence, the manual must be treated as a living document.

1.2 Context of livelihood and ecosystem vulnerability to climate change

Climate change has become the single most global issue with the potential of undermining life on earth. Over the years, the urgency to address the issue is increasingly evidenced in the impacts suffered by communities across the world. The world is at a point in time when our uncontrolled pursuit of economic development is threatening our own survival. The intergovernmental panel on climate change (IPCC) has clearly stated that humans are at the core of the causes of climate change. Global GHG emissions growth for the decade 2000-2010 was reported to be larger than in the past decades. The impacts are evident and manifesting across the globe in the form of glacial melt, sea level rise, and extreme events such as cyclones hurricanes and floods. It is projected that continued GHG emissions will cause further warming and changes in the climate system resulting in further shrinking of Arctic ice, decrease in glaciers, and sea level rise (AR5, IPCC). This in turn will lead to changes in the geophysical, biophysical, and socio-economic systems. The vulnerabilities and risks associated with such changes come in the form of food and water shortages, increased poverty, increased displacement of people, and flooding. While this demands the attention of the policymakers around the world, actions are also required at the local level to combat climate change through mitigation and adaptation (IPCC, 2014).

The evidence of vulnerability and adaptation to climate change is most prevalent in places where warming has been the greatest and in systems that are more sensitive to temperature (IPCC, 2007). The Hindu Kush Himalayas (HKH) is one such region characterized by some of the most ecologically sensitive and fragile areas in the world. Under business as usual, climate change in this region is projected to be more pronounced. The region is expected to continue warming in the 21st century at a level greater than the global average. Precipitation in the region is also projected to increase under both RCP4.5 and RCP8.5 scenarios. Scientists have warned that under persisting climate change, the HKH region will have to face serious and far-reaching consequence especially the climate-dependent sectors such as agriculture, water resources, and health (Wester, P et al. 2019).

Being located in the eastern part of the HKH, Bhutan remains vulnerable to the changing climate situation. With 60% of its population still engaged in subsistence agriculture, dependency on ecosystem services remains significant. Communities avail numerous ecosystem services of which water for irrigation and drinking, timber for house construction, fuelwood for cooking and heating, medicines, and non-timber forest products are directly derived from the natural environment and forests. Food security and self-sufficiency being a national priority, one can only expect this dependency on ecosystem services to grow over time.

Although Bhutan is championing climate mitigation through consistent efforts to conserve and protect the rich biodiversity and natural resources, both its ecosystems and communities remain vulnerable to the global changes in the climate system. As Bhutan is already a net carbon sink economy, the scope for mitigation is limited to upholding the integrity of existing ecosystems. Priority must therefore be accorded to adaptation, which entails designing and implementing adaptation strategies based on the sustained use of biodiversity and ecosystem services thereby helping communities adapt to climate change. This approach to identification and implementation of development interventions that harness the potential of ecosystem services to cope with and adapt to climate change is captured in the concept of Ecosystem-based Adaptation (EbA).

1.3 Ecosystem-based Adaptation to Climate Change (EbA)

From the earlier section, it is clear that climate change and its impacts have a direct and indirect effect on ecosystems, which in turn affect the level of ecosystem services necessary for people and communities to sustain their livelihoods. Healthy ecosystems, on the other hand, are the foundation for sustainable livelihoods and the well-being of human communities across the world. Biodiversity & Ecosystem services are the foundations of sustainable life on earth. Mountain ecosystems, in particular are recognized to be even more significant for the variety of ecosystem goods and services they provide not just to mountain residents but also to people living downstream. These ecosystems have constantly been exposed to threats from unsustainable development practices that have resulted in deforestation, degradation of natural ecosystems and declining ecosystem services. Rising temperature and changing rainfall patterns further induce extreme weather events like droughts, water stresses, and floods. The resulting destruction to ecosystems and degraded ecosystem services affects communities and the livelihoods of the people.

Ecosystem-based Adaptation (EbA) is a nature-based solution that harnesses biodiversity and ecosystem services to reduce vulnerability and build resilience to climate change. EbA interventions play an important role in delivering services that help people cope with and adapt to the adverse effects of climate change. EbA helps by providing critical ecosystem services to local communities, helping species adapt to a rapidly changing climate, and maintaining the resilience of ecosystems.

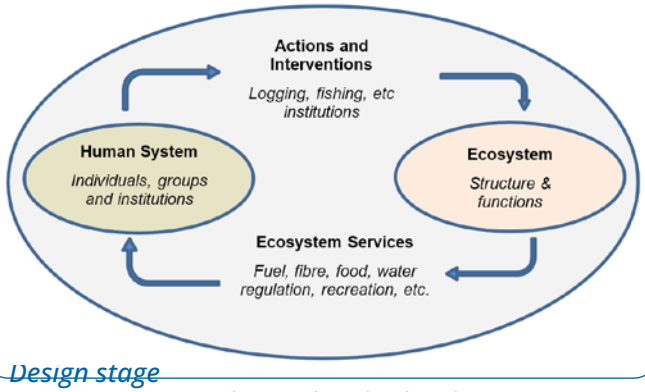
The concept of EbA was first coined by the International Union for Conservation of Nature (IUCN) and its member institutions at the UN Climate Change Convention Conference in 2008 and officially defined at the UN Convention on Biological Diversity Conference in 2009 as the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change (CBD, 2009). Since then, this approach has been adopted and implemented by intergovernmental organizations, governments, and regional and research institutions. These local, national and regional initiatives, several undertaken in collaboration with NGOs, have demonstrated multiple

economic, environmental, social and cultural benefits by ensuring livelihood sustenance and food security, conservation of biodiversity, sustainable water management, and disaster risk reduction, among other benefits.[2]

Today, EbA is regarded as an overall adaptation strategy that takes into account the multiple social, economic, and cultural co-benefits for local communities, which is best achieved through the sustainable management, conservation, and restoration of ecosystems (UNDP, 2015). It is also referred to as an approach of planning and implementing climate change adaptation considering ecosystem services and its uses for human wellbeing (MEA, 2005). Preparation of EbA strategies entails assessment of how vulnerable ecosystems and communities are to climate change and its impacts and to develop interventions for adaptation and building resilience. This requires a good understanding of the bio-geophysical components as well as the human actors and institutions that interact with each other, which is best explained through the concept of Social-ecological systems (SES) pertaining to the landscape of interest.

1.4 Social-ecological systems

The concept of social-ecological systems (SES) is based on the premise that humans are part of and not separate from nature (Berkes. and Folke, 1998). An SES consists of the bio-geophysical unit and its associated social actors and institutions. The natural and environmental aspects of an area represent the ecological system and the inhabiting human communities and their livelihood strategies represent the social system. As illustrated in Figure 1.1 below, the social system represented by human activities and livelihood strategies can change the function and structure of ecosystems through the use of ecosystem goods and services. The interactions and feedback between them affect their ability to resist change.



» *Design stage*

Figure 1.1: *Elements of Social-Ecological System*

Source: https://saras-institute.org/social-ecological-systems/

Based on Assessing and Managing Resilience in Social Ecological Systems: Supplementary Notes to the Practitioners Workbook Vol 2 (Resilience Alliance, 2007)

2 Ref. UNFCCC https://unfccc.int/files/adaptation/application/pdf/nwp_cal_2012.pdf

From the above, it is clear the landscape in which humans and nature co-exist is an SES. The interactions and feedbacks between the social (the Human system) and the ecological system determine how resilient or vulnerable the SES is.

1.5 Resilience, Adaptive Capacity and Vulnerability

Resilience, adaptive capacity, and vulnerability (RACV) are three concepts used to explain how human and natural systems respond to perturbations and shocks such as climate change and its impacts on ecosystems and human livelihoods.

Resilience and vulnerability are concepts associated with describing the state of an SES in terms of its ability to absorb or withstand perturbations and other stressors. A system is resilient if it is able to absorb or withstand perturbations and other stressors such that it can continue functioning the same way it used to before the disturbance or shocks. On the other hand, a system is termed as vulnerable if exposure to disturbance and shocks leads to changes in its structure and functions. In other words, resilience and vulnerability are inversely related i.e., the more resilient a system is, the less vulnerable it is and vice-versa.

Resilience

» *Ecosystem resilience*

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 an 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; Standish et al, 2014).

According to Bene and Headey et al. (2016), resilience is a result of the combination of three capacities, each of them leading to different short-term responses, i) absorptive capacity leading to persistence, ii) adaptive capacity leading to incremental adjustments/ changes and adaptation, iii) transformative capacity leading to transformative response (See Figure 1.2).

» *Absorptive coping capacity*

Development agencies like Oxfam International (2017), define "absorptive capacity as the capacity to take intentional protective action and to cope with known shocks and stress. Simply stated this is the capacity to 'bounce back' after a shock. It involves anticipating, planning, coping and recovering from specific, known shocks and short term stresses. Absorptive capacity is about ensuring stability because it aims to prevent or limit the negative impact of shocks on individuals, households, communities, businesses and authorities".

» *Adaptive capacity*

Adaptive capacity refers to the conditions that "empower communities or individuals to anticipate and respond to changes, to reduce the consequences, to recover, as well as take advantage of new opportunities" by using the available capital such as financial, and social when in need (Grothmann and Patt, 2005; Hinkel, 2011).

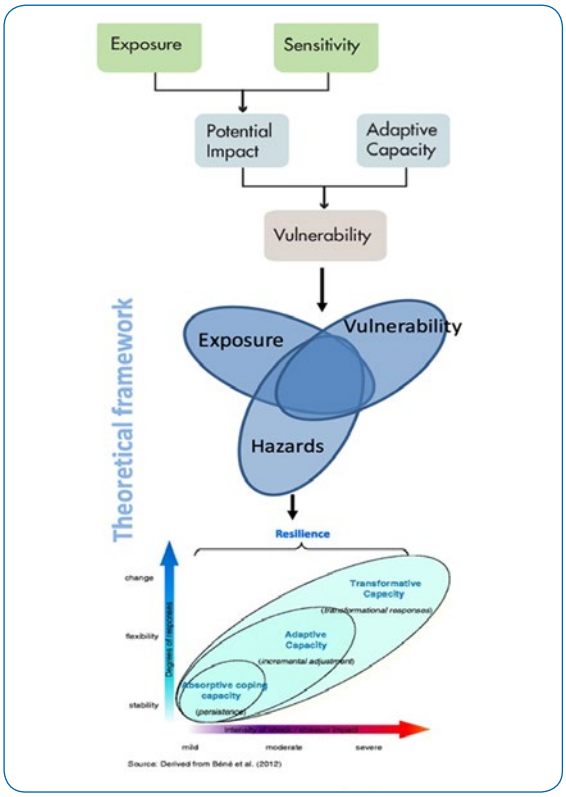


Figure 1.2: *Theoretical framework on resilience, adaptive capacity, and vulnerability*

Adaptive capacity is not simply about having the essential resources at hand, but also about the capacity to implement effectively for adaptation (Adger et al., 2011). Adaptive capacity is the capacity to make intentional incremental adjustments in anticipation of or in response to change, in ways that create more flexibility in the future. It is necessary because change is ongoing and uncertain, and because intentional transformation takes time and sustained engagement (Oxfam International, 2017). As per Cinner et al., (2018), Adaptive capacity can be implemented based on the five domains such as *"the assets that people can draw upon in times of need; the flexibility to change strategies; the ability to organize and act collectively; learning to recognize and respond to change; and the agency to determine whether to change or not."*

» *Transformative Capacity*

When the intensity of shocks and stressor impacts become severe, it may become necessary to bring about fundamental changes in the deep structures that cause or increase vulnerability and risk as well as how risk is shared within societies and the global community. This will require transformative capacity, which is defined as the *"capacity to make intentional change to stop or reduce the causes of risk, vulnerability, poverty, and inequality, and ensure the more equitable sharing of risk so it is not unfairly borne by people living in poverty or suffering from discrimination or marginalization. It is about addressing the underlying failures of development or power imbalances that cause or increase and maintain risk and poverty"* (Oxfam International, 2017).

Vulnerability

» *Ecosystem vulnerability*

Ecosystem vulnerability on the other hand may be understood as the state of susceptibility of an ecosystem to harm from exposure to stresses/ shocks associated with environmental and social change owing to inadequate adaptation capacities (Brooks, 2003). When assessing ecosystem vulnerability, one of the major components is ecosystem services.

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 benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza et al 1997)", and "...the benefits people obtain from ecosystems (MEA 2005)". 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 that are measured in terms of: (i) ecosystem type; (ii) ecosystem extent; (iii) ecosystem condition; and (iv) ecosystem services (Fisher et al 2007).

» *Socio-ecological vulnerability*

Socio-ecological vulnerability is derived from the exposure of households to livelihood stresses caused by both climatic and non-climatic factors, and their inadequate capacity to cope with or recover from the impacts or maintain the household and community wellbeing (Adger, 1999; Kelly & Adger, 2000). When a socio-ecosystem cannot cope with or recover from the impacts of a hazard or issue, the probability of systems becoming vulnerable increases (Folke et al., 2002).

In the context of climate change, the vulnerability of an SES is the stare of a specific landscape resulting from exposure and sensitivity to climate change; the socio-economic, ecological (ecosystem services) and also political outcome and their influence on ecosystems exacerbated by climate change; and the inadequate adaptive capacity of those systems to accommodate impacts of change.

Therefore, climate change vulnerability is an outcome of both external dimensions like shocks and perturbations to which a system is exposed, and internal dimensions like the inability to respond to and recover from external stressors (Gallopin, 2006).

The extent to which an SES is resilient or vulnerable to climate change depends on its capacity to adapt to the change which in turn is determined by i) the degree of its exposure to climate variation and ii) sensitivity i.e., the degree to which they could be harmed by that exposure.

Approaches to assessing resilience/ vulnerability

» *Ecological vulnerability assessment*

Ecological assessment and mapping provide the basic understanding of ecosystem goods and services where the ESs are categorized based on the definitions used by Fisher et al (2009). 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, which in turn affect the ecosystem goods and services. The status of the ESs can be assessed to determine local peoples' vulnerability to climate change. As climate change unfolds, the increasing impacts on local people will force them to increase dependency on the ecosystems, thereby driving ecosystem change. Similarly, the socio-economic status of local people may also affect the quality of ecosystems. Agriculture based communities are generally more dependent on ecosystem services the overharvesting of which may affect the quality of ecosystems.

According to Varis et al. (2019), ecological vulnerability can be assessed based on the focal species (White bellied herons for example) and other species in the ecosystems where structure and functions of ecosystems are to absorb change and adapt to changing environment.

» *Valuation of ecosystem services*

ESs are vital for human survival and that they are continuously modified for human need resulting in compromised wellbeing as well as habitats of wildlife (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).

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.

» *SES approach*

SES approach is a widely preferred approach to assessing climate change vulnerability considering that it recognizes that human and natural systems are intricately interconnected and looks at both the human system and natural ecosystems. This holistic and integrated approach has been found to be useful in assessing vulnerability/ resilience of river basins. Varis et. al. (2019) used SES approach to link ecological challenges of river basins to the capacity of the societies to cope with them. SES approach was used to relate three ecological vulnerability factors (human footprint, natural hazards, and water scarcity) with three adaptive capacity factors (governance, economy and human development. Berkes and Folke, (1998), and Turner et al. (2003) define SES approach as considering

the quantitative variables linking adaptation, vulnerability, and resilience (Adger, 2006; Gallopín, 2006; Janssen and Ostrom, 2006).

EbA Processes

Enhancing ecosystem resilience is crucial to upholding ecosystem integrity which would protect from physical exposure and reduce disaster risks from climate change impacts. However, sometimes the ecosystem resilience may be counterproductive in terms of the adverse socio-economic impacts. Ecosystem-based Adaptation (EbA) approaches focus on assessing SES to identify and implement interventions that are ecologically and socio-economically favorable.

Translating the EbA concept into ground level interventions and actions involves three main stages and five main steps as outlined in Table 1.1 below:

Table 1.1: *Stages and steps in EbA process*

Stages		Steps	
1	Design EbA	1	Define Climate threats and target people
		2	Designing and adoption of field assessment protocols
		3	Assess vulnerabilities
		4	Define and prioritize EbA Strategy and adaptation options
2	Implementation	5	Implement selected EbA interventions
3	Monitoring and Evaluation	6	Monitor and Evaluate EbA interventions

It is the first necessary stage in the process of designing EbA strategies. This requires a good understanding of the existing biophysical environment, social and economic status of the area to reflect on the ecosystem and community vulnerabilities to climate change. EbA interventions are formulated based on the logic that removing ecosystem and habitat degradation stressors would result in healthier ecosystems, which in turn are less vulnerable or more resilient to adverse effects of climate change. Healthier ecosystems are also able to provide reliable ecosystem services, which are essential livelihood sources for people and communities.

» *Implementation stage*

Once the EbA strategies and interventions are formulated and prioritized, the strategy is implemented in the target landscape area.

» *Monitoring and Evaluation*

A monitoring and evaluation system should be put in place to gauge the effectiveness of the interventions in adapting to climate change. This process allows for implementers to learn from the experiences of what works and to continually adapt their approach and interventions to manage unforeseen elements of the project and uncertainties associated with climate change.

Overall, EbAs are cost effective solutions to deal with climate change through integrated ecosystem and community based natural resource management. EbA interventions must therefore promote conservation, equitable sustainable use by optimizing benefits from mitigation and adaptation by i) allowing natural ecosystem processes to unfold, ii) preventing damages to ecosystem (deforestation, land clearing, pollution) and iii) restoring degraded ecosystems[3]

For further details, refer to the following online resources:

- https://unfccc.int/sites/default/files/resource/EbA_NAP.pdf
- https://www.iucn.org/resources/issues-briefs/ecosystem-based-adaptation
- https://www.adaptationcommunity.net/ecosystem-based-adaptation/
- https://www.unep.org/explore-topics/climate-action/what-we-do/climate-adaptation/ecosystem-based-adaptation
- https://friendsofeba.com/what-is-ecosystem-based-adaptation-eba/
- https://www.iied.org/ecosystem-based-approaches-climate-change-adaptation
- https://globalebafund.org/about/what-is-eba/

3 https://www.iucn.org/resources/issues-briefs/ecosystem-based-adaptation

02 ECOSYSTEM AND SOCIO-ECONOMIC RESILIENCE ANALYSIS AND MAPPING (ESRAM)

2.1 What is ESRAM?

As implied in the name, Ecosystem and Socio-economic Resilience Analysis and Mapping (ESRAM) refers to the EbA processes leading up to the identification and prioritization of EbA options for implementation. It is therefore the process of carrying out an assessment of the socio-economic and ecological condition of a target landscape area to identify threats from climate change and to formulate EbA interventions for implementation.

ESRAM processes entail the application of specific methodologies and protocols to assess each of the biophysical and socio-economic conditions of the target area.

2.2 Why ESRAM?

The importance of ESRAM comes from the significance of EbA as an approach to coping with and adapting to climate change.

ESRAM is the prerequisite to designing and formulating EbA strategies. Without a good understanding of the actual on the ground condition and status of ecosystems and communities in terms of their resilience and vulnerabilities to climate change, it would not be possible to identify the underlying issues and threats that are required to formulate strategies for EbA.

2.3 Conceptual Framework for ESRAM

For the purpose of the ESRAM exercise, the conceptual framework developed by the UN Statistical Commission's Experimental Ecosystem Accounting system (EU 2013), is relevant. 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. The ESRAM conceptual framework employs a social-ecological systems (SES) approach to assessing the vulnerability status of ecosystems and communities and to developing strategies to enhance resilience.

One of the outcomes of ESRAM is to document vulnerability status and develop resilience strategies to address the vulnerabilities or enhance the resilience of ecosystems and communities of the *Social-ecological system* (SES).

Figure 2.1 *A conceptual framework for ESRAM* in WBH habitat areas is the ESRAM framework depicting the social-ecological system as the landscape area comprising ecological and social systems that interact under influence of climate change and have further implications on the survival of species such as the WBH.

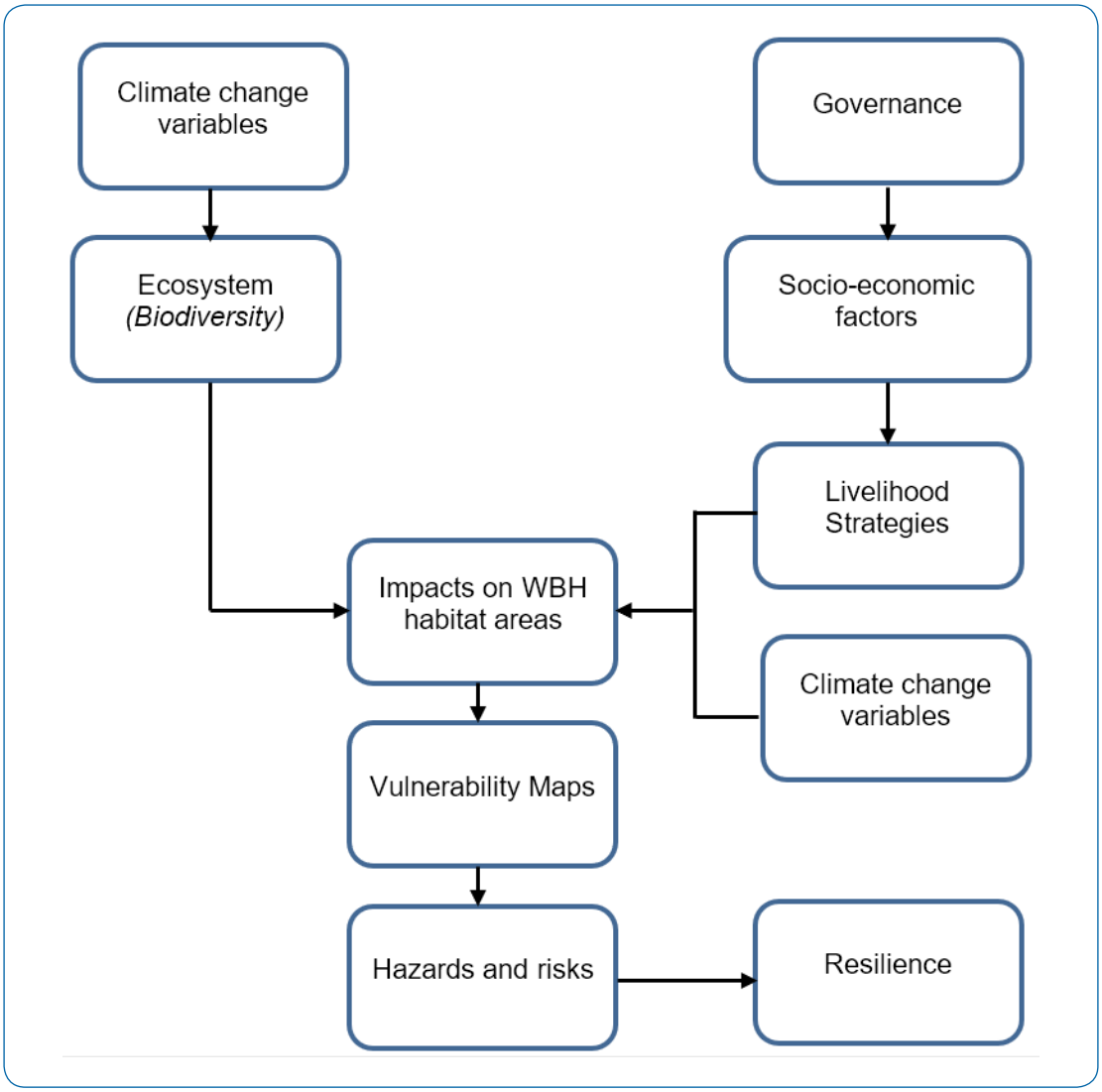


Figure 2.1: *A conceptual framework for ESRAM in WBH habitat areas*

This ESRAM framework is built around the ultimate objective of enhancing resilience through the conservation of focal species (WBH for example). The framework comprises of i) Ecosystem/ biodiversity assessment ii) Socio-economic assessment and iii) climate change assessments to arrive at climate change vulnerability indices for the administrative units in the landscape area. The outcomes of these assessments are used to identify and prioritize EbA interventions to tackle vulnerabilities or to enhance resilience. Specific methods and protocols need to be employed for data collection and analysis associated with each component.

Based on the ESRAM framework presented in Figure 2.1, the process for designing EbA options in a White-bellied heron conservation landscape is illustrated in Figure 3.1.

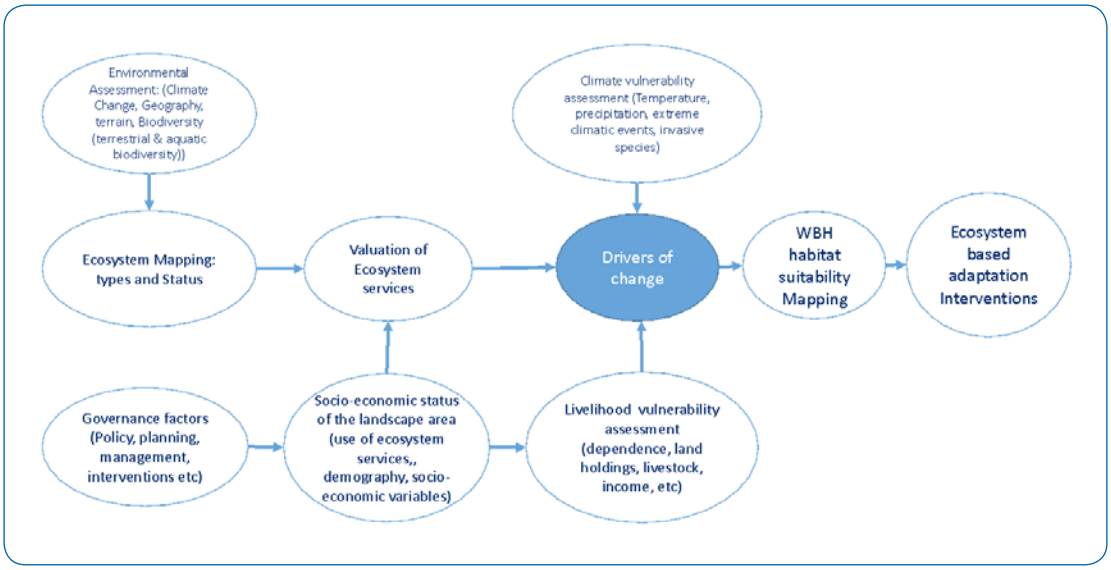


Figure 3.1: *ESRAM process framework for formulation of EbA in WBH conservation landscape*

Based on the ESRAM framework presented in Figure 2.1, the process for designing EbA options in white-bellied heron conservation landscape is illustrated in Figure 3.1.

3.1 Step by step approach to ESRAM

Carrying out the ESRAM exercise entails three major steps as explained below:

3.1.1 Step 1: Define Climate threats and target people

It is important to note that EbAs are more appropriate to be implemented at landscape levels. For this, the following activities need to be carried out:

» *Defining geographical context and EbA goals*

This activity entails defining the ESRAM study area, which is based on preliminary information on (i) Climate change and biophysical condition of the area, (ii) Administrative units, communities and households in the area. Equally important at this point is to be clear about the goal or purpose of carrying out the ESRAM exercise. This activity should result in clarity about the purpose and location of the landscape area in which EbA is

to be designed and implemented. Outputs from this activity would be in the form of maps of landscape area identified for EbA interventions, administrative units, number of households and land use classification.

3.1.2 Step 2: Designing and adoption of field assessment protocols

This step involves determining the appropriate methodology and protocols for conducting field surveys that will generate the information and data necessary for i) Analysing climate risks and vulnerability, ii) Understanding the role of ecosystem services in adaptation, and Developing an EbA strategy and designing EbA actions.

Relevant experts should be identified and engaged to design the data collection protocols for the above three areas of assessment keeping in mind the subject of assessment and the activities outlined in Table 1 below:

Table 3.1: *Checklist of activities associated with generating information for three areas of assessment*

Subject of Assessment	Activities
Analysing climate risks and vulnerability.	» Assessing the biophysical environment and climatic conditions. » Assessing Socio-economic status of communities. » Understand climate and non-climate threats to ecosystem services and livelihoods. » Conducting scientific vulnerability assessment of ecosystems and livelihoods and overall climate vulnerability index to inform the design of EbA measures.
Understanding the role of ecosystem services in adaptation.	» Identify types and assess values of ecosystem services in the area. » Identify sustainable management practices that can be used to i) reduce the climate risks identified and ii) enhance adaptive capacity.
Developing an EbA strategy and designing EbA actions.	» Identify priority EbA actions. » Develop site-specific interventions that address climate risks and vulnerabilities and maximise co-benefits based on good understanding of policy constraints and opportunities.

The development and design of the above studies needs the involvement of relevant experts in-house or external experts to develop and design field survey methods and protocols. The design of questionnaires and data collection protocols should take into account the information and data to be collected for the analysis and generation of the following information:

- » Biophysical and Environmental condition of the area
  - Biodiversity by ecosystem types
    - * Terrestrial
    - * Aquatic

- Socio-economic status of communities in the area
- Types of Ecosystem Services
- Value of Ecosystem Services
- Ecosystem services related issues faced by communities
- Climate Vulnerability Assessment to derive:
  - Ecosystem Vulnerability Assessments
  - Livelihoods Vulnerability Assessment
  - Climate Vulnerability Index (CVI)
- WBH habitat suitability assessment

Keeping in mind the above areas of assessment and analysis, the following preparatory activities need to be carried out.

» *Formulate guidelines for sampling to fit the resources available*

Depending on the level of resources available, the ESRAM exercise needs to be guided in terms of the resolution of data and information to be collected. For this, it is necessary to define the required sampling resolution and confidence levels. The higher the resolution, the more costly it will be. Resources must be allocated to allow for optimal sampling and representation of the study area.

» *Selection and adoption of field assessment methods*

This activity requires the management to engage experts to review and update existing methodologies and protocols (if already in place) or to design new ones. While overall concepts and areas of the investigation remain, there is no one size fits all type of methodology for the different components of the assessment. There are a variety of methods and approaches for every area of inquiry. For the purpose of ensuring optimal use of available resources, it is necessary to:

- Prioritize the areas of inquiry: Biodiversity is a broad subject and its assessment ideally would comprise several specialized subjects each with its own set of assessment methodologies and protocols. Selecting the most relevant aspects of biodiversity needs to be considered for assessment. For the first ESRAM exercise, biodiversity assessment was focused on vegetation and aquatic surveys.
- Select the choice of approach and methodology: The choice of approach and methodology is important for those areas of inquiry that have multiple approaches and methods. For example, valuation of ecosystem services can be carried out through different methods such as travel cost, contingent valuation, benefits transfer, discreet choice experiment etc. The methodology or a combination of methodologies that meets the objective of the assessment should be selected. The 2021 ESRAM exercise employed a discrete choice experiment.

Expert opinion and inputs would be required to select the methodologies, approaches and protocols best suited for the assessment. Accordingly, survey protocols and associated data collection questionnaires, forms, and database systems need to be developed. Questionnaires and protocols for data collection must take into account the data needed for the following analyses:

- Socio-economic status and issues faced by communities in the area
- Identification of ecosystem services and valuation
- Biodiversity status with a focus on vegetation and aquatic species diversity to reflect on the i) habitat and food base for White-bellied herons and ii) vegetation types as the source of ecosystem services.
- Climate Vulnerability Assessment to derive:
  - Ecosystem Vulnerability Assessments
  - Livelihoods Vulnerability Assessment
  - Climate Vulnerability Index (CVI)
- WBH habitat suitability assessment

The methodology and protocols developed and adopted for each of the components of ESRAM carried out in 2021 are presented in the sections specified below:

- Section 4. Protocols for ESRAM Socio-economic assessment
- Section 5. Protocols on use of Discreet Choice Experiment for Valuation of Ecosystem Services
- Section 6. Climate Vulnerability Assessment Protocols
- Section 7. Protocol for WBH habitat Suitability Assessment

Protocols on biodiversity assessment are available in a separate manual.

» *Formation and training of field enumerators*

ESRAM study in a landscape level area will require surveyors and enumerators for data collection. This step may be initiated simultaneously or after step 2. The field assessment team comprising of surveyors and enumerators should be formed for each area of investigation. Surveyors/ enumerators with knowledge and experience in the specific subjects of inquiry and backgrounds should be formed.

Decisions must be made on the mode of data collection i.e., whether manual paper based questionnaire surveys or computer/ tablet/ mobile phone based online data collection. With advancements in technology and the internet, the use of tablets for data collection is cost-effective and therefore being increasingly used. This will certainly require designing online questionnaires and database systems.

With the methodology, survey instruments and protocols in place, the ESRAM enumerators need to be trained specifically to cover the following topics:

- Data collection modality.
- Methods and protocols for a specific area of investigation.
- Logistic arrangements.
- Dos and Don'ts while in the field.

3.1.3 Step 3. Assess vulnerabilities of human populations and ecosystems

This step covers the actual act of conducting field surveys, analyzing the data collected and making sense of the data to formulate EbA strategy and adaptation measures. The activities to be carried out under this step are:

- *Conduct field surveys*

Though time consuming, this step is straightforward in terms of ensuring conformity to the approaches and protocols specified for each area of inquiry. Administrative and logistical support such as communication with local authorities, transportation, permits, equipment etc. needs to be arranged and provided to the enumerators and experts for field surveys. It is advisable to have the concerned experts to guide and supervise the enumerators.

- *Data entry, Analysis and Interpretation*

The data collected should allow for the following analyses to be carried out:

- Socio-economic and livelihoods conditions in the study area:
  - Socio-economic status and issues faced by communities in the area. This entails carrying out socio-economic data analysis to derive the demography, occupation of local people, income sources, social and economic issues, constraints and challenges, etc.

Socio-economic data collection, entry, and analysis methods and protocols adopted in the first ESRAM exercise are given in section 4.

- Environmental condition of the study area
  - Climatic conditions and climate change projections for the landscape of interest. This information is generally sourced from secondary sources desirably from official sources.
  - status of biodiversity and environmental condition in the area - information on:
    * Terrestrial biodiversity – ecosystem types, and diversity, richness, and abundance of flora and fauna.
    * Aquatic biodiversity - diversity, richness, and abundance of aquatic species.
    * Ambient water quality – pH, turbidity, total suspended solids, etc.

» Understanding the value of ecosystem services and their role in adaptation

- Identification of ecosystem services availed by local people categorized into provisioning, regulating, supporting, and cultural services.
- Local people's perception of the changes in ecosystem services
- Value of ecosystem services. Note that there are several valuation methods from which the relevant ones need to be employed.

Selected references on ecosystem services valuation are given below:

https://www.ecosystemvaluation.org/

https://www.climateandforests-undp.org/sites/default/files/downloads/an_initial_estimate_of_the_value.pdf

Environmental Valuation with Discrete Choice Experiments Guidance on Design, Implementation and Data Analysis https://d-nb.info/1223023087/34

Discrete choice experiment (DCE) method was the primary ecosystem services valuation method adopted in the first ESRAM exercise. The details of this methodology are given in Section 5.

» Analysis of climate risks and vulnerability

This step entails analysis of field data to derive the Climate Change Vulnerability Index (CVI) of the SES. This entails analyzing data on major components of Adaptive capacity, sensitivity, and exposure.

Table 3.2: *Vulnerability Components and Sub-components*

Vulnerability components	Sub components
Adaptive capacity	Socio-demographic profile
	Livelihood Strategies
	Social Network
Sensitivity	Health
	Food
	Water
Exposure	Natural Disaster
	Climate Variability

This should result in climate change vulnerability index (CVI). Selected references and literature on climate change vulnerability assessment methods are given below:

IPCC references:

Assessing Vulnerability for Climate Adaptation by Thomas E. Downing and Anand Patwardhan available at https://www4.unfccc.int/sites/NAPC/Country%20Documents/General/apf%20technical%20paper03.pdf

https://www.ipcc.ch/apps/njlite/ar5wg2/njlite_download2.php?id=10996

The methodology adopted for computing CVI at the river basin, Dzongkhag and Gewogs during the first ESRAM exercise is given in Section 6

» Species Habitat Assessment

Considering species conservation priorities (WBH in this case), conduct habitat suitability assessments. These assessments should help identify drivers of change for the preservation and protection of WBH habitat while enhancing ecosystem services for the livelihoods of communities. For species of interest (WBH for example), provide population data, habitat condition and food base (fish species diversity and abundance), ii) analyze habitat changes under climate change projection scenarios. Details of the habitat assessment methodology adopted in the first ESRAM exercise are given in Section 7.

3.1.4 Step 4. Define and prioritize EbA strategy and adaptation options

This step utilizes the data collected and the analyses carried out in earlier steps to identify and define EbA strategy and adaptation priorities. This final step in the ESRAM process comprises the following activities:

Develop EbA strategy and adaptation measures

The analysis and assessment reports from earlier steps should serve as the basis for the identification of drivers of change, which in turn should be used for the formulation of Ecosystem-based adaptation interventions. Table 3.3 provides a checklist of activities that need to be undertaken or taken into account during the process of developing interventions against each EbA principle.

Table 3.3: *Principles and requirements for formulation and prioritization of EbA options*

Principle	Requirements
Promote resilient and healthy ecosystems	» Modeling of projected climate change Systematic planning » Protected area systems design » Involve local communities in restoration and management » Adjust management programs and actions
Maintain ecosystem services	» Valuation of ecosystem services » Determine climate change impact scenarios » Identify options for managing ecosystems or managing the use » Involve local communities in adaptation action » Trade-off analysis
Support sectoral adaptation	» Include approaches in national adaptation plans » Incorporate ecosystem services in land management frameworks » Influence sectoral development plans – e.g. agriculture; water supply
Reduce risks and disasters	» Restore key habitats that reduce vulnerability » Catastrophic fire – fire-adapted forests » Water security – watersheds » Involve vulnerable communities in restoration efforts
Complement infrastructure	» Dam re-engineering – maintain ecological flows in rivers » Dams, levees – Restoration of flood plains » Reservoirs – the restoration of forests and watersheds
Avoid mal-adaptation	» Improve analysis of impacts from adaptation activities » Reduce negative impacts on the natural environment » Avoid inadvertent impacts on natural ecosystems and communities
Generate multiple and co-benefits	» Social and cultural - Biodiversity » Economic » Mitigation
Cost-effectiveness	» Low cost, small scale investment » Mobilise local resources » Integrate both soft and hard approach

Source: *IUCN, 2014. Ecosystem based Adaptation: Concept, Principles and Options. IUCN Nepal Country Office. Kupondole, Lalitpur, P.O.Box 3923, Kathmandu, Nepal*

As the name suggests, ecosystem-based adaptation options should be identified for each type of ecosystem in the landscape area. For example, forest, riverine and agricultural ecosystems are the common types of ecosystems in Bhutan. Interventions that are cross cutting and generally applicable may be identified under the generic category.

When developing EbA strategies and interventions, the first point to take care is to be clear about the intended outcomes of the adaptation interventions being developed and be cognizant of ecosystem services delivery in the area under consideration. EbA options must therefore take into account possible synergies, cost efficiency and trade-offs. EbA measures for each ecosystem type should clearly address the i) climate change adaptation function, ii) environmental benefits, iii) social benefits and iv) economic benefits. An example of EbA measures related to forest ecosystems is given in Table 3.4 below.

Table 3.4: *Example of EbA measures framework related to forest ecosystem*

EbA Measures	Climate change Adaptation function	Environmental benefits	Social benefits	Economic benefits
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

EbA options that have a negative effect on other sectors should receive lesser priority. EbA strategies should optimize synergies between various interventions and sectors while equally emphasizing cost effective approaches such as cost sharing mechanisms, community participation with in-kind contributions, etc.

Once a set of EbA measures are identified for each ecosystem as well as a generic category, it is important to identify the location in which the interventions are to be implemented. The Climate Vulnerability Index (CVI) generated from the Climate Vulnerability assessment should provide the basis for pinning down the specific intervention for specific locations (Chiwogs) under the Gewogs. It will also help define measures that need to be put in place to ensure the effectiveness of the proposed interventions. The CVI should help provide information on the vulnerable and highly vulnerable areas within the landscape area where the interventions should be implemented. EbA strategies are formulated by weighing the positive and negative effects on other sectors. This process should result in the final draft of the EbA strategy with a list of adaptation options, which should be subject to further review and prioritization by stakeholders.[4] Based on the detailed interventions, an overview of the EbA measures proposed for each ecosystem and the proposed location have complied in the following format (Table 3.5).

4 For a more exhaustive approach to formulation of EbA strategy and adaptation options, please refer to Jiménez Hernández, A. (2016). Ecosystem-based Adaptation Handbook. IUCN NL, Amsterdam.

Table 3.5: *Example of overview of EbA strategy specifying adaptation measures*

Ecosystems	Adaptation options	Proposed location
Forest	» Maintain and manage provisional and regulatory services of the forest ecosystem. » 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.	1. Dagana: Chiwogs falling in WBH habitat areas of i) Kana, ii) Laja, iii) Tashiding, and iv) Tshendagang. 2. Punakha: Chiwogs falling in WBH habitat areas of i) Barp, ii) Shelnganang, and iii) Toedwang. 3. Tsirang: Chiwogs falling under Tsirang Toed. 4. Wangdiphodrang: Chiwogs falling under Thoedtsho.
Agriculture		
Riverine		
Generic, applicable to all ecosystems within WBH habitat		

Prioritize EbA strategy and adaptation measures

While it is expected that the proposed EbA strategies and measures have already gone through the prioritization process, stakeholder consultations should be conducted to further prioritize the strategies and interventions.

Considering that the interventions will be implemented at the Chiwog levels, it is of utmost importance to involve the concerned sector heads at the Dzongkhag and Gewog levels to review and agree on the i) relevance of the types of interventions proposed and ii) the location of specific EbA interventions. The Climate Vulnerability Index (CVI) generated from the climate vulnerability assessment should provide the basis for pinning down the specific intervention for specific locations (Chiwogs) under the Gewogs. It will also help define measures that need to be put in place to ensure the effectiveness of the proposed interventions. The EbA strategy and interventions should be further supplemented with information on partners and mechanisms for implementation.

Final EbA strategy and Action Plan

The prioritization process should provide RSPN as the EbA implementation agency with the final EbA strategy. The priorities identified in the strategy should be further broken down into action plans with budget provisions and co-financing inputs from partner agencies or communities clearly specified.

04 SOCIO-ECONOMIC ASSESSMENT PROTOCOL

4.1 Overview and Introduction

As stated by Abdrabo and Hassaan (2003), a socio-economic study is learning about the social, cultural, economic, and political conditions of stakeholders including individuals, groups, communities, and organizations in the study area. Socio-economic is a branch of economics, and as social science, studies the relationship between social behaviour and economics. The socio-economic studies in WBH habitats, therefore, are intended to help in understanding community dynamics, issues, and resource gaps essential for initiating new development investments, necessary to support the conservation and management of WBH, bio-aquatic ecosystems, and the people whose livelihoods are relatively dependent on the exploitation of ecosystem resources.

Bhutan is one of the few countries harboring the White-bellied Heron *(Ardea insignis)* a critically endangered heron species in the world, found only in the freshwater ecosystems of the Himalayas. As one of the rarest herons, its population is dwindling in the world and Bhutan as well. Therefore, with the Royal decree, Bhutan through the Royal Society for Protection of Nature (RSPN), a citizen-based non-profit, non-governmental environment organization, is committed to the conservation and protection of WBH in Bhutan. The extremely low and shrinking population of WBH across the country due to habitat degradation and increased disturbance by human activities in the habitats, has rendered conservation and protection of WBH and their habitats a core mandate and program objectives of RSPN (RSPN, n.d.).

4.2 About the Protocol

This manual relates to the socio-economic component of the Ecosystem and Socio-economic Resilience Analysis and Mapping (ESRAM) exercise initiated under "Developing Ecosystem-based Solutions for Managing Biodiversity Landscapes in Bhutan". The overall goal of the project is to develop ecosystem-based solutions for managing biodiversity landscapes, with a special focus on establishing approaches and tools for protecting and managing White-bellied Heron habitats. The project aims to design and apply ecosystem-based biodiversity survey and community engagement strategies for WBH conservation based on the ESRAM approach.

The ESRAM project objectives are as follows:

- To Design study protocols and methods for ESRAM study and Biodiversity survey
- To undertake ESRAM study and conduct biodiversity assessment (Flora, Fauna, and Aquatic Biodiversity in WBH sites).
- To survey, identify and map degraded WBH habitats and potential new habitats,

- To survey, Identify and map sites for restoration plantation & site-specific livelihood interventions
- To analyze data and prepare reports on ESRAM and Biodiversity survey,
- To conduct training on ESRAM approaches and activities (including monitoring and report),
- To conduct hands-on training on biodiversity survey (includes all aspects of ESRAM).

4.3 Objectives

The objective of this manual is to provide a basic conceptual framework and practical steps for field-based practitioners in conducting a reliable assessment of the socio-economic conditions of the households and villages within the WBH habitats using structured questionnaire interviews and personal observations, focused group, and key informant interviews. These tools are essential to collect information that is useful for improving the understanding of the use and management of local resources by the communities and their dependence on them. In addition, it is also important to collect information on the interaction between government agencies and community perceptions of trends and priority issues including community-based organizations and their roles in the sustainable use and conservation of ecosystems in the project areas.

4.4 Scope and limitations

In view of varied methods and information available for carrying out socioeconomic assessments, this manual briefly presents a very basic set of guidelines that focuses on the collection of a minimum set of socioeconomic data about communities particularly residing in the WBH habitats who are relatively dependent on the bio-aquatic resources in the areas. As such this manual presents the use of fully structured questionnaire surveys, the easiest and most effective method in terms of time, and financial and human resource inputs required. The WBH socioeconomic survey has used the structured questionnaire interview as the main method complemented by a self-administered questionnaire for key informant interviews for the primary data collection involving a simple random sampling of households.

4.5 Socio-Economic Assessment (SEA) Methods

While many methodologies exist, but all the socio-economic survey tools are designed to collect information as a means of improving understanding of the socioeconomic conditions of the target communities. Therefore, the process of data collection should be systematically organized and must be cost-effective with due consideration of the resource available for use. This can be assured by developing carefully planned, precise, and logical data collection methodologies. Figure 1 summarizes the basic stages essential to cover in designing and conducting a socio-economic survey, and Annexures 1 and 2 provide brief outlines of the components of a work plan and costs respectively in preparing a socioeconomic survey.

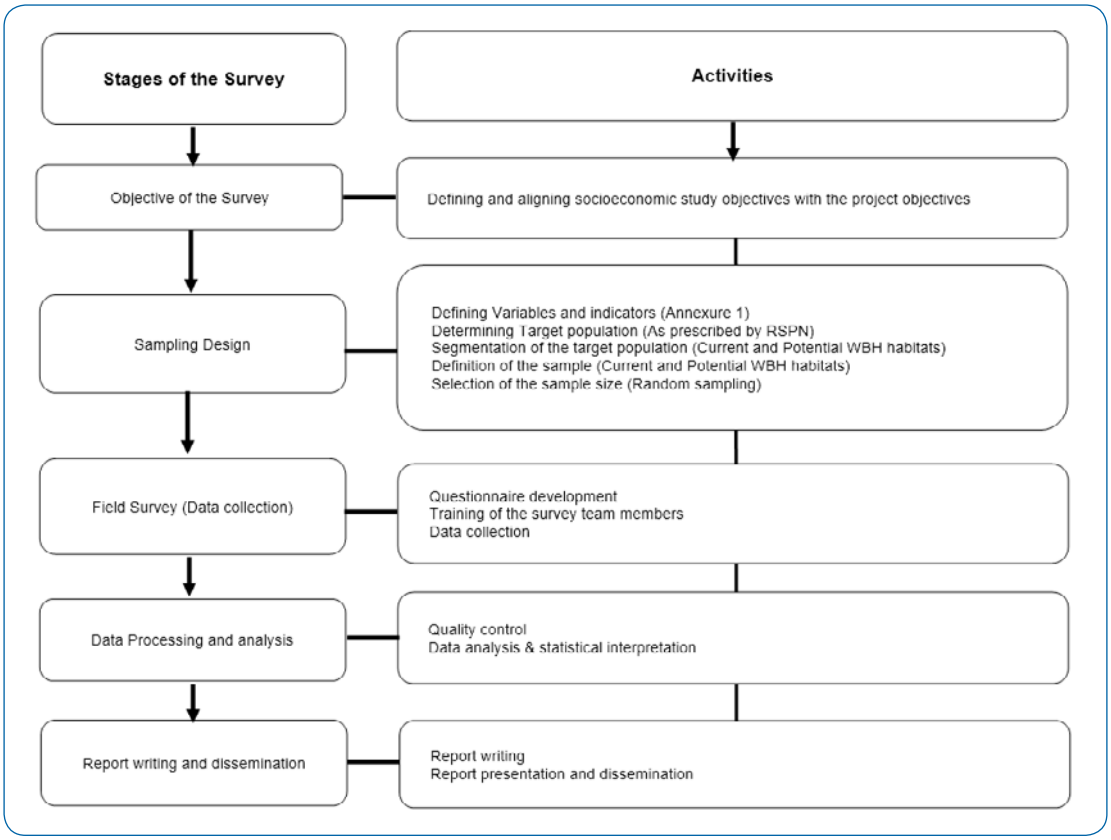


Figure 4.1: *The socio-economic data collection design process*

4.6 Purpose of the WBH Socio-Economic Assessment

Generally, the primary objective of any socioeconomic study is to understand the current socio-economic conditions of a community focusing on the livelihoods and the impacts likely to result from the development initiatives in the project area. First, it is necessary to determine the objectives and purpose of the survey as it provides the basic framework for the content and scope of the survey which is useful in identifying the stakeholders. In the present case, the specific objectives of the SEA of the WBH habitat areas are intended to:

- Assess and understand the prevailing socioeconomic conditions of the study areas (demographic, livelihoods activities, income, and sources – crop, livestock, and off-farm activities, the land-use patterns, tenure, and rights)
- Assess ecosystem base (natural resources types – biotic and aquatic, availability and trend in base and uses, community perceptions, impacts of the prevailing environmental conditions)
- Identify areas for feasible interventions or development potentials and opportunities in enhancing community livelihoods and sustainability of WBH conservation measures.

The information obtained will help make informed decisions especially in planning, designing, and implementing realistic and sustainable WBH protection and conservation programs that are beneficial to the WBH, ecosystem, and the immediate communities in the project areas.

4.7 Sampling Design

The sampling design encompasses several methodological aspects of the survey (Figure 4.1) involving making decisions on how each of these will be carried out. As commonly mentioned in many of the socio-economic assessment guidelines, it is important to balance between what is statistically ideal with what is practical or feasible in the field considering the availability of financial and human resources to effectively conduct and complete the surveys.

» *Indicators for WBH Socio-economic Assessment*

Socioeconomic environment refers to a wide range of interrelated and diverse aspects and variables relating to social and economic factors which are dynamic, and often difficult to identify and assess as they are related to the human beings and their characteristics, which usually differ even within as well as between communities (Abdrabo and Hassaan, 2003). Therefore, considering the limitations imposed by the diversity and dynamic nature of socioeconomic aspects, it is important to identify the issues or indicators to fulfill the primary objectives of understanding the ecosystems and socio-economic conditions of the communities in the WBH project areas as summarized below:

- 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 resources 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 and community participation, etc.)

For details refer (Annexure 3)

» *Determining Target Population*

The target population is the population of interest for the socio-economic assessment. In other words, the target population is the individuals and groups that the survey intends to cover for the data collection and draw conclusions from. Determining the target population is necessary for setting clear direction on the scope and objective of the survey and data types, defining the characteristic variables, and confirming the sample size. For the WBH socioeconomic assessment, the study areas and target population were identified and assigned by RSPN.

» *Segmentation of the target population*

The definition of the target population should be followed by segmentation. The segmentation of population is a separation of populations into subgroups for better assessment of each group's wants, needs, and priorities. The segmentation can be based on geographic, demographic, economic, farming practices, and income characteristics of the population. For example, the segmentation of the population in the WBH project areas was done based on the current WBH habitats and potential habitats. The segmentation of the target population is useful in tailoring programs to meet the needs of the specific segments.

» *Definition of the Sample*

A sample is a group of people from a larger population selected for measurement. So a good sample must be a representative subset of the population that the project is interested to study, and each participant should have an equal chance of being randomly selected for the study. In the case of the WBH survey, the samples have been selected from the current and potential WBH habitats.

» *Selection of the Sample Size*

The determination of sample size is important to maintain the required data quality and validity by ensuring the minimum or lowest sample units. Generally, the larger the sample size, the more accurate the predictions from the sample. As a general rule, statisticians have found that for many population distributions, when the sample size is at least 30, the sampling distribution of the mean is approximately normal (Levine et al., 2008). The determination of sample size is also often constrained by budgetary resources, which caps the maximum number of sample units. Researchers should evaluate a sample frame based on three factors: inclusiveness, the probability of selection is known and cost effectiveness (Fowler, 2009).

After determining the sample frame, the probability or non-probability sampling techniques can be used to draw samples. Probability sampling include Systematic (*a system is used to select participants like random*), random (*where every member in the target population has an equal chance of being selected*), stratified (*the population is divided into smaller groups, called strata*) and cluster (*similar to stratified sampling where the population is divided into groups*

or clusters but unlike stratified sampling, the participants are not selected from all the clusters) sampling techniques. On the other hand, non-probability sampling techniques include such as; Convenience Sampling, Judgment Sampling, Quota Sampling and Volunteer Sampling. For the current study simple random sampling was used for determining the sample size in the current and potential WBH habitats.

4.8 Field Survey for Data Collection

Accurate and systematic data collection is critical to conducting scientific research. Therefore, data collection allows the researcher to collect information that he/she wants to collect about the respondents of the research. Depending upon the research type, methods for data collection include: documents review, observation, questioning (Personal, Mail, Telephone and Web), measuring, or a combination of different methods. The conduction of a field survey can be summarized as questionnaire development, recruitment and training of survey team members, and collection of data.

» *Questionnaire development*

Different tools such as personal observations, discussions, and interviews are used to obtain different types of information from individuals and groups. The use of structured or semi-structured questionnaires (closed or open) interviews is generally the main tool used for collecting the primary data depending on the type of information required.

It should be borne in mind that the questions provided in the questionnaires are a reminder of what data is needed. The sequence of questions is put into a logical order according to the priority of information required. The sequence and/or way questions are finally formulated and posed may vary according to the situation, the interviewer, and the respondents. O'Leary (2014) suggests that ambiguity, leading, confronting, offensiveness, unwarranted assumptions, double-barreled questions, or pretentiousness should be avoided. The following general norms apply to all types of questions. The questions should be:

- Simple and easily understood by all individuals irrespective of their educational and cultural levels.
- Formulated to be accurate and clear (minimize open answer questions).
- Ordered so that the difficult and sensitive questions come later.
- Sensitive questions are asked indirectly and their answers verified

(Annexure 4: Questionnaire design guidelines)

Training of the survey team members

The questionnaire is the tool used for collecting data, and therefore data collectors need to be familiar with all of the variables and their meanings. It is important to ensure, that the language in the questionnaire and the terms used by the enumerators must be well understood by the respondents. Therefore, organizing training is important to prepare the

survey team for the smooth collection of data to fulfill the survey objectives. If necessary, pilot testing may be performed to familiarize and train survey team members and decide on the most appropriate language, and way of approaching the target community and conducting individual interviews. The feedback from the pilot survey or testing will help fine-tune the questionnaires to attain the objectives more effectively.

» *Field survey*

Household and key informant interviews were conducted using the fully structured, closed questionnaires provided in this manual (Annexures 5 and 6). The questionnaires were prepared to focus on the minimum dataset identified in the project proposal. Households are used as reference units, for collecting socio-economic as well as ecosystem information. While the socioeconomic assessment proposed here could be independently conducted, the information generated can be analytically linked to ecosystem livelihood assessment data.

There are several techniques of survey methods such as telephonic, mail, personal and electronic interviews used for research purposes (O'Leary, 2014). A personal interview, where an interviewer asks the questions face-to-face with the interviewee, despite high costs and time, is the most commonly used especially in rural areas to collect the primary data. Personal interviews can be conducted in any place like in the house, outside, in the field, shops, on the road, and so on. The purpose of a personal interview survey is to explore the responses of the people to gather more and deeper information. The field survey data collection instruments (Figure 4.2) used in the current study are briefly explained below.

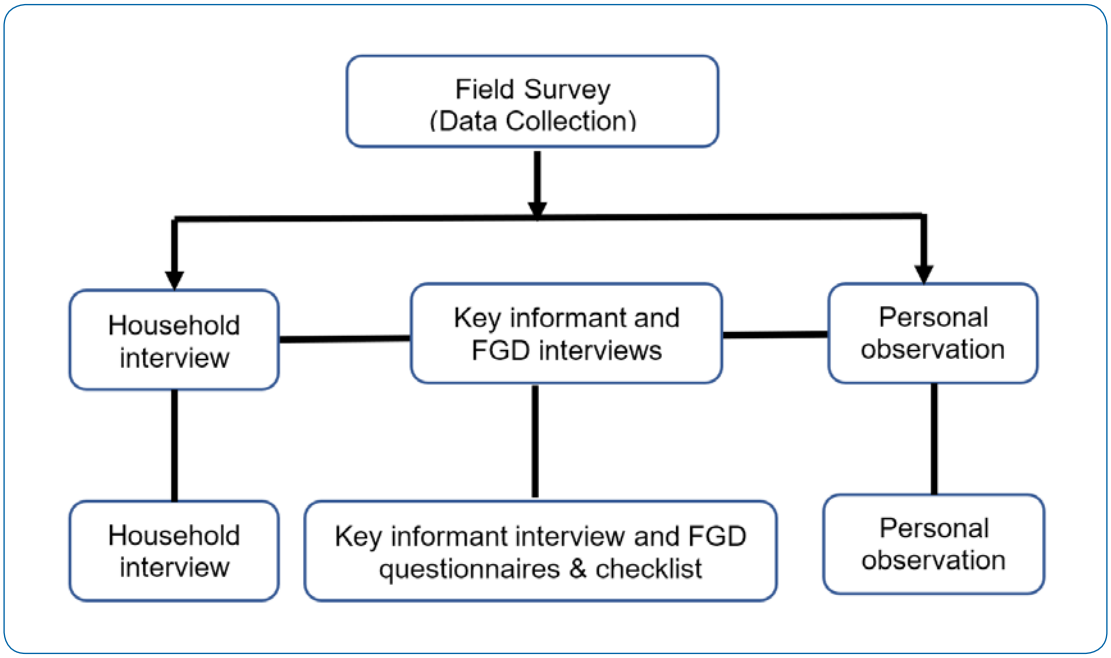


Figure 4.2: *The survey instruments*

» *Household interviews*

The household survey or interview is used for understanding households and individuals' perspectives on the socio-economic issues in the WBH areas. Therefore, the objective of the household survey is to collect up-to-date information on:

- » Demographic information (household size and composition, age);
- » Household members' education level;
- » Household livelihood activities (crops, livestock, forestry, and off-farm activities)
- » Household economic activities (income sources, consumption patterns, areas of expenses);
- » Household knowledge on WBH and ecosystem (Ecosystem resource base, access, uses, and changes)
- » Policy implications

The household interview should focus on those household members who can provide information. These may include the household head, in charge of household management; and/or those who are actively contributing to the household survival. The way one ask questions influences the quality of responses one receives.

» *Key informant interviews and focus group discussions*

The key informants are individuals who are more knowledgeable and familiar with the place, community and livelihoods, developmental needs and potentials, the WBH protection, and conservation measures in the study areas. Their experiences and knowledge can provide insight and information into the larger population or a particular community. Therefore, the objectives of the key informant interviews are to learn about:

- » The community's livelihoods and social capital
- » The community's knowledge and perceptions on WBH;
- » Potentials and problems relating to the access, use, and management of the ecosystem resources in the WBH areas.

Key informants usually include those people like local government officials, civil servants (local school teachers, health workers, and RNR officials), project officials if any, an official of the NGOs, Farmers' groups, local shop keepers, etc.

» *Personal observation and informal discussions*

Personal observation is a strong tool. Many things need not be asked, for example, the housing conditions, soil types, land use patterns, and crops in the field at the time of the visit. The information collected through personal observation should complement the overall and specific objectives of the socio-economic survey. The observation and informal discussions should focus on important aspects of the communities that can further enhance the understanding of the social and cultural contexts of the community

and their relationships to resource use and community structure. The observation and discussion notes should be short and precise highlighting aspects useful and essential to the survey objectives contributing to the planning and management of WBH protection and conservation measures or programs.

4.9 Data Management and analysis

Management of a large amount of data will require a systematic approach for data coding, tabulating, and entry which are generally done in excel after the verification of the data.

On the other hand, the analysis will involve standard statistical analysis of the data and information collected based on the criteria developed before and the objective and scope of the survey.

4.10 Report Writing and Dissemination

The results of the analysis must be written and compiled into an acceptable format and structure often approved and prescribed by the funding agency or the parent organization producing the report.

The most common means of dissemination of findings and information are done through the preparation and distribution of reports and publications. Organizing seminars and workshops are also used as alternatives for disseminating the findings to the relevant stakeholders and policy decision-making bodies and organizations.

Annexure 4.1: Work plan components for socio-economic survey

- Preparation of study area baseline conditions or profile (Collection of secondary information and data)
- Identification of issues and determining the criteria for socio-economic assessment (Components for socioeconomic assessment and identifying the relevant indicators against each component)
- Fieldwork (Survey questionnaire preparation and checklists, team formation and training, field survey logistics, applying for necessary approval and consents, fieldwork implementation pilot field testing of the questionnaires, and finalization of the questionnaires and checklists)
- Data entry and analysis (Data entry, analysis, report writing, and dissemination of the findings)

Annexure 4.2: Tentative components for costs estimation of the socioeconomic survey

No	Activities	Responsible person	Estimated unit of works (person(s)/ No of day(s)/ week(s) /month(s)	Unit cost Nu. (person/ hr(s)/days/ week(s)/ month(s)	Estimated total cost (Nu.)
I	I PLANNING AND PREPARATORY ACTIVITIES A. Initial planning and subsequent monitoring 1. Initial planning and subsequent monitoring 2. Identifying subject-matter specialists and recruitment. 3. Preparation and secretarial works				
	B. Development of survey design 1. Secondary information collection 2. Identification of issues and indicators for the survey 3. Initial design planning (survey structure, population coverage, sampling procedures, field household listings and sample selection data collection methods etc.)				
	C. Design and printing of questionnaires and other forms 1. Questionnaire development 2. Printing costs (after pre-tests)				
	D. Pre-testing of questionnaires if necessary 1. Professional fees 2. Field supervisors fees (personnel and travel costs 3. Interviewers (personal and travel costs)				
	E. Preparation of field instructional materials 1. Professional fees, secretarial and other services 2. Reproduction costs				

	F. Miscellaneous (planning - public relations and publicity, acquiring official approvals, etc.)				
	I) TOTAL OF PLANNING AND PREPARATORY ACTIVITIES				
II	II. FIELD OPERATIONS A. Training of field supervisors and interviewers 1. Personnel costs 2. Lodging and meals 3. Travel and vehicle hiring costs.				
	B. Data collection (including quality control) 1. Supervisor costs (Personnel and Travel costs) 2. Interviewer costs 3. Field administration costs (direction, travel guide, etc.)				
	II) TOTAL FIELD OPERATIONS				
	III. DATA ENTRY AND ANALYSIS				
	1. Systems planning and computer programming 2. Data entry and supervision 3. Data analysis and report writing 4. Report reproduction and dissemination				
	III) TOTAL DATA ENTRY AND ANALYSIS				
	GRAND TOTAL				

Annexure 4.3: Components of Socio-economic assessment

No.	Socioeconomic Components	Indicators
1	Demographic conditions and respondent information	» Age, gender, ethnicity, religion, education, occupation, household size, household income, household members and age structure., household head
2	Economic conditions and household livelihood and cash income sources	» Household income, income level and sources » Household livelihood activities Crops, livestock, off farm) » Challenges in pursuing crop and livestock activities » Potentials economic and social development
3	Household Food Security	» Seasonal food supplies, » Food supply trends » Food shortages and measures
4	Community Groups and household memberships	» Community groups and types, » Members participation, social capital (attitudes, lifestyle, networking and cooperation)
5	Community's knowledge and awareness of WBH	» Household knowledge on WBH » Significance of WBH in the society » Household and village perceptions on WBH conservations » Availability of timely information and training WBH
6	Biodiversity and WBH Conservation	» Awareness and need for protection and conservation of WBH » Measures for sustainable conservation of biodiversity » Household participation in WBH conservations
7	Climate Change	» Awareness and knowledge about climates change » Climate change experiences and impacts on crops and livestock activities » Mitigation measures tried and effectiveness » Suggestions
8	Human Wildlife Conflict	» Types of animals, » Common human wildlife conflicts and impacts,, » Crops and livestock damages, » Compensations programs, » Government measures and individual initiatives taken, » Suggestions.
9	Policy and Governance	» Human wildlife policy » WBH conservations » Household participation and incentives » Sanctions and implications for non-participation » Suggestions

Annexure 4.4: Brief Guidelines for Designing Questionnaires

Brief guidelines for designing questionnaires

This supporting document briefly outlines the steps for developing survey questionnaires. To collect quantitative primary data, researchers must design a questionnaires that translate the information needed into a set of specific questions. A questionnaire should allow the researcher to collect complete and accurate data in a logical flow to draw reliable conclusions. The steps for questionnaire design can be summarized as

- Defining the objectives of the study
- Define the target respondents and methods to reach them.
- Questionnaire design
- Questionnaire pilot testing

1. Defining the Objectives of the Study or information needed

First and foremost to define the objectives and specify what information is needed. Therefore, a well-designed questionnaire should meet the research goal and objectives and minimize unanswered questions.

2. Define the target respondents

Next is to clearly define the target groups and their educational level and experience for designing appropriate questions. Questionnaires that fail to consider the characteristics of the respondents particularly their educational level and experience usually lead to a high incidence of "uncertain" or "no opinion" responses. (Malhotra, 2004). The respondents can be reached through personal contact, interview, mail/Internet-based questionnaires, and telephone interview.

3. Questionnaire Design

Before writing the questionnaire researcher must decide what should be included in the questionnaire and also determine whether the question is required or not. Each question should contribute to testing one or more hypothesis/ research questions established in the research design.

Generally closed and open questions are most commonly used in the questionnaires.

- Open questions that are without a predetermined set of responses.
- Closed questions that take the form of a multiple-choice question.

Malhotra (2004) states that questionnaire design is as much an art as it is a science. According to him, the creativity, skill, and experience of the researcher play a major role in the end design. As mentioned above, the first step in questionnaire design is to specify the information needed. Saul McLeod (2018) proposes seven important factors that need to be duly considered in preparing research questionnaires (Table 1)

Table 1: *Important factors to consider in questionnaire design*

No	Factors	Necessary Conditions
1	Aim(s)	Make sure that all questions are asked to address the aims of the research.
	Problems	What kind of answer(s) the researcher is looking for.
2	Length	Questions should be short, clear, and to the point; Avoid any unnecessary questions/ items.
3	Pretest	Pretest the questions through a small-scale practice study to ensure people understand the questions. Reformulate questions based on feedback.
4	Question order	Logical progression - from the least sensitive to the most sensitive, factual and behavioral to the cognitive, and more general to the specific.
5	Question order	The researcher should ensure that the answer to a question is not influenced by previous questions.
6	Terminology	Use no/minimum technical jargon.
		Questions should be simple, to the point and easy to understand.
		The language - should be appropriate to the vocabulary of the group of people being studied.
		For example, the language should match the social background of respondents' age / educational level / social class / ethnicity etc.
7	Presentation	Make sure it looks professional, and include clear and concise instructions. If sent through the post make sure the envelope does not signify 'junk mail.'

On the other hand, according to O'Leary (2014), in designing questions researchers must avoid:

- Poorly worded questions
- Biased, leading, or loaded questions
- Problematic for the respondent, including
  - Recall-dependent questions
  - Offensive questions
  - Questions with assumed knowledge
  - Questions with unwarranted assumptions
  - Questions with socially desirable responses.

4. Questionnaire pilot testing

The major challenge in questionnaire design is to make it clear to all respondents. Therefore, pretesting is necessary and helpful for the researcher in identifying confusing items, mistakes, potential biases, respondents' comprehension problems, and uninformative questions. The participants for the pilot testing can be randomly selected from the target groups.

Pilot testing can enhance the reliability and validity of measurement. Validity refers to the extent to which our measurement process is measuring what we intend to be measuring. The pretesting and evaluation of questionnaires are intended to reduce the opportunity for respondents' error by framing clear questions and making it easy for the respondents to provide valid, accurate, and reliable answers.

5. Conclusion

Questionnaires allow the collection of both subjective and objective data in a large sample of the study population in order to obtain results that are statistically significant, especially when resources are limited. But questionnaire design is a multi-step process, and as rightly mentioned by Malhotra (2004) no scientific principles guarantee an optimal or ideal questionnaire. Therefore, it is important to consider the multidimensional aspects of questionnaire design to ensure the reliability and validity of intended measurements. Although the validity of data and information depends on the honesty of the respondents, yet the clarity of questions and easiness of comprehension by the respondents are equally crucial for obtaining correct information. The questionnaires can measure both qualitative and quantitative data, but it is more appropriate for quantitative data collection. A questionnaire is also a good tool for the protection of the privacy of the participants.

Annexure 4.5: WBH socio-economic survey questionnaires

SECTION D: RESPONDENT INFORMATION

Age .....Years Gender ☐ Male ☐ Female

3. Occupation: .....

4. Education level	None	Primary	Middle Secondary	High School	Undergraduate	Master	Others (Specify)
Tick [√]							

5. Ethnic group	Ngalop	Sharchop	Lhotshampa	Khengpa	Mangdep	Others (Specify)
Tick [√]						

SECTION E1: GENERAL HOUSEHOLD (HH) INFORMATION

1. Household Head: a) Male ☐ b) Female ☐

2. Household members registered in the same census

No	Household members	Male	Female	On the farm	Away
1	Less than 18 years				
2	Between 19-60 years				
3	Above 61years				
4	Total				

3. Annual Household Income

Annual Income	Less than Nu. 50000	Between Nu.51000 - 100000	Nu. 101000 -200000	Nu. 201000 -500000	Above Nu.500000
Tick in the appropriate level [√]					

4. Household Land holding

No.	Land Types	Area (Acres)	Ownership	Crops cultivated	Purpose
1	Wetland				
2	Dryland				
3	Orchard				
4	Others (Specify)				

5. Challenges in crop production? Rank according to the seriousness

No.	Types	Tick	Rank	Your Measures	Any Suggestion
1	Damage by wild animals				
2	Unavailability of inputs				
3	Marketing problem				
4	EA not supportive				
5	Climate change				
6	Irrigation problem				
7	Degrading soil fertility				
8	Others (Specify)				

1 = Most Serious; 2 = Serious; 3 = Neutral; 4 = Not serious

SECTION E2: LIVESTOCK ACTIVITIES

1. What types of livestock do you raise?

No	Livestock Types	No	Breed	Purpose
1	Cattle			
2	Horses			
3	Pigs			
4	Poultry			
5	Sheep			
6	Goat			
7	Others (Specify)			

2. What are the main constraints in raising livestock? Enter the Codes from below*

No	Challenges	Cattle	Pigs	Poultry	Add....
1	Poor quality local breed				
2	Outbreak of diseases				
3	Insufficient grazing				
4	Insufficient EA support				
5	Losses to predators				
6	Inputs not readily available				
7	Others (specify).....				

** Codes: 1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree*

SECTION E3: HOUSEHOLD LIVELIHOOD AND CASH INCOME SOURCES

1. What are the main household livelihood sources?

No	Livelihood Sources	*Rank in order of importance
1	Agriculture	
2	Livestock	
3	Off-farm labor	
4	Trade/business (specify)	
5	Others (specify)	

**1 = Very Important; 2 = Important; 3 = Medium; 4 = Not important; 5 = Not at All*

2. What are the main household annual cash income sources?

No	Sources of Cash income	Annual Amount earned (Nu.)	*Rank in order of importance
1	Sale of agric. products		
2	Off farm Labor		
3	Livestock products		
4	Remittances		
5	Business/trade		
6	Others Specify:		

**1 = Very Important; 2 = Important; 3 = Medium; 4 = No important; 5 = Not at All*

3. Transfer and other Household incomes in the past year

Type of income	Income Code	Has the household received any [...] in the past 12 months? 1= Yes 2 = No (>> to next category	Amount received during the past 12 months. If the amount was in kind, give the estimated cash value		What were the reasons why the person(s) sent the remittances and assistances for? Up to two in order of their importance (See code below)	
			Cash (Nu.)	In kind (estimated cash value)	1st	2nd
1	2	3	4	5	6a	6b
Pension and life insurance						
Remittances and assistance received locally (within the country)						
Remittances and assistance received from abroad						
Income from the sale of assets including livestock						
Other income (inheritance, loan, etc.)						

Code for 6a and 6b

1 = Buy livestock 2 = Buy land 3 = House construction	4 = Purchase of house construction materials 5 = Buy farm inputs such as seeds, fertilizer, pesticides 6 = Perform annual ritual (lochoes and rimdoes)	7= Pay for health expenses 8 = School fees or academic expenses 9 = Others (specify).....

SECTION E4: HOUSEHOLD FOOD SECURITY

1. Are you able to produce enough food for your household annually a) Yes ☐ b) No ☐

2. If No, which months did you experience shortages?

English months	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Bhutanese months												
Tick [√]												

3. How do you cope with the food shortage in your household? The food here refers to the shortage of cereals.

No	Mechanisms	Tick	Frequency*
1	Sale of farm products		
	» vegetables		
	» livestock products		
	» others (NTFP, contracts)		
2	Off-farm activities (business, carpentry, monk services, wages, etc.)		
3	Remittance from family members		
4	Borrowing from neighbours (cash or kinds)		

**1 = Always; 2 = Often; 3 = Sometimes; 4 = Rarely; 5 = Not at all*

SECTION F: GROUPS AND MEMBERSHIP

1. Are there any farmers' groups and cooperatives in the village? a) Yes ☐ b) No ☐

2. If yes, what groups are there in your locality?

No	Types of Groups	When was it formed?	Are You Member		Purpose of the group
			Yes	No	
1	Vegetable marketing group				
2	Dairy Groups				
3	CFMG				
4	Poultry Group				
5	Others (specify).....				

3. Is the group membership open to both females and males?	a)Yes		b) No	

4. Farmers groups

No	Performance and members' participation	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1	Group approach is beneficial					
2	All the groups are performing well					
3	Members' participation are strong					
4	Farmers will be interested to form new groups					
5	Farmers' understand group concepts					

5. What benefits do you enjoy from your membership?

1.....

2.....

6. How do you rate the cooperation in your community?

No	Community	Very Poor	Poor	Fair	Good	Very Good
1	Sense of we feeling					
2	Helpfulness and support					
3	Reciprocity					
4	Self sufficiency					
5	Relationship					
6	Solidarity					

SECTION G1: CLIMATE CHANGE

1. Do you believe in climate change?	a)Yes		b) No	

2. If yes, what are the extreme weather events you have experienced that have affected the crop and livestock production activities? Tick the events and rank them as per the seriousness

No	Events	Tick	Since when?	Rank*	Impacts on
1	Changes in temperature				
2	Erratic rainfall				
3	Flood				
4	Drought				
5	Land slides				
6	Soil erosion				
7	Pest and disease				
8	Wind/hail storms				
9	Forest fires				

* *1 = Very serious; 2 = Serious; 3 = Medium, 4 = Neutral; 5 = Not at all*

3. Mitigation measures you have undertaken and suggestions for mitigation

No	Events	Personal Measures Undertaken	Effectiveness*	Measures Suggested for mitigation
1	Changes in temperature			
2	Erratic rainfall			
3	Flood			
4	Drought			
5	Land slides			
6	Soil erosion			
7	Pest and disease			
8	Wind/hail storms			
9	Forest fires			

** 1 = Very effective; 2 = Effective; 3 = Neutral; 4 = Not Effective; 5 = No comments*

4. Climate change has become a serious concern for the rural farmers?

Level	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Tick [√]					
Reasons					

SECTION G: BIODIVERSITY AND WBH CONSERVATION

1. How do you feel about the biodiversity and ecosystem of your community ten years before and now?

No.	Biodiversity and ecosystem	Before 10 years	Now	Reasons
1	Forest cover			
2	Plant species and resources			
3	Animal habitats			
4	Water resources			
5	Plant and animal diversity			
6	Population of WBH			
7	Crop productivity			
8	Frequency of plant and animal disease outbreaks			
9	Others (Specify).....			

1= More; 2 = Less; 3 = Same; 4 = No comment / No idea.

2. Do you know what WBH is? a)Yes ☐ >> Q3 | b) No ☐ >> Q4

3. If yes, how significant is WBH in the social life of the local community?

No	Importance of WBH	As what
1	Very Important	
2	Important	
3	No comment	
4	Do not know	

4. Are you aware of the WBH conservation activities? a)Yes ☐ >>Q5 b) No ☐ > Section H

5. If yes, how do you see the WBH conservation efforts initiated by the concerned agencies?

Importance of Initiatives	Not at all impotent	Not Important	Moderately important	Very Important	Extremely important
Tick (√)					
Reasons					

6. What are the measures taken by the community for the sustainable conservation of biodiversity and ecosystem related to WBH? Tick [√] accordingly.

No	Conservation Measures	Implemented		No idea	Not at all effective	Slightly effective	Effective	V. Effective
		Yes	No					
1	Afforestation							
2	Checking Illegal activities							
3	Changes in agricultural practices							
4	New protection measures introduced							
5	Community awareness programs and Trainings							

7. How do you rate the level of participation by the people in the conservation measures? Tick [√]

No	Conservation Measures	Very Poor	Poor	Good	Very Good	Excellent
1	Afforestation					
2	Checking Illegal activities					
3	Changes in agricultural practices					
4	New protection measures introduced					
5	Community awareness programs and trainings					

8. Is participation in the conservation activities open to both males and females? a)Yes ☐ b) No ☐

8. Why?.....

9. What are the Benefits and Losses of conservation activities? Tick [√]

No	Conservation Measures	Gains or Benefits	Losses or Costs
1	Afforestation		
2	Checking Illegal activities		
3	Changes in agricultural practices		
5	New protection measures introduced		
6	Community awareness programs and training		

SECTION H: POLICY AND GOVERNANCE

1. Have you participated in any of the conservation measures?	a) Yes		b) No	

2. If yes, in which measures have you participated? Tick [√]

No	Conservation Measures	Participation 1 = Yes 2 = No	Beneficial 1 = Yes 2 = No	Why?
1	Afforestation			
2	Checking Illegal activities			
3	Changes in agricultural practices			
4	New protection measures introduced			
5	Community awareness programs and trainings			
6	Others (Specify).....			

3. If, No why? .....

4. What are the sanctions community members have to face for not adhering to the conservation programs?

No	Sanctions	Your perceptions
1		
2		

SECTION I: HUMAN-WILDLIFE CONFLICT

1. Is human-wildlife conflict common in the area?	a) Yes		b) No	

2. If yes, what are the common human-wildlife conflicts? Tick [√]

No	Types of conflicts	Tick	Trend			Reasons
			Increasing	Decreasing	Same	
1	Crop Damages					
2	Livestock predation					
3	Poaching					
4	Loss of human lives					
5	Others (Specify).....					

3. List the common wild animals and rank them by their intensity of destruction?

No	Types of animals	*Rank	Destruction on
1	Wild Pigs		
2	Monkeys		
3	Barking Deer		
4	Bear		
5	Birds		
6	Sambar		
7	Tiger		
8	Wild dogs		
9	Others (Specify).....		

*Codes: *1 = Most Destructive; 2 = Destructive; 3 = Neutral; 4 = Not destructive*

4. Did you lose your crops or livestock to wild animals?	a) Yes		» Q 5	b) No		» Q

5. If yes, did you receive any compensation?	a)	Yes		b) No	

6. What compensation did you receive? Tick [√]

No	Compensation	Value (NU)	Satisfaction Level					
			Very unsatisfied	Unsatisfied	Neutral	Satisfied	Very satisfied	Reasons
1	Financial							
2	Kinds							
3	Others							
4	Others.....							

7. How satisfied are you with the compensation you have received?

No	Level of satisfaction	Very Unsatisfied	Unsatisfied	Neutral	Satisfied	Very Satisfied
1	Tick [√]					
2	Reasons					

8. What are the impacts of HWC?

No	Impacts of HWC	Tick [√]	*Rank
1	Changes in cropping pattern		
2	Reduction in crop yield		
3	Abonnement of land		
4	Shift in livelihood activities		
5	Reduction in cultivation area		
6	Others (Specify).....		

1 = Very Frequently, 2 = Frequently; 3 = Occasionally; 4 = Rarely; 5 = Never

9. What are the measures taken and supports received?

No	Human wildlife Conflict Measures	Tick	*Effectiveness	Reasons
1	Normal Fencing (Bamboo and wooden)			
2	Electric fencing			
3	Barbed wire fencing			
4	Trench Digging			
5	Guarding			
6	Laying traps in the field			

7	Use of Scarecrows			
8	Use of artificial explosives			
9	Others (Specify).....			

**Codes: 1= Very effective; 2 = Effective; 3 = Neutral; 4 = Less effective; 5 = Not at all*

10. Did you receive support for initiating interventions to minimize human-wildlife conflict?	c) Yes		d) No	

11. If yes, what initiatives have you started?

No	Types of initiatives and supports	Supporter	Monetary or kinds	Your own contribution
1	Electric fencing			
2	Change in cropping pattern			
3	Traps			
4	Others			

12. How satisfied are you with the supports you have received?

No	Level of satisfaction	Very unsatisfied	Unsatisfied	Neutral	Satisfied	Very satisfied
1	Tick [√]					
2	Reason					

13. Any suggestions for minimizing human-wildlife conflict?

Annexure 4.6: WBH key informant interview questionnaires

KEY INFORMANT SELF ADMINISTERED SURVEY QUESTIONNAIRES

Project Title: Ecosystem and Socioeconomic Resilience Analysis and Mapping (ESRAM)

Assignment:	Develop protocols and undertake an Ecosystem and Socioeconomic Resilience Analysis and Mapping (ESRAM) and Biodiversity Assessments in White-bellied Heron (WBH) habitats in 6 districts along Punatsangchhu and Mangdechhu basin.

NOTE:	This interview aims to identify the appropriate approaches and measures for enhancing rural livelihood in designing and implementing WBH conservation activities. It will focus on thematic areas critical to rural livelihood and WBH conservation as perceived by the key informants in the study areas. Like Government officials, academic scholars and experts, local leaders, representatives of specialized groups, and members of the target populations, NGOs, and project personals, if any.

SECTION A: IDENTIFICATION PARTICULARS
1. Dzongkhag :
2. Gewog:
3. Chiwog:
4. Village:

SECTION B: RESPONDENT

1. Age: ..... Years 1. Gender ☐ Male ☐ Female

2. Education level	None	Primary	Middle Secondary	High School	Undergraduate	Master	Others (Specify)
Tick							

3. Occupation	No of years	Job title	Name of Organization

Date of Interview:	DD		MM	YYYY			

SECTION B 1: RESPONDENT'S GENERAL KNOWLEDGE OF LOCAL AREA		
1. How long have you been in this place?	**..... years**	**Since when .....**

2. What is your experience of the place and people?

No	Experiences	Positive	Negative
1	People		
2	Place		
3	Market		
4	Transport		
5	Health		
6	Social life		

3. How do you rate the cooperation in your community?

No	Community	Very Good	Good	Fair	Poor	Very Poor
1	Sense of we feeling					
2	Helpfulness and support					
3	Reciprocity					
4	Self sufficiency					
5	Relationship					
6	Solidarity					

4. What are the main livelihood economic activities pursued by the people in the area?

No	Economic Activities	Specify	Rank*
1	Agriculture (cereal crops)		
2	Agriculture (horticulture)		
3	Livestock		
4	Business		
5	Off farm activities		
6	Tourist		
7	Others		

** Codes: 1 = Not at all important; 2 = Slightly important; 3 = Moderately important; 4 = Very important; Medium; 5 = Extremely important*

5. Any idea about the problems faced by the people in carrying out the following activities?

No.	Problems in	Mention the problems
1	Agriculture	
2	Livestock	
3	Farm businesses	
4	Tourism related	
5	Off-farm activities	
6	Others (specify)	

6. What potentials do you see in the locality?

No.	Potential development areas	Specify	Reasons
1	Agricultural		
2	Livestock		
3	Farm businesses		
4	Tourism		
5	Natural resources		
6	Others		

SECTION C: RESPONDENT'S KNOWLEDGE OF WBH

1. Do you know what WBH is? a) Yes ☐ b) No ☐ If no, procced to Q.

2. If yes, since when did you know about it? .....

3. What is the current status of WBH in the world?	Endangered	Not endangered	No idea

4. Have you seen WBH in the locality? a) Yes ☐ b) No ☐

5. If yes,	When did you see it?	Where?	How many?

6. Are you aware of WBH conservation activities in the locality? a) Yes ☐ b) No ☐

7. If yes, in your opinion, which conservation activities are successful and which are not?

No	Conservation Activities	Success*	Reasons
1	Afforestation		
2	Checking Illegal activities		
3	Changes in agricultural practices		
4	New protection measures introduced		
5	Community awareness programs and trainings		
6	Others (Specify)		

**Codes for Success: 1 = Successful; 2 = Unsuccessful; 3 = No Comments*

8. Any suggestions for improving the livelihood of the people and conservation activities of the WBH?

THANK YOU FOR YOUR TIME AND PARTICPATION.

Confidentiality and use of Information

The information will be used solely for research purposes and will remain confidential.

05 PROTOCOL FOR ECOSYSTEM SERVICES VALUATION: DISCRETE CHOICE EXPERIMENT

5.1 Introduction

Forests occupy 70% of the land surface area in Bhutan and are home to many species of birds, mammals, reptiles, amphibians, plants and trees. Forest and river ecosystems have an ecological, aesthetic, and socioeconomic significance, not only for those living in these areas, but also for people living close to them. Most of the population depends directly on forest and river resources for their livelihoods and well-being, and indirectly on these resources for water, hydroelectricity, timber, biodiversity and niche products, mineral resources, flood control, and recreation. Regardless of their important contribution, they are still marginalized in the development agenda. The importance of ecosystem services arising from mountains is not well recognized in the country. Methods for economic valuation of services and payment mechanisms in these areas are necessary to understand and realise the benefits.

Lately, there has been some progress in applying economic thinking to the use of biodiversity and ecosystem services. The two critical points to consider are (1) why livelihood depends on maintaining the flow of benefits from ecosystems; and (2) why successful conservation needs to be grounded in sound economics, including clear recognition, efficient allocation, and fair distribution of the costs and benefits of conservation and sustainable use of natural resources. Conducting value of ecosystem services has grown rapidly in other countries with a similar context in recent times. While the use of the value of mountain ecosystems is increasing in many parts of the world, there is a need to develop sound methodologies and practice of valuing them in Bhutan in order to realise the benefits of an ecosystem.

5.2 About the Manual

This manual aims to provide a framework for the economic valuation of ecosystem services focusing on forest and water resources in Bhutan. The manual focuses on the Discrete Choice Experiment (DCE) as one method of assessing the value of ecosystem services.

The manual begins with a general introduction to ecosystem services valuation and its importance. Thereafter the manual explains the stages and steps in conducting a systematic DCE. To illustrate the points for better understanding, the manual uses a case study from RSPN's first ESRAM exercise to assess preferences for ecosystem services and willingness to pay by the communities along the Punatsangchu and Mangdechhu[5] basins.

[5] The study was conducted in September-October 2021 by Center for Environment and Development (CED) for Royal Society for Protection of Nature (RSPN).

First, it presents the background to the study, then examines the stages of a DCE, identification of attributes and level, experimental design and constructing choice sets, with the properties of the design assessed, questionnaire development, data input, with consideration to the formation of the data matrix, and analysis and interpretation of data, with a focus on the policy relevant uses of a DCE, such as what attributes are important, and the monetary value of attributes (willingness to pay). The focus is "hands-on" advice—common in all DCEs.

This guide aims to provide easy-to-read information and step-by-step advice on a quantitative research method that can help identify appropriate policy responses to ecosystem valuation. This method can deliver policymakers with measurable measures of the relative importance of different ecosystem characteristics that influence the choice conservation in rural and semi-urban areas.

The manual provides specifics about the variety of questions such a method can (or cannot) answer, and the type of data, analysis, and analytical skills required to perform the research. Finally, it will provide information on the logistical and scientific requirements to perform such research and will offer links to resources for more detailed scientific and academic materials that can be consulted by advanced researchers.

Who is this manual intended for?

- Policy and decision-makers who are interested in examining the question of ecosystem valuation in more detail and want to use this information to improve the design of their conservation programs.
- Researchers in the field who want to familiarize themselves with the technical requirements of conducting such a DCE. Certain sections of the guide are relatively straightforward (some steps of the method, for example) while others require a higher level of statistical and methodological skill.

How to use this manual

This manual gives an overview of the stages involved in conducting a DCE, and the issues that can arise. For each step, a summary box highlights the key messages, followed by detailed explanations of the concepts, data requirements, and statistical approaches. This manual uses examples from ESRAM DCEs to illustrate the various elements of each step. It offers good practical guidance to the reader, along with further details, useful technical resources, and references to software packages.

A small subsection pulls together information on logistical requirements and challenges in conducting a DCE. Section 1 then offers some concluding comments.

A reference list is provided at the end, broken down into areas. Useful websites for software and other statistical methods or tools are also given.

5.3 Ecosystem Services Valuation

5.3.1 What is ecosystem services valuation?

The ecosystem is part of the pool of capital owned by an economy. These capitals include physical, financial, human and natural capital. Ecosystem services can be further categorized into provisioning (direct inputs for livelihood and economy), regulating services (flood and disease control), supporting services (conditions for life and maintenance), and cultural services (recreation, spiritual). The dependence on the ecosystem is more pronounced in developing economies, and this increasing demand can put pressure on the ecosystem with far-reaching unintended consequences outside the natural world.

In order to sustain livelihood by optimally using ecosystem services, there is now an increasing focus on the sustainable use of ecosystem resources. One of the constraints towards sustainable management of the ecosystem is the lack of a market. For instance, it is difficult to put a monetary value on regulating, supporting, and cultural services as compared to provisioning services. In an economy, there is a cost involved for any benefit. But, for the case of ecosystem services, cost attribution is difficult. When cost is not incurred, the use of ecosystem resources will increase. This issue has now received much importance in the policy world. However, lack of market is not the only reason for dwindling ecosystem services. There are many factors such as lack of policy, the opportunity cost of conservation, technological development and ideology and politics among others. All of these have resulted in a lack of investment and management of the ecosystem.

One of the approaches to understanding and conserving an ecosystem is the economics approach. The economic approach tries to frame the debate in terms of cost and benefit. One of the prominent methodologies in recent times is the valuation of ecosystem services. Valuation of ecosystems in the mountainous country can be difficult because of heterogeneity in space and users. The way the ecosystem interacts in a dynamic and multifunctional way further complicates the valuation exercise. Hence, the valuation of ecosystem services can help to provide an understanding of the tradeoffs between society and nature. Understanding this tradeoff can help to enhance human welfare in a sustainable way. This is why the valuation of ecosystem services is essential in providing baseline information for future policy. Most of the critical conservation areas in the country are located in remote and poorly accessible areas. The local communities living in these fragile areas have limited livelihood options, and often receive little benefit from development activities. Although some of the provisioning services such as food are relatively easy to assess in monetary terms; others, which do not have a direct market value, pose a greater challenge. Ecosystem services are also vulnerable to natural disasters such as landslides, floods, and the impacts of climate change.

The economic valuation of an ecosystem requires a clear understanding of both the ecological and economic aspects and of how these are interrelated. Ecosystems are highly interdependent and often the survival of one species depends on the existence of another - the ecological threshold and interdependency of the different components are essential

to the survival of the ecosystem as a whole. It is thus important to integrate both ecological and economic perspectives into the valuation.

5.3.2 Why carry out economic valuation?

There are numerous reasons why it is necessary to value ecosystem services, and different ways in which economic valuation aids in improving ecosystem management. Among others, economic valuation is a prerequisite for designing programs on Payments for Ecosystem Services (PES).

Attaching a monetary value to ecosystem services in mountain areas will help to increase awareness of the importance of the services that upstream systems provide to downstream users. For example, when a downstream urban town makes a monetary payment to an upstream village for conserving and protecting water. This willingness to pay for conserving water by communities helps to create awareness of the importance of the ecosystem.

Valuation of ecosystem services is essential for generating a market. An economic valuation can contribute to the conservation of mountain ecosystems by incentivizing mountain communities for their conservation of the ecosystem resources. The market for carbon known as carbon trading is one good example of how valuation creates a market for ecosystem services.

Valuation also helps in choosing between diverse policy options, recognizing more efficient and cost-effective alternatives, and in designing suitable institutional and market (and non-market) instruments, including PES. For example, helping communities to set up stay-home in Phobjikha has shown to be a more effective policy in protecting Black-necked Crane compared to the lack of incentives for conservation of these endangered species.

The valuation exercise will provide supporting arguments for the protection of ecosystem resources. They would also help to improve our understanding of ecosystems in general by evaluating the costs and benefits of development and environmental choices as a trade-off between the resources and their utility values. For example, if valuation finds that WBH habitat is demanded by communities and they are willing to bear the cost, it will offer a valuable justification for more investment in the conservation of WBH.

Assigning a monetary value to biodiversity and to the services derived from it is important because it means that the benefits associated with biodiversity are able to be directly compared with the economic value of alternative resource use. For example, communities are willing to buy and use solar stove. This cost can be taken as the value of fuelwood that they have been using from the ecosystem.

When valuations have been conducted, it is possible to show how costs and benefits are spread across society. In addition, when a compensation instrument exists, it is possible to extend justice and equity by distributing the benefits and costs of any change in ecosystem services. This can facilitate cost-sharing for management creativities that provide incentives to the poor, who are the main custodians of mountain ecosystems. For

example, the policy of providing compensation for wildlife damage to crops and humans by the government provides a good example of how cost and benefit should be distributed in conservation.

5.3.4 Types of economic value

To assign an economic value to the benefits from ecosystem services (or costs), it is first necessary to describe what goods or services are being valued. There are two different approaches for assigning value: anthropocentric and ecocentric or biocentric. The former approach defines the value of an ecosystem in terms of its ability to serve human beings. In other words, ecosystems have only 'instrumental' value in so far as they serve a purpose for mankind. The later approach takes the view that all living organisms have 'intrinsic' value that is independent of their instrumental value to serve human beings.

To capture all the ecosystem services, economists have developed a framework for 'total economic value' In this, the benefits derived from these services are grouped into two broad categories: 'use values' and 'non-use values. Use values are further subdivided into direct use values, indirect use values, and option values. Direct use values are those that derive from both the consumptive uses of ecosystem goods and services (such as food, fibre, fuelwood, and medicine) and the non-consumptive uses (such as satisfaction and recreation). Indirect use values are those that arise from indirect ecosystem support in production, regulation, and supporting services, such as nutrient cycling, climate regulation, hydrological recycling, and flood control. Option values are those that are associated with maintaining the availability of certain ecosystem services with the awareness that it is difficult to accurately anticipate future demand for such resources. Non-use values are commonly divided into existence values and bequest values. Existence values derive their economic worth from the fact that people appreciate knowing that certain ecosystems resources exist, even if they have no intention of actually using them. Bequest values are related to the satisfaction that people derive from ensuring the continued existence of ecosystem resources for the future generation.

5.3.5 Economic valuation techniques

Environmental valuation techniques can be classified in many different ways. A broader classification would describe them as revealed preference methods and stated preference methods. Revealed preference methods use the actual behaviour of individuals as revealed in the market. The demand on existing data that are actually a true representation of the behaviour as it exists. There are a number of techniques under this category and policymakers generally prefer these techniques to the stated preference methods. This is mainly because stated preference methods use hypothetical behaviour stated in surveys in response to a hypothetical question. In developing countries, the prevalence of stated method usage is higher because of a lack of data.

In another classification, valuation techniques are categorized under three main headings: actual market-based methods, surrogate market-based methods, and contingent market-

based methods. This is another way of distinguishing the basis of the existence of a market. For example, if there exists a formal market for land, then this market can be used to estimate the value of any ecosystem service like the lake, fortress, religious sites etc. The revealed preference method is further divided into two categories; actual market-based methods and surrogate market-based methods.

Another way to classify them is to interpret the two major categories (revealed preference and stated preference) into direct and indirect methods. The direct methods are mostly used for ecosystems where the benefits are direct such as demand for piped drinking water. In the past, their applications have also been mainly in developed countries. Most of the techniques are relatively new and the theoretical frameworks of some of the techniques are in the process of further refinement. These techniques are founded on the Microeconomics Theory. Combined with statistical tools, there are numerous practical cases of economic valuation in developing countries too, now.

5.4 Discrete Choice Experiments

5.4.1 Introducing Discrete Choice Experiments

Discrete Choice Experiments (DCEs) are a quantitative method for valuing ecosystem services. This methodology has recently emerged as a very attractive method for researchers and policy makers alike, because it provides quantitative information on the relative importance of various ecosystem characteristics that influence conservation measures. This method goes beyond the traditional qualitative assessments and provides quantifiable data that can better guide the selection of the most appropriate strategies for conservation of ecosystem. 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.

As well 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 actually do— referred to as revealed preference data. A key advantage of this hypothetical approach is that it allows preferences to be elicited for ecosystem conservation policies that do not exist but which are planned for the future. It helps policy makers to make decisions on informed preference revealed through this type of state preference experiment.

It is useful to contrast DCEs with randomized experiments for public policy, which would be a form of eliciting revealed preferences. Randomized experiments would be constrained by the range of job opportunities available. While a DCE commonly presents individuals with a number of hypothetical choices, it would be hard to offer individuals such a range of job choices in reality.

The hypothetical nature of DCEs also allows the independent variables to be identified in advance (via experimental design methods, which allows identification of all effects of interest. This contrasts with revealed preference data, which cannot be controlled a

priori so that model identification cannot be guaranteed because multi-collinearity may be present. Moreover, the use of revealed preference data is limited in most developing countries given the lack of data. Stated preference methods also allow large quantities of data to be collected at a moderate cost.

The DCE has several key stages:

- Identification of attributes and assignment of levels;
- Experimental design: deciding what choices (policy alternatives) to present to individuals;
- Development and administration of the survey (data collection);
- Data input; and
- Analysis and interpretation.

Given that DCEs involve responses to hypothetical choices, it is crucial that each stage of a DCE is carried out well. Failure to do so may result in numbers that lack validity.

5.4.2 What can policymakers get out of DCEs?

DCEs are a quantitative methodology, or technique, for assessing willingness to pay for ecosystem services, as a function of ecosystem characteristics. DCEs are useful for policy makers who want to investigate ideal parcels of incentives or policy options to induce society to the conservation of ecosystem and biodiversity.

More specifically, a well-conducted DCE can answer the following types of questions: What is the range of feasible and affordable policy interventions or incentive packages to address ecosystem conservation? (This information should be collected during the qualitative research phase, before starting a DCE, as part of the Focus Group Discussion (FGD).

- What characteristics of the ecosystem (or conditions) are most important for conservation for society?
- What characteristics of the ecosystem (or conditions) are most important in encouraging society to practice conservation?
- How much of the ecosystem services are society willing to trade for monetary or nonmonetary incentives?
- How do individual characteristics (such as sex, rural origin, socioeconomic status, intrinsic and extrinsic motivations) affect the preference for ecosystem services?

5.4.3 When to conduct a DCE?

Policymakers who want to assess or introduce new strategies for encouraging ecosystem and biodiversity conservation can use a DCE to get answers to the above questions. Before conducting a DCE, however, a thorough situation analysis through an FGD should be conducted to inform the current level and conditions of society's dependence

on the ecosystem, as well as the barriers and opportunities for conservation. A DCE should therefore be seen as one component of broader policy review and planning of conservation of our ecosystem and biodiversity. Unlike studies of revealed preference (which means actual choices) DCEs can also be used to estimate the effect of policies yet to be implemented, such as an increase in labour contribution for encouraging more conservation. This makes DCEs helpful for planning future policy reforms. Ideally, DCEs should be followed by real-world experiments that present the preferred package to the target population.

5.4.4 Logistical issues in conducting DCEs

» *Why conduct a DCE?*

In most circumstances, DCE comes as a pure research interest. However, more and more policymakers have developed an interest in the results of DCE studies, and in some situations it has been used to evaluate ecosystem valuation in many parts of developing countries with a similar context to Bhutan. In this context, it was the policy question, suitability and strength of the method that gave intriguing and desired results for valuing ecosystem services coming both from RSPN and the expert.

This manual endorses that before starting a DCE, substantial discussions need to take place in order to make full use of the results in the policy decision process. The method is quite expensive and requires significant investment in time and other resources; therefore, it is critical that its results are effectively used for policy implementation.

» *How long does it take?*

Conducting a DCE can take on average 3 months for a single case study like the ESRAM valuation exercise. The several stages of conducting this work are:

- a planning phase: 4 weeks
- qualitative work: 3 weeks
- design of questionnaires, including piloting and testing: 3 weeks
- survey administration: 2 weeks
- data entry and analysis: 2 weeks
- report writing: 3 weeks

» *How much does it cost?*

It is not always easy to get accurate information on costs, as often complex research programs are funded from various sources. A rough assessment of costs for conducting DCEs in five low- and middle-income countries (Ghana, Thailand, Uganda, Tanzania and Malawi) from 2009–2011 showed that total costs varied from $20,000 to $150,000, including costs of international consultants, local research teams, in-country travel, and other elements (such as laptops). In the ESRAM it must have cost 1.5-2M in local currency.

» *What skills and competencies does the research team need?*

The research team is usually composed of both international and national researchers and requires multidisciplinary skills. This includes expertise in qualitative research for developing attributes; knowledge of experimental design methods for informing the selection of choices to be presented; and advanced analytical and statistical skills, in particular varieties of logistic regression, for analysis of the data. Other competencies include logistic management, enumerator training and field expertise. Many institutions may benefit and will need much capacity building and support to conduct a DCE well.

» *What logistical challenges are likely?*

Weather often delays or impedes the execution of a DCE, so this has to be taken into account in planning. Local transportation, infrastructure, and availability of cars, along with security issues, need to be considered. Access to heads of local institutions is sometimes difficult, so good discussions for the introduction of the study to policy makers are needed.

» *How can policymakers use the results?*

The results of a DCE can be valuable for policymakers who want to better understand the relative importance of ecosystem characteristics on household preference and conservation. The DCE should not be conducted isolated from the policy debate but should inform discussions around ecosystem valuation issues and targeted conservation intervention measures. Once the national conservation of ecosystem policy and plan has been discussed by policymakers, adequate policies to complement these policies can be designed, based on quantitative information coming from the DCE.

Such information as the stated preference for ecosystem services, or the estimated willingness to pay for such services, are of critical importance in designing appropriate conservation strategies. Once the results of a DCE are made available, real-life experiments can be set up to implement the strategies suggested by the DCE results, then monitor and evaluate implementation outcomes.

5.5 Step by Step Approach to conducting DCE

5.5.1 Step 1: Identification of attributes and levels

DCEs are an attribute-based measure of value, as said. Thus, the first stage is to define the attributes and levels. The study began with a long list of possible attributes, based on available empirical literature on ecosystem valuation, as well as other factors that economic theory predicts will be important for the choice of ecosystem services. The list is featured in Table1.

Having established the initial list of potential attributes, the next FGD was conducted to further investigate these attributes and their respective levels to include in the DCE. This FGD was conducted with community members of Berti to identify additional attributes and their levels. Through discussion, confirmation on the above attributes was carried out

that are relevant for the community and conservation. As an example, habitat for WBH was added to the list.

As indicated in the study report, the theoretical background to a DCE assumes that when an individual completes a DCE, for each choice he or she considers all the attributes and levels, and makes trade-offs. It is therefore important not to include too many attributes in the final DCE, or individuals may resort to simple decision-making strategies (such as always making decisions based on drinking or irrigation water). The discussion also provided information on the relative importance of attributes indicating how to reduce the number to a manageable level. In addition the discussions were used to discuss levels for the attributes. Details of the interviews are given in Box 1. Seven attributes were identified as both important to interviewees and policy relevant (Table 5.1). Evidence suggests that this is a manageable number.

Box 1: *Summary of interviews to derive attributes and levels*

Although due to time limitations, only one FGD was conducted in Berti, in theory many such FGD should be undertaken in different study sites before the choice set is constructed.

What ecosystem services are taken from the forest in this village? [List them on a chart]

What do you think is the trend of these services?

Could you please tell which of these services are most preferable to least preferable?

Among these most preferable ones, let us look at the chart and see if we can find out your desirability of these resources? [Quantity value is preferable in most cases]

How would you prefer to manage these forest resources to maintain your dependence and reliability on ecosystem services?

Has fees or labour contribution been used or would you like to use them as part of your contribution?

What is the current level of contribution for fees or labour? What changes are acceptable for you?

Are there any other forms of contribution you have thought about or might prefer?

Table 5.1: *Attributes and levels in the ESRAM Study*

Attributes	Description of attribute	Levels	Modelling
Drinking water	Amount of water availability per household per day during	» As much as now (100 lit/per day) » Increase » Decrease	Dummy variable
Irrigation water	The number of months during which the irrigation water is available for farming	» As much as now (6 months) » Increased » Decreased	Dummy variable
Fuelwood collection	Amount of fuelwood available per household per year from community forest	» As much as now (100 loads) » Increase » Decrease	Dummy variable
Fodder and animal grazing	Amount of fodder available per household per day	» As much as now (1 load) » Increase » Decrease	Dummy variable
Timber	Amount of timber collected per household per year	» As much as now (100) » Increase » Decrease	Dummy variable
Fishing	Amount of fish taken from river per household per year	» As much as now (10 kg/per year) » Increase » Decrease	Dummy variable
Wild food items	Amount of wild food harvest per household per year	» As much as now » Increase » Decrease	Dummy variable
White Bellied Heron (WBH)	Presence of WBH around the communities	» Status quo » Yes » No	Dummy variable
Labour contribution OR Resource management fee	Number of working days household are willing to participate to implement a resource management OR An introduction of a new annual fee for resource management. This is additional to what households are currently paying	» No additional contribution » 1 month » 2 months OR » No additional fee » plus Nu.500 per year » plus Nu.1000 per year	Dummy variable Dummy variable

5.5.2 Step 2: Experimental design and construction of choice sets

» *Design*

Once agreeing on attributes and levels, the researcher defines the choice sets, which are hypothetical ecosystem service benefits and costs resulting from combining the attributes and levels. Often, the combinations derived from the full set of attributes and levels (full factorial) result in too many choice sets to present to individuals. So, for example, in this study, the full factorial is 19683 possible job profiles (9 attributes at 3 levels). This implies (19683*19682/2) 193,700,403 possible choice sets. Experimental design methods are commonly used to reduce the choice set to a manageable level while allowing the researcher to infer preferences for all profiles.

Cognitive fatigue is a major factor you have to consider while developing the choice set. Even after using experimental design methods, a large number of choices may remain for presentation to respondents. This raises the question of the number of choices subjects can respond to, before becoming tired, bored, or unmotivated. The practitioner should address the issue of the feasible number of choices in the pilot work. When the number of choice sets and the attributes within the choice set is numerous but essential, other methods like double randomization can be explored. When the experimental design produces too many choices to present to one respondent, it is possible to block the design into smaller sets. A design with 40 choices may be blocked into two groups of 20 choices. This may be done randomly or the software package called DCREATE for STATA generates blocks that still satisfy efficient design criteria.

Once choices have been derived from the experimental design it is important to consider whether to have a forced choice or add an opt-out option. A forced choice, as the name suggests, forces respondents to choose one of the conservation policies on offer. An opt-out gives respondents the option of not choosing any of the policies on offer. If an opt-out is included it is important to be very clear to respondents what this means. Where respondents in a community are being surveyed, the opt-out would be to continue doing what they are doing; hence information on what they are doing must be collected. The inappropriate use of forced choices may result in biases with respect to parameter estimates. That is, individuals may be forced to take up a policy when in reality they would choose not to. Given that the objective of many studies is to look at WTP estimates and the probability of take-up, the practitioner is encouraged to consider the role of opt-out options in their DCE. When constructing choices the researcher simply adds an opt-out/ current situation option to the choice set derived from the experimental design.

Designing an experiment generally involves the identification of choice sets made up of optimal combinations of attributes and their levels. In addition, combining these into a limited number of choice sets or combinations of alternatives is not easy. For this purpose, we will use the DCREATE module in Stata which is often used for generating experimental designs. Using this software, 20 choice sets will be created using a D-efficient design as seen in Box 2. Each choice set will include three policy alternatives (Alternative

1, and Alternative 2) plus the status-quo. In addition, the researcher must consider the specification of the utility function to be estimated at the design stage, taking into account of potential interaction terms and the choice between labeled and generic experiments. Table 1 shows that all the attributes are modeled as dummy variables in the regression analyses. It also shows the regression coding labels for the variables.

Having defined the functional form of the utility function to be estimated, the researcher must then employ experimental design methods to derive the choice set. As shown elsewhere, both orthogonal and D-efficient designs have been employed in several studies. Here a D-efficient design was developed with a priori assumptions made about the parameters using Bayesian Design. Not all researchers con ducting a DCE have the skills to write the experimental design program, and catalogues, software, and experts can help them generate such designs. The experimental design applied in this study generated 20 choice sets (Table 5.2).

Box 2: *Stata programming for DCREATE module to create D-Efficient Experiment Design*

```
/*DCE with uncertainty in the priors using a Bayesian design:
Create a dataset containing the full-factorial using genfact.
The three-level attributes are coded 1/2/3/4 and the two-level attributes 1/2 */
clear
matrix levmat = 2,2,2,2,2,2,2,3,3
genfact, levels(levmat)

/*Define b, the coefficient matrix. In this and the following examples all of
the coefficients are assumed to be equal to zero:
Create a matrix containing the attribute levels for the opt-out alternative.
All the attribute levels are set to the base level (1): */
matrix optout = J(1,9,3)
matrix b = J(1,11,0)
/*Define V, the coefficient covariance matrix, which in this example is assumed to be equal
to the identity matrix: */
matrix V = I(11)

/*Create a design with 20 choice sets using dcreate. Dummy coding of the design
attributes is specified using factor variable notation (see fvvarlist). The lowest level
(1) is treated as the base level*/
dcreate i.x1 i.x2 i.x3 i.x4 i.x5 i.x6 i.x7 i.x8 i.x9, nalt(2) nset(20) fixedalt(optout) ///
asc(3)  bmat(b)  vmat(V)
/*Divide the design into two blocks with 8 choice sets each using blockdes*/
blockdes block, nblock(5)
```

Table 5.2: *Choice Set generated for ESRAM Study*

Drinking Water	Irrigation Water	Fuelwood	Animal FodBed	Timber	Fishing	NWFP	WBH Habitat	Labour Fee	Choice set	Alternative	Block
1	1	1	2	1	1	1	2	1	1	1	5
2	2	2	1	2	2	2	1	2	1	2	5
0	0	0	0	0	0	0	0	0	1	3	5
1	1	2	2	1	1	1	1	2	2	1	4
2	2	1	1	2	2	2	2	3	2	2	4
0	0	0	0	0	0	0	0	0	2	3	4
1	2	1	2	2	1	2	2	1	3	1	5
2	1	2	1	1	2	1	1	3	3	2	5
0	0	0	0	0	0	0	0	0	3	3	5
1	2	2	2	1	2	2	1	1	4	1	3
2	1	1	1	2	1	1	2	2	4	2	3
0	0	0	0	0	0	0	0	0	4	3	3
1	1	1	1	2	2	2	1	1	5	1	2
2	2	2	2	1	1	1	2	2	5	2	2
0	0	0	0	0	0	0	0	0	5	3	2
2	1	1	2	1	1	2	1	3	6	1	5
1	2	2	1	2	2	1	2	2	6	2	5
0	0	0	0	0	0	0	0	0	6	3	5
2	1	2	1	1	2	2	2	1	7	1	2
1	2	1	2	2	1	1	1	3	7	2	2
0	0	0	0	0	0	0	0	0	7	3	2
1	1	2	1	2	1	2	2	1	8	1	2
2	2	1	2	1	2	1	1	2	8	2	2
0	0	0	0	0	0	0	0	0	8	3	2
2	2	2	1	1	1	2	1	1	9	1	3
1	1	1	2	2	2	1	2	2	9	2	3
0	0	0	0	0	0	0	0	0	9	3	3
2	1	1	2	2	2	2	1	2	10	1	1
1	2	2	1	1	1	1	2	3	10	2	1

0	0	0	0	0	0	0	0	0	10	3	1
1	2	1	1	1	1	2	2	2	11	1	1
2	1	2	2	2	2	1	1	1	11	2	1
0	0	0	0	0	0	0	0	0	11	3	1
1	2	1	1	1	2	1	1	3	12	1	1
2	1	2	2	2	1	2	2	2	12	2	1
0	0	0	0	0	0	0	0	0	12	3	1
2	2	2	2	2	1	1	1	3	13	1	4
1	1	1	1	1	2	2	2	2	13	2	4
0	0	0	0	0	0	0	0	0	13	3	4
2	1	1	1	1	1	1	1	1	14	1	3
1	2	2	2	2	2	2	2	3	14	2	3
0	0	0	0	0	0	0	0	0	14	3	3
2	1	1	1	2	1	1	2	3	15	1	2
1	2	2	2	1	2	2	1	2	15	2	2
0	0	0	0	0	0	0	0	0	15	3	2
1	1	2	1	2	1	1	1	2	16	1	5
2	2	1	2	1	2	2	2	1	16	2	5
0	0	0	0	0	0	0	0	0	16	3	5
2	2	1	1	2	1	2	1	2	17	1	4
1	1	2	2	1	2	1	2	1	17	2	4
0	0	0	0	0	0	0	0	0	17	3	4
2	1	2	2	1	2	2	2	3	18	1	3
1	2	1	1	2	1	1	1	1	18	2	3
0	0	0	0	0	0	0	0	0	18	3	3
1	1	2	2	2	1	2	1	3	19	1	4
2	2	1	1	1	2	1	2	1	19	2	4
0	0	0	0	0	0	0	0	0	19	3	4
2	2	2	2	2	1	1	2	1	20	1	1
1	1	1	1	1	2	2	1	3	20	2	1
0	0	0	0	0	0	0	0	0	20	3	1

» *Development of the questionnaire, pretesting, and data collection*

An introduction to the questionnaire will be required, indicating the subject of the study, why the respondent has been chosen, who is carrying out the survey, and how the results will be used. The challenge for the researcher is to ensure the questionnaire that the respondent engages and responds honestly. The following may also be included:

- » warm-up choices—to familiarize respondents with the question design; and
- » Rationality/internal consistency checks to allow the researcher to ensure that respondents were engaged in the exercise and taking it seriously.

Once the choices have been decided (from the experimental design, warm-up questions, and rationality/internal consistency checks), consideration should be given to their presentation. Often pictures are useful to explain attributes in a rural context where literacy rate is low. Since, DCEs target concerned villages and in most instances farmers, visual elements may help by reducing potential boredom and helping respondents engage.

» *Warm-up question*

One warm-up exercise is recommended, where respondents are introduced to the choice situation. The questionnaire should include a one-page introduction to the task during which the enumerator explains the choice set, stresses the importance of considering all attributes, and makes the respondents understand the exercise before attempting to complete the choice sets.

» *Pilot questionnaire*

The DCE was tested in the field with some enumerators during the training. It was further tested with a few respondents. The respondents completed a relatively long questionnaire before the DCE exercise and were then interviewed about various issues concerning their participation. The focus was on three parts of the DCE:

- » Formulation of attributes and levels: were the attributes and levels clear and did they have the right range? Were any important attributes lacking for the choices to be meaningful or were any included attributes perceived not relevant when making choices?
- » Was the task understood? Were instructions good enough? Were all attributes traded off for each other?
- » How did the respondents experience the exercise: were there too many choices to make? Was it fun or boring?

As a result of the pilot, the formulation of some of the attribute levels was changed to make them more clear to the respondents and to get the cost variable levels right in particular. Moreover, some of the questions respondents were asked before they participated in the DCE were reformulated.

The pilot also indicated that respondents found 20 choices, a large number to complete. They were therefore divided into two blocks each for labour and fee, with each respondent facing 4 choices. Each of these 20 choices was divided among 10 enumerators with each enumerator asking only 4 choice sets to a respondent. There were two types of DCE questions; one for the WBH area and one for the WBH-potential area. The DCE choice exercise between these areas differed in one attribute only, i.e. WBH habitat. The status quo of the WBH area will be 'Presence of WBH habitat', while it will be 'Absence of WBH habitat'.

» *Data collection*

The data were collected during the autumn of 2021 during the month of September and October with the help of 10 enumerators. The enumerators were graduates who could comprehend the purpose of the research and data collection procedures. All the enumerators were deployed together in one study site to ensure that respondents will cover all the 20 blocks of the choice experiment. As whole respondents were visited at the time that was practical to have required time for interview. They were guided supervisor during the entire data collection period. It may well be sufficient to have one researcher or research assistant in the field. The team leader traveled on occasions for logistic facilitation. Some 1256 respondents in WBH spotted and potential areas were selected to ensure maximum representations. These study sites are located within 2 kilometers of the river basin to ensure data reliability and reality. These were followed for Zhemgang, Gasa and Punakha districts. For Tsirang, Trongsa, Dagana and Wangdue Phodrang maps were provided for reference by field officers from RSPN and Forest Division.

The data were mostly collected during the daytime, on the household premises. This largely explains the high response rate, which is required for a DCE. They were given an individual introduction to the study, signed consent forms, and were guided through a couple of examples of choice sets before completing a paper version of the DCE by themselves (often at the respondent's house).

Participation was voluntary, and respondents were not compensated in any way. In addition to the DCE choices, the respondents answered a series of questions that covered, among other things, their background, motivation, beliefs, and attitudes. The questionnaire took on average 45 minutes to complete, confirming that it was wise to let each respondent make only 4 choices instead of the total of 20 choices generated by the design. Data collectors spent one day at the training center at the College of Natural Resources.

If the intention is to conduct a DCE on respondents in remote and far-flung rural areas of the country, logistical challenges in reaching the respondents will probably be greater, because more travel will be required, and so the DCE is likely to be more costly in terms of time and money. It took over 46 days to collect data from 1256 households. However, if conducted correctly, they will provide important and valuable information on the preferences of ecosystem services among the existing stock of communities along the river basins that are the habitats of WBH, and the gains may more than outweigh the costs.

Even though relatively thorough testing had been carried out in the pilot, enumerators were asked to explain how they made their choices understandable to the respondents. This was done to check that the task was understood, that real trade-offs were being made, and to get a better impression of the reasoning behind choices that each respondents made. The interviews were very reassuring in the sense that all respondent reported making trade-offs between the attribute levels and were able to reconstruct and demonstrate the trade-offs they had made. Because respondents were mostly uneducated, making this effort and reassuring the data collection procedures were immensely important.

Who receives the questionnaire will depend on the group of potential-WBH or WBH in which the researcher is interested. The DCE objectives should be relevant to the targeted individual or community. For example, it is likely that communities without relevance to WBH and ecosystem dependence would make a different choice on policy options and how they perceive the attributes. This highlights the importance of having a representative sample and of collecting background information on the respondent. The sample may be purposely selected according to certain characteristics. This in most part can be achieved by communicating with stakeholders in the field. Given a defined target sample, the sample size must be determined. This is a very important issue because samples that are "too large" may waste time, resources, and money, while samples that are "too small" (less than 30) may lead to inaccurate results (imprecise estimates).

Various questions need to be answered before a suitable sample size can be determined. The first refers to the level of accuracy (precision) required. In general, the higher the level of accuracy required, the larger the sample size should be. Sometimes the sample size required is so close to the entire survey population that it makes more sense to simply survey everyone. More often "smart" designs are used to reduce the required sample size without reducing the accuracy. A second issue is whether estimates for subgroups, as well as for the overall population, are required. The overall sample size needs to be large enough to ensure that an adequate level of accuracy for these subgroups can also be achieved. Another important question affecting the sample size required is the level of variability between responses. Usually, the less variable the responses, the smaller the sample size required to achieve the same level of accuracy. Finally, the burden placed on respondents needs to be evaluated. If people are surveyed too frequently, they are less likely to take the survey seriously, so the sample size should not be larger than necessary to obtain the accuracy needed.

Ultimately the selection of sample strategy and size largely depends on the budget and resources available. However, using econometric criteria, subgroups of smaller than 30 individuals would be too small to conduct meaningful statistical analysis. In some rural areas, it is often difficult to use random sampling to obtain sufficient sample sizes.

Consideration must then be given to how to collect the data. Several data collection methods exist, including a self-administered questionnaire can be opted. In rural areas, where different languages may be spoken, translation of the questionnaire may be required. This can also be achieved by having appropriate enumerators with the necessary language skills.

5.5.3 Step 3: Data input

This section is included because the data matrix generated from DCEs is quite different from that generated for most questionnaires. One feature common to all DCE datasets is that respondents answer more than one discrete choice question, resulting in multiple observations for each individual. Furthermore, choice sets presented to individuals contain two or more alternatives, giving multiple observations for each choice set.

The number of observations in a dataset depends on the number of respondents, the number of choice sets per respondent, and the number of alternatives in each choice set. For instance, in the study covered here each choice set has three alternatives (Alternative 1, Current Situation, Alternative 2), so each choice set contributes three observations to the dataset. Moreover, each respondent is presented with 4 choices. As each choice contributes three observations and each respondent faces 4 choices, there are 12 observations per respondent (4 choices x 3 observations per choice). A sample of the final data matrix (an extract from the full dataset) for the case study is in Table 5.3.

Table 5.3: *Example of Data Input in SPSS*

reference_no	site_type	cost_type	Choice_set	policy_alternative	fuelwood_collection	drinking_water	wild_food_items	WBH_habitat	timber	fishing	irrigation	fodder_bedding	Fee
729	WBH	Fee	13	Alternative 1	increase	decrease	increase	Yes	increase	increase	decrease	decrease	100
729	WBH	Fee	14	Alternative 1	increase	increase	decrease	Yes	increase	increase	decrease	increase	1500+
729	WBH	Fee	15	Alternative 1	increase	decrease	increase	Yes	increase	increase	increase	increase	500+
729	WBH	Fee	16	Alternative 1	decrease	decrease	increase	No	increase	decrease	increase	decrease	500+
730	WBH	Fee	13	Alternative 1	increase	decrease	increase	Yes	increase	increase	decrease	decrease	500+
730	WBH	Fee	14	Alternative 2	decrease	increase	increase	No	increase	increase	increase	decrease	1000+
730	WBH	Fee	15	Alternative 1	increase	decrease	increase	Yes	increase	increase	increase	increase	500+
730	WBH	Fee	16	Current situation	No changes	No changes	No changes	No	No changes	No changes	No changes	No changes	100
731	WBH	Fee	13	Current situation	No changes	No changes	No changes	Yes	No changes	No changes	No changes	No changes	100
731	WBH	Fee	14	Alternative 2	decrease	increase	increase	No	increase	increase	increase	decrease	1000+
731	WBH	Fee	15	Alternative 2	decrease	increase	decrease	Yes	decrease	increase	increase	decrease	1000+
731	WBH	Fee	16	Current situation	No changes	No changes	No changes	Yes	No changes	No changes	No changes	No changes	100
732	WBH	Fee	13	Current situation	No changes	No changes	No changes	No	No changes	No changes	No changes	No changes	100
732	WBH	Fee	14	Current situation	No changes	No changes	No changes	No	No changes	No changes	No changes	No changes	100
732	WBH	Fee	15	Alternative 1	increase	decrease	increase	Yes	increase	increase	increase	increase	500+
732	WBH	Fee	16	Current situation	No changes	No changes	No changes	No	No changes	No changes	No changes	No changes	100
733	Potential-...	Fee	13	Current situation	No changes	No changes	No changes	No	No changes	No changes	No changes	No changes	100
733	Potential-...	Fee	14	Alternative 2	decrease	increase	increase	No	increase	increase	increase	decrease	1000+
733	Potential-...	Fee	15	Alternative 2	decrease	increase	decrease	Yes	decrease	increase	increase	decrease	1000+
732	Potential-...	Fee	16	Current situation	No changes	No changes	No changes	No	No changes	No changes	No changes	No changes	100
734	Potential-...	Fee	13	Current situation	No changes	No changes	No changes	No	No changes	No changes	No changes	No changes	100
734	Potential-	Fee	14	Current situation	No changes	No changes	No changes	No	No changes	No changes	No changes	No changes	100

As with any dataset it is useful to start by ordering the variables in some logical way. One suggestion followed here is to present all the variables in a sequence that first describes how the data are organized (such as respondent identifier, choice set identifier), then present the independent variables from the experimental design (attribute levels) followed by the dependent variable (what option respondents chose). Datasets also include other variables relating to the individual, such as socio-economic characteristics. This is not shown here due to space.

Data can be entered in many different ways, but in case of this study, it was coded and entered into SPSS 23. The variables were coded by the experts and distributed to the enumerators who finally entered the questionnaires with the responses that they

collected. It is also much advisable to let the enumerators to enter the data that they have gathered especially when paper questionnaires are used

5.5.4 Step 4: Model Estimation and Interpretation

Statistical inquiry of data generated through is based on the random utility model. The random utility model is the theoretical basis for analysis of the DCE data and those researchers who are appointed to analyze DCE data, should be familiar with it. In this context an individual is assumed to choose between different ecosystem policies or attribute, and opting for the one associated with the highest utility or benefit. Numerous models can be used to estimate respondent preferences for ecosystem services included in the DCE. Some of these models include random effects binary probit and logit, conditional logit, and mixed logit. Irrespective of the method employed for analysis, results from DCE analyses can be used to determine:

- » which attributes are important and how important one attribute is in comparison to other attribute;
- » how individuals trade between attributes of ecosystem (how much of one attribute they are willing to give up for improvements in another);
- » how much individuals are willing to pay for benefiting from these attributes of ecosystem; and

The probability of individuals taking up a policy with these specified attributes. For an application of this model see the report of the ESRAM Ecosystem Valuation Report. Readily available software such as Stata, Limdep/nlogit, SAS, and Sawtooth can be used to estimate such models. Matlab and R are the only free programs for analysis, which are also available but require the researcher to do their own programming. The researcher analyzing the data should look for data analysis coding using terms such as logit, probit, and mixlogit since software packages differ in the exact terms they use.

The coefficients (effect) generated from the logit (or probit) model can be used for two main purposes:

- » To determine whether the attributes are important (statistically significant, as shown by the significance level of the coefficients), the direction of importance (shown by the sign of the estimated coefficients) and relative importance (size of the estimated parameter).
  - The direction of the coefficient signs also provides a check on the theoretical/ internal validity of the DCE model—that is, whether the coefficients move as economic theory or a priori expectation would predict.

Although the above information is very useful, the real value of DCEs is in using them to look at two things: the trade-offs that respondents are willing to make among attributes; and the probability of take-up of defined policy.

- » Trade-offs among attributes can be estimated as long as a continuous variable is included. If this continuous variable is labour days, the monetary value for

other attributes can be estimated. For example, the ratio of any given coefficient divided by the negative of the price proxy (management fee or labour days in this application) can be used to estimate individuals WTP for various ecosystem attributes. For example, we can find the cost people are willing to bear in terms of labour days for managing forest resources in return for more firewood.

» The probability of individuals taking up a policy with specified attributes can be estimated. These predictions are very useful to policy makers as they show the predicted impact on individual's decisions of alternative levels of policy attributes, that is, alternative policies being offered. For example, what factors contribute positively for policy A or Current Situation whichever is chosen by the individual?

All the above analysis can be performed for the total sample, or for subgroups of the sample. For instance, analysis can be done separately for two river basins, different dzongkhags or between WBH and Potential WBH areas. This type of subgroup analysis is commonly carried out in analysis of DCE data.

A discussion on the normality assumption is guaranteed here. It implies that there will be both positive and negative values across the sample being sampled for a given attribute. For example, for the WBH-habitat attribute taking on the values "Yes" and "No", the normal assumption implies a proportion of the population prefers to have habitat for WBH in their area while others may prefer not having habitat. It is often the case that this assumption may not be realistic, and it would be more intuitive to assume a log-normal. It must be understood that the assumption of normality is often made for ease of estimation rather than realism.

» *Setting up the basic regression model*

Researchers should be aware of the requirements of the statistical software packages they are using to analyze the data. This section presents useful tips to prepare data for analysis in a commonly used software package, Stata.

The final sample used in the analysis comprised 1185 respondents, each providing responses to 4 out of 20 completed choices and resulting in 14208 observations. The probability a respondent will select a specified policy alternative is modeled. The probability of choosing a given alternative is determined by the indirect utility. Here it is assumed that this is linear and additive and of the form:

$$V_i = ASC_i + \beta_1 Drinking\_W_i + \beta_2 Irrigation\_W_i + \beta_3 fuelwood_i + \beta_4 timber_i + \beta_5 fodder_i + \beta_6 NWFP_i + \beta_7 WBH_i + \beta_8 fishing_i + \beta_9 Cost_i + e_i$$

where *V* is the utility derived from a given alternative, e refers to the error term. Given the binary choices presented to individuals, the binary logit model and conditional logit model could be used to analyze the data. In Stata researchers can do a logit regression by using the logit command. However, when the data are presented as in Box 4, a conditional logit should be used (since the data are stacked, with each option within a choice on a different

row). The way this data was set up, the clogit command was used. The exact syntax in Stata is:

clogit Choice DrinkingWater IrrigationWater FuelwoodCollection AnimalFodder Timber Fishing NWFP WBH LabourFee if cost_type==1, group (HouseholdNo)

This command runs a conditional logit model and displays as shown in Box.3. Researchers are encouraged to read the documentation for clogit function in Stata to understand the code. This code tries to estimate how each ecosystem services affect the choice of policy alternative. This code is specifically run to find for fee cohort.

When looking at the output of a DCE the first thing the researcher should do is see whether the attributes are significant, and therefore have an impact on the probability of choosing an alternative. He or she should consider the sign of the coefficient, where significant. A positive sign implies that the attribute has a positive impact on the take-up of a given alternative in comparison to the current situation; a negative coefficient is the opposite.

ß1 for instance, shows that increasing loads of drinking water, compared to the current situation, increases the utility of the alternative. This means drinking water is a significant ecosystem service valued in the data set. Further interpretations can be found in the ESRAM valuation report. Overall, the model fits (Prob > Chi2= 0.000) the data well and it converges fast (only after 4 iterations, which shows the match in data and the model.

Box 3: *Sample result of the conditional logit*

```
Iteration 0:   log likelihood = -2561.8823
Iteration 1:   log likelihood = -2555.6282
Iteration 2:   log likelihood = -2555.6025
Iteration 3:   log likelihood = -2555.6025

Conditional (fixed-effects) logistic regression        Number of obs =   6,251
                                                       LR chi2(10)   = 1351.75
                                                       Prob > chi2   =  0.0000
Log likelihood = -2555.6025                            Pseudo R2     =  0.2092
```

Answer	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ASC	-2.451128	.1687556	-14.52	0.000	-2.781883	-2.120373
DrinkingWater	.0155627	.0007253	21.46	0.000	.0141412	.0169842
IrrigationWater	.1472614	.0110854	13.28	0.000	.1255344	.1689885
FuelwoodCollection	.0003992	.0005471	0.73	0.466	-.0006731	.0014715
AnimalFodder	.0254772	.0603188	0.42	0.673	-.0927455	.1436999
Timber	.0035647	.0006202	5.75	0.000	.0023493	.0047802
Fishing	-.0148001	.0056979	-2.60	0.009	-.0259678	-.0036325
NWFP	.0681573	.0533559	1.28	0.201	-.0364183	.1727328
WBH	.2599863	.0758615	3.43	0.001	.1113005	.408672
LabourFee	-.0000986	.0001103	-0.89	0.371	-.0003147	.0001175

5.6 Estimating Willingness to pay

Within the context of ecosystem services issue, inclusion of a cost proxy (such as fee contribution or labour contribution) allows the researcher to estimate of the monetary value of attributes of a ecosystem, that is, how much fee (labour) contribution a respondent would be willing to give up to have an improvement in other aspects of the ecosystem service. This can be estimated as the ratio of the value of the coefficient of interest to the negative of the cost attribute—in this case, fee using the following equation:

$$WTP_{drinking\_water} = \frac{\partial U/\partial(Drinking_{water})}{\partial U/\partial(Fee)} = -(\frac{\beta_1}{\beta_9})$$

The WTP values can be easily estimated by hand (with a calculator). The figures in Box 6 are calculated within Stata and may deviate somewhat from the results obtained with a calculator, simply because of the number of decimals included in the coefficients above. The advantage of estimating WTP within Stata is that the program will also estimate the confidence intervals (reported in parentheses under the WTP estimates). Hole's wtp command for Stata implements the delta method, the Fieller method, and the Krinsky Robb (parametric bootstrap) method.

wtp Labour Fee Drinking Water Irrigation Water Fuelwood collection Animal Fodder Timber Fishing NWFP WBH, krinsky reps (2000)

The interpretation is quite straight forward. For the drinking water, it says that an individual is willing to bear a cost of Nu. 157 in fee contribution to derive the benefits of having more drinking water.

Box 4: *Showing willingness to pay estimates and their confidence intervals*

	DrinkingWater	IrrigationWater	FuelwoodCollection	AnimalFodder	Timber	Fishing	NWFP
wtp	157.84039	1493.558	4.048863	258.3954	36.154457	-150.10617	691.26622
ll	-1166.5015	-11489.479	-51.045826	-5226.7412	-283.58499	-1603.2156	-5136.2516
ul	1559.1851	15018.586	55.607788	5207.0662	370.58171	1112.2324	6966.6962

	WBH
wtp	2636.8385
ll	-20323.115
ul	27360.577

5.7 Estimating ecosystem values for each chiwog using DCE

So far, we have estimated the role of ecosystem services in making choices and estimated the willingness to pay to determine the demand for different ecosystem services. We can go a step further and estimate the total value generated. For this, we use the levels of ecosystem services attributes. We can limit the analysis to the current and a scenario where an intervention leads to an increase in the levels of each attribute. We also use the WTP values for the sample which constitutes the respondents from the fee module. Next, we multiply the WTP values with the values of the current scenario and upper bound as shown in Box 4. The upper bound represents a situation where the value of ecosystem

services increases. We sum the values of both of these scenarios and find the difference. The difference is converted into a dollar value using 73.25 as the existing exchange rate. This value of 348.816 USD represents the total value of the ecosystem generated by the intervention. The total ecosystem value generated is multiplied by the population in each chiwog to find the value of the ecosystem generated by the intervention in each chiwog. This process should be reported for each chiwog in the sample as shown in Table 5.4.

Table 5.4: *Estimating the total value for all ecosystem services*

			Fee	Fee		Value		
	Current Situation	Upper Bound	WTP	Current Situation	Upper Bound	Current Situation	Upper Bound	
Drinking water	100	200	157.84	15784	31568	15784	31568	
Irrigation water	6	9	1493	8958	13437	8958	13437	
Fuelwood	100	200	4.05	405	810	405	810	
Animal bed/ fodder	1	2	258.4	258.4	516.8	258.4	516.8	
Timber	100	200	36.15	3615	7230	3615	7230	
Fishing	10	20	-150.11	-1501.1	-3002.2	318.1	636.2	
NWFP	1	2	691.27	691.27	1382.54	691.27	1382.54	
WBH habitat	1	1	2636.84	2636.84	2636.84	2636.84	2636.84	
						32666.61	58217.38	
						445.9605461	25550.77	348.816

Table 5.5: *Example of Ecosystem value generated for Chiwogs*

OBJECT ID	DZONGKHAG	GEWOG	CHIWOG	HH COUNT	DCE
1	Zhemgang	Bardo	DIGALA	64	22324.22
2	Zhemgang	Goshing	BUDHASHI	82	28602.91
3	Zhemgang	Goshing	LAMTHANG	58	20231.33
4	Zhemgang	Goshing	LICHIBI	45	15696.72
5	Zhemgang	Goshing	LINGMAPONG_ SAMCHHOELING	104	36276.86
6	Zhemgang	Nangkhor	BULI	7	2441.712
7	Zhemgang	Nangkhor	DAKPHEL_TALI	27	9418.031

8	Zhemgang	Nangkhor	DUENMANG	83	28951.73
9	Zhemgang	Nangkhor	GOLENG	102	35579.23
10	Zhemgang	Nangkhor	NYAKHA	97	33835.15
11	Zhemgang	Ngangla	MARANGDUED	81	28254.09
12	Zhemgang	Ngangla	PANBANG_SONAMTHANG	289	100807.8
13	Zhemgang	Ngangla	RIBATI	82	28602.91
14	Zhemgang	Pangkhar	MAMONG TRONG_ PANTANG	85	29649.36
15	Zhemgang	Goshing	BUDHASHI	1	348.816
16	Zhemgang	Phangkhar	CHAG-NGAR-ZAM	10	3488.16
17	Zhemgang	Phangkhar	PANABI	37	12906.19
18	Zhemgang	Phangkhar	SHALINGTOED_TASHIBI	68	23719.49
19	Zhemgang	Trong	BERTI_TAGMA	235	81971.75
20	Zhemgang	Nangkhor	DAKPHEL_TALI	3	1046.448
21	Zhemgang	Trong	DANGKHAR_TRONG	170	59298.72
22	Zhemgang	Nangkhor	GOLENG	13	4534.608
23	Zhemgang	Trong	GONGPHU	133	46392.52
24	Zhemgang	Trong	SOOBDRANG	10	3488.16
25	Zhemgang	Trong	TSHANGLAJONG_ZURPHEL	83	28951.73

Table 5.6: Sample computation of estimates ecosystem values using benefit transfer method

	Ref	Total area (ha)	Min value ($US/ha/ year)	Max value ($US/ha/ year)	Mean value ($US/ha/ year)	Min value ($US/year)	Max value ($US/year)	Mean value ($US/year)	Household Mean value ($US/ year)	Household Mean value (Nu/year)	Percentage contribution
A. Cropland	**17**	**1313.25**	**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	

Table 5.7: *Example of how total ecosystem values are estimated using benefit transfer method*

	Total area (ha)	Min value ($US/ha/ year)	Max value ($US/ha/ year)	Mean value ($US/ ha/year)	Min value ($US/year)	Max value ($US/year)	Mean value ($US/year)	Household Mean value ($US/year)	Household Mean value (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

Table 5.8: *Sample output of ecosystem value for chiwog using benefit transfer*

OBJECT ID	DZONGKHAG	GEWOG	CHIWOG	HH_COUNT	Benefit Transfer
1	Trongsa	Dragten	KUENGA RABTEN	159	1555655.05
2	Trongsa	Dragten	SAMLING KHAMAED	146	1428463.13
3	Trongsa	Dragten	SAMLING KHATOED	88	860991.48
4	Trongsa	Dragten	TAGTSE_TASHIDINGKHA	113	1105591.33
5	Trongsa	Dragten	UESAR	33	322871.8
6	Trongsa	Korphu	KORPHOOG MAED	75	733799.55
7	Trongsa	Korphu	KORPHOOG TOED	29	283735.83
8	Trongsa	Korphu	NABI	92	900127.45
9	Trongsa	Korphu	NYIMZHONG MAED	101	988183.4
10	Trongsa	Korphu	NYIMZHONG TOED	46	450063.73
11	Trongsa	Langthe	BALING	120	1174079.29
12	Trongsa	Langthe	DANGDOONG	172	1682846.98
13	Trongsa	Langthe	JANGBI	44	430495.74
14	Trongsa	Langthe	LANGTHIL	109	1066455.35
15	Trongsa	Langthe	YUEDROONGCHHOELING	199	1947014.82
16	Trongsa	Nubi	BAGOCHEN_ OOLINGPANG_UELING	36	352223.79
17	Trongsa	Nubi	BJI_SENGM-BJI	6	58703.96
18	Trongsa	Tangsibji	KELA	74	724015.56
19	Trongsa	Tangsibji	NYALA DRANGLA	10	97839.94
20	Trongsa	Tangsibji	TANGSIBJI	163	1594791.03
21	Trongsa	Tangsibji	TSHANGKHA	55	538119.67

5.8 Limitations of economic valuation

An economic valuation cannot value everything; not all benefits provided by ecosystems are fully translatable into economic terms. As a result, valuation analysis often ignores or does not adequately account for the internal structure of ecosystems, and the interdependencies and inter-linkages of different ecosystem entities. Moreover, by relying on revealed or stated preferences, the economic valuation methods are not able to capture normative and ethical aspects of ecosystems. Thus, economic valuation remains an indication of the value of an ecosystem rather than an actual value.

06 CLIMATE VULNERABILITY ASSESSMENT PROTOCOL

6.1 Concept of Vulnerability

The term "vulnerability" is used widely in development and adaptation contexts and the usage of the term varies and is contextual. However, definitions of vulnerability basically fall into the two categories such as natural hazards, and based on which vulnerability is defined as a function of the "internal characteristics of a population or system that mediates the extent to which that population or system experiences harm as a result of exposure to an "external" hazard". The second category is associated with the IPCC definition which is defined the vulnerability as a function of exposure, sensitivity, and adaptive capacity. In this manual a second definition of vulnerability is used. It differs from the natural hazards approach where IPCC defines vulnerability as the various climate hazards associated with climate change and variability to which a population 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". While adaptive capacity 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.

6.2 Multidimensional Livelihood Vulnerability Index (MLVI)

The Multidimensional Livelihood Vulnerability Index (MLVI), is designed to measure Multidimensional Livelihood Vulnerability to climatic, environmental, and socio-economic change at the gewog level, dzongkhag level, and basin level which captures the change predominantly rural, mountainous, river basins. The MLV represents three dimensions of vulnerability: exposure, sensitivity, and adaptive capacity. Each dimension is broken down into a number of components, and each component is broken down into number of indicators. Here 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. The adaptive capacity includes components such as socio-demographic profile, livelihood strategies, social networks; sensitivity includes a social network, health, food, and water ,and exposure is indicated by a major component of natural disaster and climate variability (Table 6.1).

Table 6.1: *Dimensions and major components of vulnerability*

Vulnerability components	Major components
Adaptive capacity	Socio-demographic profile
	Livelihood Strategies
	Social Network
Sensitivity	Health
	Food
	Water
Exposure	Natural hazard
	Climate Variability

The LV includes seven major components, as a function of vulnerability, and each major component includes several indicators or sub-components. The components, sub-components and indicators are based on Hahn et al (2009) and Pandey and Jha (2012). In ESRAM study design, we used seven major components and 64 sub-components or indicators (See Annexure I).

» *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, the status of housing, and the location of agricultural land.

» *Adaptive capacity*

Adaptive comprises of 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.

6.3 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 $S_d = \frac{Sd-Smin}{Smax-Smin}$ 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 shortage of water in a 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. So using this logic, the inverse of the crude indicator is computed. The maximum and minimum values are also transformed and standardized for the sub-components. For example, if the maximum and minimum household size is recorded as 19 and 1 respectively in the whole region; and if the average household size in particular gewog is found to be 4, the data can be standardized by using the formula:

$S_d = \frac{Sd-Smin}{Smax-Smin}$ where $S_d = \frac{4-1}{19-1} = 0.167$.

» *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: $M_d = \frac{\sum_{i=1}^{n} Index\ Sdi}{n}$ where M_d is one of the eight major components for specific location d, the Sdi 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:

$LVI_d = \frac{\sum_{i=1}^{8} Wmi\ Mdi}{\sum_{i=1}^{8} Wmi}$ which can also be written as

$LVI_d = \frac{WsdpSDPd+WlsLSd+WsnSNd+WhHd+WfFd+WwWd+WndNDd+WcvCVd}{Wsdp+Wls+Wsn+Wf+Ww+Wnd+Wcv}$ 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). For example; if the standardized values for major-components such as socio-demographic profile are computed as 0.609; Livelihood strategies as 0.648 and similarly for other major-components as given below; the values (index) of the vulnerability components such as Adaptive capacity, Sensitivity and Exposure is computed as 0.521; 0.353 and 0.312 respectively (Table 6.2).

Table 6.2: *Example of computing indexes for different major components and sub-components*

Vulnerability components	Major-components	Standardized values (example)	Number of indicators or sub-components	Vulnerability index
Adaptive capacity	Socio-demographic profile	0.609	5	$= \frac{((0.609*5)+(0.648*3)+(0.249*3))}{(5+3+3)}$ = 0.521
	Livelihood strategies	0.648	3	
	Social network	0.249	3	
Sensitivity	Health	0.317	4	= 0.353
	Food	0.364	5	
	Water	0.370	5	
Exposure	Natural disasters and climate variability	0.312	6	= 0.312

Thus Livelihood vulnerability is defined as the function of exposure, sensitivity, and adaptive capacity. 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.

6.4 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. The sub-components are used to compute the climate change vulnerability (VI-IPCC). The use of an index diverges from the LVI in how the major components are combined (Pandey and Jha, 2012; Panthi et al, 2015). The major components are first combined according to the categorization into exposure, sensitivity and adaptive capacity as follows: $CF_d = \frac{\sum_{i=1}^{n} Wmi\ Mdi}{\sum_{i=1}^{n} Wmi}$ 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 are 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).

» *Computing and interpreting of Climate Vulnerability indices*

Using the indices from Table 2, the climate vulnerability can be computed using the IPCC formula such as *VI-IPCCd = (Exposure – Adaptive capacity) * Sensitivity*

$VI\text{-}IPCC_d$ = (0.312 – 0.521)*(0.353) = -0.073 *where* the *VI-IPCC* index ranges from -1 (least vulnerable) to +1 (most vulnerable). Higher the value of indices more vulnerable the households/gewogs or dzongkhags is while the smaller the indices lesser the vulnerability.

Annexure 6.1: WBH socio-economic survey questionnaires

	Livelihood Strategies (Adaptive capacity)
Adaptive capacity	Family size (household) (number)
	Number of illiterate farmers (percentage)
	Number of individuals older than 65 years (number)
	Number of individuals younger than 12 years (number)
	Number of years of farming experience (number)
	Percent of house type (percent)
	Main person in decision making at home (percent)
	Livelihood Strategies (Adaptive capacity)
	Total farm size (in acres)
	Major source of income for livelihood (percent)
	Number of family members migrated out of village (number)
	Household connected to power supply (percent)
	Household connected to drinking water (percent)
	Household connected to Television (percent)
	Household changed crop variety for farming (percent)
	Household introduced new crop variety for farming (percent)
	Household changed crop sowing time (percent)
	Number of times fodder collected from forest (per month)
	Household used pesticide(Yes/No) – (percent)
	Household used farm yard manure (yes/No) – (percent)
	Household collected fuelwood from the forest (Yes/No) – (percent)
	Distance to the nearest road point (in minutes)
	Distance to the nearest market (in minutes)
	Social Network (Adaptive capacity)
	Membership to social networks such as village committees etc (number)
	Number of times the household received help from neighbours in the last 12 months (number)
	Number of professions practiced by the household members (number)

	Health (Sensitivity)
Sensitivity	Time taken to the nearest health centre from the household (in minutes)
	Number of family members who are chronically ill in the household (number)
	Number of households having access to toilet (number)
	Food (Sensitivity)
	Number of food sufficient months of the household in a year (number of months)
	Number of crop varieties that the household cultivate (diversity index)
	Number of household saving seeds for following year (percent)
	Number of food shortage months in a year (percent)
	Water (Sensitivity)
	Source of household drinking water (percent of most reliable source)
	Number of household having consistent water supply (percent)
	Time taken to get to the water source (in minutes)
	Total area of field under rain-fed agriculture (farm size in acres)
	Natural Disaster (Exposure)
Exposure	Perception on forest degradation due to climate change in the last 10 years (Yes/No) – (percent)
	Perception on water quantity decreased due to climate change in the last 10 years (yes/No)-(percent)
	Experiences of occurrences of new crop disease in the last five years (Yes/No) – (Percent)
	Perception on water problem for irrigation in the last 10 years (Yes/No) – (Percent)
	Perception on inconsistency water problem in the last 10 years (Yes/No) – (Percent)
	Perception on increase in landscape fragmentation over the last 10 years (Yes/No) – (Percent)
	Perception on occurrence of any invasive species in the last 10 years (Yes/No) – (Percent)
	Perception on increase of invasive species over the last 10 years (Yes/No) – (Percent)
	Perception on increase in temperature over the last 10 years (Yes/No) – (Percent)
	Perception on frequency of precipitation over the last 10 years (Yes/No) – (Percent)
	Climate variability (exposure)
	Number of droughts occurred in the last five years (number)
	Number of floods occurred in the last five years (number)
	Number of times properties lost due to natural disaster in the last five years (number)
	Number of times floods occurred (number)
	Number of times household members were injured due to natural disasters in the last five years (number)
	Number of times crops were damaged by natural disasters in the last 5 years (number)
	Number of times hailstorms occurred in the last 5 years (number)
	Number of times storms occurred in the last 5 years (number)

	Perception on increase in disease infestation due to temperature increase in the last 5 years (Yes/No) – (Percent)
	Perception on drying up of spring water (Yes/No) – (Percent)
	Perception on stress due to climate change in the last five years (Yes/No) – (Percent)
	Number of streams dried up in the last 10 years (number)
	Number of forest fires occurred over the last 5 years (number)
	Mean standard deviation of monthly average of maximum daily temperature
	Mean standard deviation of monthly average of minimum daily temperature
	Mean standard deviation of monthly average precipitation
	Perception on disappearance of species in over the last 10 years (Yes/No) – (Percent)
	Perception on disappearance of useful species in the last 10 years (Yes/No) – (Percent)

Annexure 6.2: Data source and assumed functional relationships

Livelihood Strategies (Adaptive capacity)	**Data source**	**Functional relationships**
Family size (household) (number)	Survey	More the household size stronger the adaptive capacity
Number of illiterate farmers (percentage)	Survey	Literate farmers appear to understand more about the changing environment.
Number of individuals older than 65 years (number)	Survey	More people older than 65 years mean less adaptive capacity.
Number of individuals younger than 12 years (number)	Survey	Higher percentage reflects less capacity to adapt.
Number of years of farming experience (number)	Survey	More number of farming experience mean more adaptive capacity
Percent of house type (percent)	Survey	Concrete house is considered stronger than mud house.
Main person in decision making at home (percent)	Survey	Female headed household mean less adaptive capacity
Livelihood Strategies (Adaptive capacity)	**Survey**	
Total farm size (in acres)	Survey	Less land holding mean less areas for farming hence less adaptive capacity
Major source of income for livelihood (percent)	Survey	Diverse source of income mean higher adaptive capacity
Number of family members migrated out of village (number)	Survey	Income diversification means more adaptive capacity however migrated and no remittance also mean less adaptive capacity
Household connected to power supply (percent)	Survey	Connected to facility mean more adaptive capacity
Household connected to drinking water (percent)	Survey	Connected to facility mean more adaptive capacity

Household connected to Television (percent)	Survey	Connected to information channel mean more informed and hence more adaptive capacity
Household changed crop variety for farming (percent)	Survey	Changed crop varieties mean more experience and knowledge towards adaptive capacity
Household introduced new crop variety for farming (percent)	Survey	Changed crop varieties mean more experience and knowledge towards adaptive capacity
Household changed crop sowing time (percent)	Survey	Changed crop varieties mean more experience and knowledge towards adaptive capacity
Number of times fodder collected from forest (per month)	Survey	More dependent on forest resources may mean more adaptive capacity however limited access and limited forest resources may mean less adaptive capacity
Household used pesticide(Yes/No) – (percent)	Survey	More use pesticides mean more occurrence of pests and hence less adaptive capacity
Household used farm yard manure (yes/ No) – (percent)	Survey	Mean more adaptive capacity
Household collected fuelwood from the forest (Yes/No) – (percent)	Survey	Having access to forest resources mean more adaptive capacity
Distance to the nearest road point (in minutes)	Survey	Less distance mean more adaptive capacity
Distance to the nearest market (in minutes)	Survey	Less distance mean more adaptive capacity
Social Network (Adaptive capacity)	**Survey**	
Membership to social networks such as village committees etc (number)	Survey	More network mean more help and hence more adaptive capacity
Number of times the household received help from neighbours in the last 12 months (number)	Survey	More help mean more network and receive more help and hence more adaptive capacity
Number of professions practiced by the household members (number)	Survey	Diverse professions also mean diverse source of income and more adaptive capacity
Health (Sensitivity)	**Survey**	
Time taken to the nearest health centre from the household (in minutes)	Survey	Less distance less sensitivity
Number of family members who are chronically ill in the household (number)	Survey	More family members ill may mean more sensitivity
Number of households having access to toilet (number)	Survey	Having access to toilet mean better sanitation and hence less sensitivity
Food (Sensitivity)	**Survey**	
Number of food sufficient months of the household in a year (number of months)	Survey	Sufficient food mean less sensitivity
Number of crop varieties that the house-hold cultivate (diversity index)	Survey	More crop varieties mean more source of food
Number of household saving seeds for following year (percent)	Survey	Farmers saving seed mean, farmers not dependent on external sources.

Number of food shortage months in a year (percent)	Survey	More number of food shortage more sensitive they are
Water (Sensitivity)	**Survey**	
Source of household drinking water (percent of most reliable source)	Survey	More than one source mean less sensitivity
Number of household having consistent water supply (percent)	Survey	Reliable source mean less sensitivity
Time taken to get to the water source (in minutes)	Survey	Shorter the distance less sensitivity
Total area of field under rain-fed agriculture (farm size in acres)	Survey	More areas of rain fed mean more sensitivity in the context of changing climate
Natural Disaster (Exposure)	**Survey**	
Perception on forest degradation due to climate change in the last 10 years (Yes/No) – (percent)	Survey	Forest degradation mean more exposed to changing climate
Perception on water quantity decreased due to climate change in the last 10 years (yes/No)- (percent)	Survey	More water shortage mean more exposure and hence more vulnerable
Experiences of occurrences of new crop disease in the last five years (Yes/No) – (Percent)	Survey	New crop disease mean exposure to new challenges
Perception on water problem for irrigation in the last 10 years (Yes/No) – (Percent)	Survey	More irrigation issue may mean more exposed to uncertainty
Perception on inconsistency water problem in the last 10 years (Yes/No) – (Percent)	Survey	More inconsistency may mean more exposure to changing environment
Perception on increase in landscape fragmentation over the last 10 years (Yes/No) – (Percent)	Survey	More landscape fragmented may mean more challenges and more exposure
Perception on occurrence of any invasive species in the last 10 years (Yes/No) – (Percent)	Survey	Occurrence of invasive species may mean more exposure to more changing environment
Perception on increase of invasive species over the last 10 years (Yes/No) – (Percent)	Survey	Occurrence and increase of invasive species may mean more exposure to more changing environment
Perception on increase in temperature over the last 10 years (Yes/No) – (Percent)	Survey	Changing temperature may mean more exposure
Perception on frequency of precipitation over the last 10 years (Yes/No) – (Percent)	Survey	Changing frequency may mean changing environment
Climate variability (exposure)	**Survey**	
Number of droughts occurred in the last five years (number)	Survey	More droughts may mean more exposure
Number of floods occurred in the last five years (number)	Survey	More floods may mean more exposure

Number of times properties lost due to natural disaster in the last five years (number)	Survey	More properties lost may mean more exposure
Number of times floods occurred (number)	Survey	Occurrence of more floods may mean increasing exposure
Number of times household members were injured due to natural disasters in the last five years (number)	Survey	More natural disasters more exposure
Number of times crops were damaged by natural disasters in the last 5 years (number)	Survey	More damages more exposure
Number of times hailstorms occurred in the last 5 years (number)	Survey	More extreme events more exposure
Number of times storms occurred in the last 5 years (number)	Survey	More extreme events more exposure
Perception on increase in disease infestation due to temperature increase in the last 5 years (Yes/No) – (Percent)	Survey	More extreme events more exposure
Perception on drying up of spring water (Yes/No) – (Percent)	Survey	Drying up of the spring water mean increasing exposure
Perception on stress due to climate change in the last five years (Yes/No) – (Percent)	Survey	More extreme events more exposure
Number of streams dried up in the last 10 years (number)	Survey	Drying up of more spring water mean increasing exposure
Number of forest fires occurred over the last 5 years (number)	Survey	Increasing forest fire may mean more exposure
Mean standard deviation of monthly average of maximum daily temperature		Higher standard deviation may mean higher uncertainty
Mean standard deviation of monthly average of minimum daily temperature		Higher standard deviation may mean higher uncertainty
Mean standard deviation of monthly average precipitation		Higher standard deviation may mean higher uncertainty
Perception on disappearance of species in over the last 10 years (Yes/No) – (Percent)		Disappearance of species may mean more exposure
Perception on disappearance of useful species in the last 10 years (Yes/No) – (Percent)		Disappearance of species may mean more exposure

07 PROTOCOL FOR WHITE-BELLIED HERON(WBH) HABITAT SUITABILITY ASSESSMENTS

7.1 Introduction

The second largest heron in the world, WBH is known to occur only in the Eastern Himalayan foothills from Bhutan, North-East India to the hills of Bangladesh and Northern Myanmar (Kushlan and Hancock 2005). There are 50-249 matured individuals occuring in its entire range (Birdlife International 2013). As per RSPN (2011), the habitat range are confined above 800 m and below 1500 m asl. The total area covered is 56,300 sq. km. In Bhutan, about 30 individuals are known to occur with the total national population of about 50 individuals (Pradhan *et al.* 2007). It is observed along the Phochhu, the confluence of Phochhu-Mochhu, Punatsangchhu, Kamechhu (Digchu), Zawa, Ngagshina and Burichhu confluence (Pradhan 2007). According to Pradhan (2007) about six active nests were recorded in Bhutan in 2007 with six breeding sites from two rivers of central Bhutan. However most of these sites mentioned here are now disturbed significantly due to the massive hydroelectric scheme that is believed to have recently caused the bird to disappear from the *Punatsangchhu* and *Sunkosh* basins.

In Bhutan, two major locations are known for the occurrence of the WBH; *Punatsangchhu* and *Mangdechhu* basins. For the purpose of this study, these two river basins are assessed. The river system harbouring potential WBH habitats are *Phochu, Mochu, Punatsangchhu, Sunkosh, Dagachhu* and its tributaries in the West, *Mangdechhu, Bertichhu* and its tributaries in central Bhutan. This manual comprises habitat suitability analysis using collected data from the study site only with multi-criteria analysis tool: Analytical Hierarchical Procedure (AHP) and GIS tool however the second part comprises the suitability analysis using Maxent modelling that includes global climate data sets and sighting of heron data obtained since 2001.

7.2 Habitat Suitability analysis using AHP and GIS based on the observed data

7.2.1 Habitat characteristics

One important habitat characteristic for WBH is the presence of chirpine and broadleaf forests along the river where they normally nest and breed. Based on past observations, chirpine forest is highly used. Thus the bird requires a habitat for three specific activities such as nesting, roosting and feeding areas.

7.2.2 Assessing the habitat suitability

Factors such as level of disturbance, including road, agricultural land, settlement, transmission line, dam location and other criteria such as fish species occurrence, the width of the river basin, etc are important for feeding, roosting, and nesting. Therefore, to

assess the habitat suitability multi-criteria site suitability analysis is most relevant. Based on the importance of variables eight different criteria and constraints such as rivers, land use, and land cover, settlements, road, and dam site are used. The elevation is not considered as the study site is located within the elevation range of WBH.

The habitat of WBH requires rivers for feeding and needs to be away from human settlements, roads network, and dam sites. For nesting and roosting WBH requires a pine forest and near the rivers without human interference is the ideal habitat for WBH. While hydropower projects fall within the habitat of WBH it creates a disturbance to the feeding, nesting, and roosting of the birds.

7.2.3 Analytical Hierarchical Process (AHP)

In this, all the habitat indicators or factors are judged based on their relative importance and compared using a pairwise comparison called Analytical Hierarchical Process (AHP) and computed against each criterion. The overall weighted score is then multiplied by the suitability score to get the weighted value of each criterion or variable. These weighted values are then added to produce a final land suitability map.

AHP is used for a group of the criteria to set up the hierarchical structure by selecting the weightage of individual criterion and a pairwise comparison between the criteria was applied to reduce the complexity (Saaty 1977). AHP derives the weights by comparing pairwise taken two at a time based on the relative importance of criteria used. The pairwise comparison matrix can be generated by using a scale of 1–9 in which 1 having equal importance and 9 having extreme importance of in between two criteria following the methods used by Malczewski, (1999) and Saaty (1980). For example, pine forests appear to be of the highest importance for bird nesting and roosting, therefore, land use with pine forest is assigned 9 and river 9 which is extremely important for feeding. The strength of AHP is that it helps to identify the inconsistencies while using indicators (Saaty 1990, Garcia *et al*. 2014). The strength of the AHP is calculated in Table 7.1 and Table 7.2.

Table 7.1: *Assigning weights based on Saaty (1977)*

	1	2	3	4	5	6	7	8
Settlement	1.00	0.20	0.14	0.50	1.00	1.00	0.14	0.1429
Broadleaf forest	5.00	1.00	0.71	2.50	5.00	5.00	0.56	0.7143
Chir pine forest	7.00	1.40	1.00	2.33	7.00	7.00	1.00	1.0000
Agricultural land	2.00	0.40	0.29	1.00	1.00	1.00	0.29	0.2857
Dam site	0.50	0.20	0.14	0.50	1.00	1.00	0.14	0.1429
Road network	1.00	0.20	0.14	0.50	1.00	1.00	0.14	0.1429
River basin	7.00	1.40	1.00	3.50	7.00	7.00	1.00	1.0000
Fish occurrence	7.00	1.40	1.75	4.50	7.00	7.00	1.00	1.0000
	30.500	**6.200**	**5.179**	**15.333**	**30.000**	**30.000**	**4.270**	**4.429**

Table 7.2: Criteria weights based on Saaty (1977)

	1	2	3	4	5	6	7	8	Criteria weights
1	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.032**
2	0.16	0.16	0.14	0.16	0.17	0.17	0.13	0.16	**0.156**
3	0.23	0.23	0.19	0.15	0.23	0.23	0.23	0.23	**0.216**
4	0.07	0.06	0.06	0.07	0.03	0.03	0.07	0.06	**0.056**
5	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.030**
6	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	**0.032**
7	0.23	0.23	0.19	0.23	0.23	0.23	0.23	0.23	**0.225**
8	0.23	0.23	0.34	0.29	0.23	0.23	0.23	0.23	**0.252**

7.2.4 Consistency Relationship (CR), Consistency Index (CI) and Random Index (RI)

AHP efficiency criteria are measured by Consistency Relationship (CR) which is estimated using the equation: CR $=\frac{CI}{RI}$. CR which depends on the Consistency Index (CI) and Random Index (RI) represents a measure of the error made by the use of an indicator of the degree of consistency or inconsistency indicating the likelihood that the matrix judgments were generated randomly (Saaty 1977, Chen *et al.* 2010, Park *et al*. 2013). While CI (CI= $\frac{\lambda max - n}{n-1}$); where λmax is the largest principal eigenvalue of the matrix, and n is the order of the matrix. RI is the average of the resulting consistency index depending on the order of the matrix given by Saaty, (1977). The consistency ratio is calculated in Table 7.3.

Table 7.3: Calculating Consistency Ratio (CR)

	1	2	3	4	5	6	7	8	Sum	Criteria Weights	Sum/ Weights
1	0.0322	0.031	0.0308	0.028	0.0302	0.0322	0.0322	0.0360	0.2529	0.0267	9.4775
2	0.161	0.156	0.1542	0.14	0.151	0.161	0.1252	0.1798	1.2289	0.1270	9.6766
3	0.2254	0.219	0.2159	0.131	0.2114	0.2254	0.2254	0.2517	1.7051	0.2214	7.6996
4	0.0644	0.063	0.0617	0.056	0.0302	0.0322	0.0644	0.0719	0.4435	0.0534	8.3084
5	0.0161	0.031	0.0308	0.028	0.0302	0.0322	0.0322	0.0360	0.2368	0.0250	9.4826
6	0.0322	0.031	0.0308	0.028	0.0302	0.0322	0.0322	0.0360	0.2529	0.0267	9.4775
7	0.2254	0.219	0.2159	0.196	0.2114	0.2254	0.2254	0.2517	1.7705	0.2430	7.2850
8	0.2254	0.219	0.3778	0.252	0.2114	0.2254	0.2254	0.2517	1.9885	0.2768	7.1842

The average of sum/criteria weights is computed as 8.574, thus the consistency index (CI) can be calculated as

$$CI = \frac{Weigts\ average - number\ of\ variables\ used}{Degrees\ of\ freedom\ (n-1)} = \frac{8.574-8}{(8-1)} = 0.082$$

RI is the average of the resulting consistency index depending on the order of the matrix whereas in the case of this analysis RI = 1.41.

Therefore, Consistency Relationship (CR) = $\frac{CI}{RI} = \frac{0.082}{1.41}$ = 0.058. When CR <0.10 this means that the pairwise comparison matrix is acceptable and the weight values are valid. In our case the CR was 0.058 which is under acceptable limits.

7.2.4 Land suitability assessment

For the study area, the FAO (United Nations Food and Agriculture Organization) classification system for habitat suitability can be applied i.e. S1 (highly suitable), S2 (moderately 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. For this method, the weights of factors for heron habitat and habitat suitability evaluation using a pairwise comparisons analysis are used. The weights of factors used are 9 most important to 1 least important. Once the weights for each factor are determined, the weighted overlay method in the ArcGIS 10.0 software can be applied to generate multi-criteria decision-making analysis maps. Finally, multi-criteria decision-making analysis and the AHP process can generate a habitat suitability assessment map (see Figure 7.1).

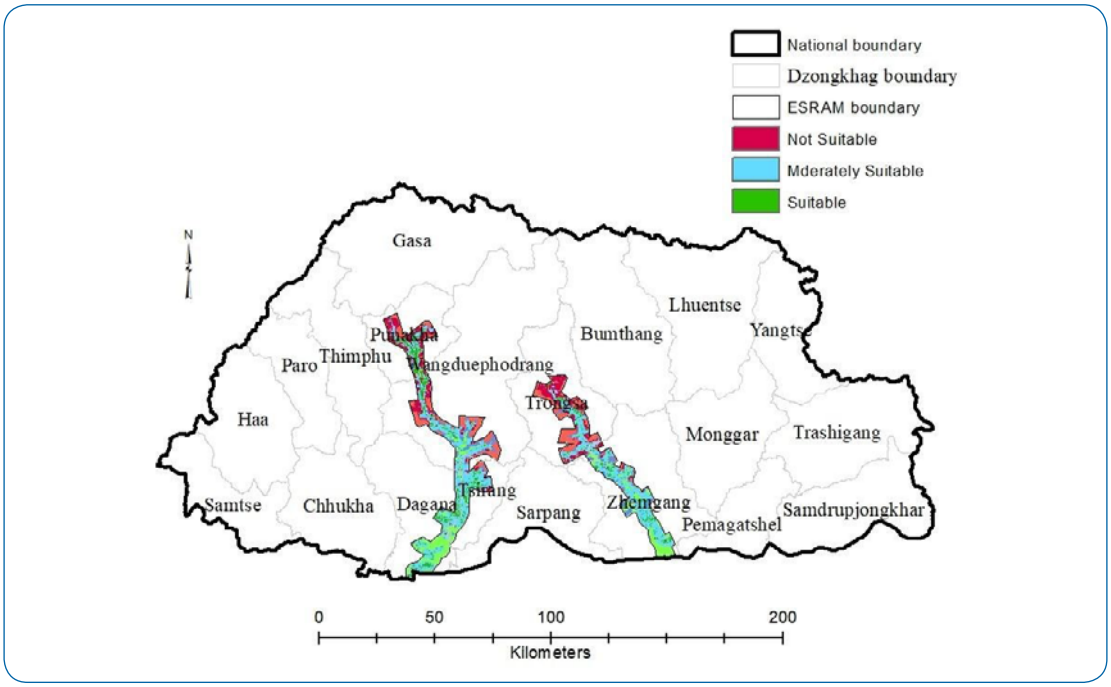


Figure 7.1: *Habitat suitability map*

7.3 Habitat Suitability Analysis using global climate data sets

7.3.1 Distribution of White-bellied Heron in Bhutan under different climatic Scenarios

The occurrence coordinates of the WBH were used from across Bhutan. The data were collected from field observation and the Global Biodiversity Information Facility (GBIF). A total of 175 coordinates were recorded. To reduce over-fitting of the model arising due to spatial clusters of species records, spatial autocorrelation was performed using 'spatially rarefy occurrence data tool' in SDMtoolbox 2.0 at 1km (Brown, 2014). From 175 coordinates, 73 were used for running the MaxEnt model. Coordinates were cleaned and converted into comma-separated values (.csv file) for running the model algorithm. The stepwise process and data requirement is given in Figure 7.2.

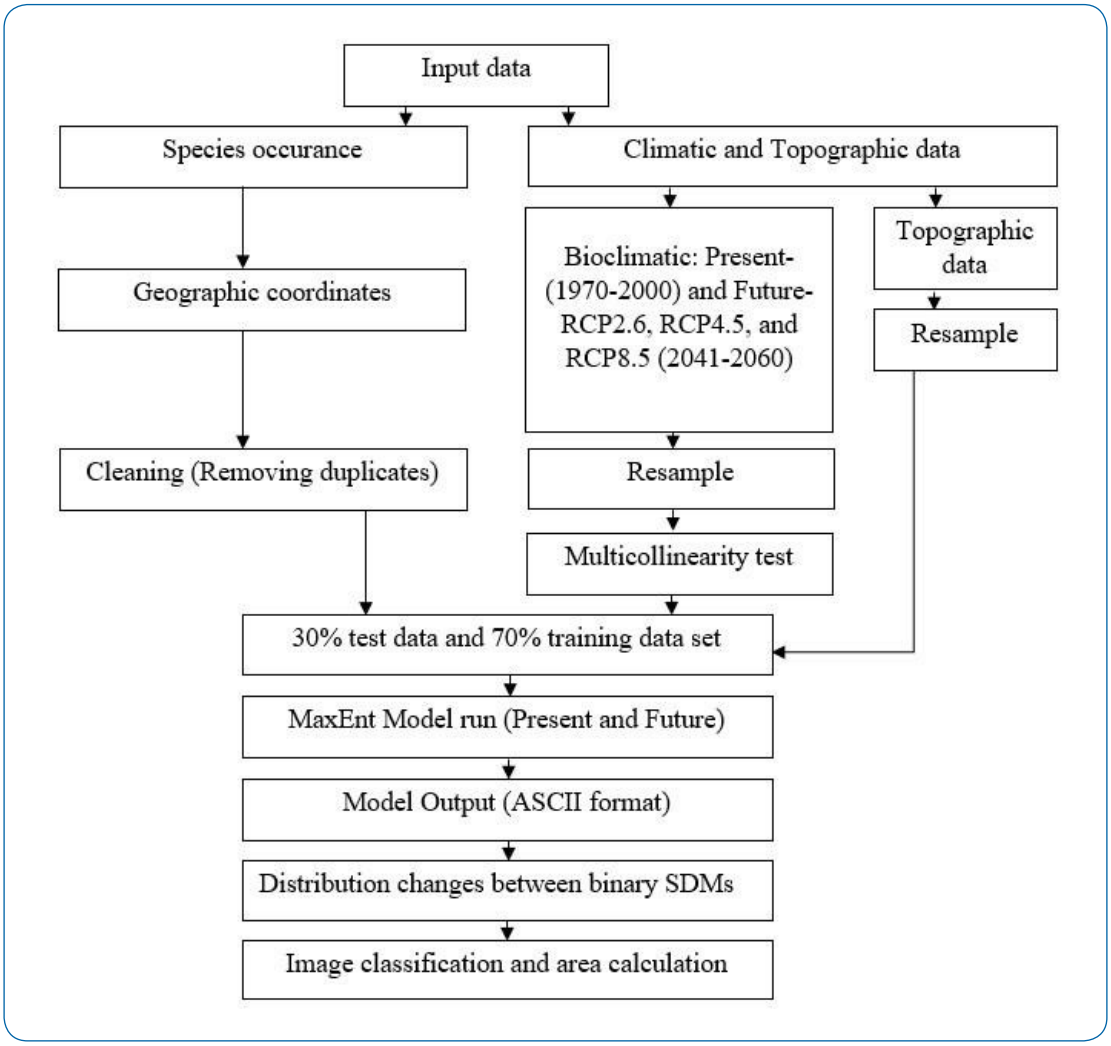


Figure 7.2: *Conceptual framework for the distribution of White-bellied Heron using MaxEnt model*

7.4 Species Ecological Modeling using MaxEnt

Maximum Entropy (MaxEnt) (Phillips, 2017), model was used for ecological modelling, an open-source modeling software which can be downloaded from https://biodiversityinformatics.amnh.org/open_source/maxent/. MaxEnt is widely used in species distribution modelling to predict the habitat of target species such as mammals, plants, and birds (Phillips, 2017).

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 modeling 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 (MIROC6) 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 RCP8.5 was used for the distribution of White-bellied Heron under different climatic scenarios. A Representative Concentration Pathway is a greenhouse gas concentration trajectory adopted by the Intergovernmental Panel on Climate Change.

7.4.1 Preprocessing of environmental layers

Multicollinearity among bioclimatic variables leads to over-fitting or poor model development leading to misinterpretation of model output (Brown, 2014). Highly correlated bioclimatic variables were removed through a multicollinearity test performed in ArcGIS using SDMtoolbox 2.0. A total of six bioclimatic variables were selected for model development. These variables had a Pearson coefficient (R) of $r \leq 0.8$, which were later used for MaxEnt Modelling. Bioclimatic variables with Pearson's $r \geq 0.9$ were removed. The topographic layers used are elevation, slope, and aspect. In addition, land-use land-cover data were also used.

The environmental layers used in modelling are Annual Mean Temperature (BIO1), Mean Diurnal Range (BIO2), Isothermality (BIO3), precipitation of the wettest month (BIO13), and precipitation of the driest month (BIO14), and precipitation seasonality (BIO15). All environmental variables were processed in ArcGIS version 10.8. The data obtained from WorldClim were the extracted for the extent of Bhutan (26.45°N and 28.10°N; 88.45°E and 92.10°E) using extract by mask feature of the spatial analyst tool. The area extracted was projected using geographic coordinate system 1984 and resampled into 1 km resolution using raster package in R software. The MaxEnt Model version 3.4.1 was used for running the model which was downloaded from https://biodiversityinformatics. amnh.org/open_source/maxent/ (Phillips et al., 2017). Based on "presence only" data of 73 coordinates, the model for the current and future scenarios is generated by using MaxEnt software. The MaxEnt can generate output for future scenarios using Representative Concentration

Pathway (RCP) (for example, RCP 2.6, RCP 4.5, and RCP 8.5) for the years 2041- 2060 and current scenario using historical data of the year 1970-2000. For list of the variables (see Table 7.4). The detailed procedures are described in Figure 7.3.

Table 7.4: *Bioclimatic variables obtained from the WorldClim*

Sl.no.	Acronyms	Climatic variables
1	BIO1*	Annual Mean Temperature
2	BIO2*	Mean Diurnal Range
3	BIO3*	Isothermality (BIO2/BIO7) (*100)
4	BIO4	Temperature Seasonality (Standard Deviation *100)
5	BIO5	Maximum Temperature of warmest Month
6	BIO6	Minimum Temperature of Coldest Month
7	BIO7	Temperature Annual Range (BIO5 - BIO6)
8	BIO8	Mean Temperature of Wettest Quarter
9	BIO9	Mean Temperature of Driest Quarter
10	BIO10	Mean Temperature of Warmest Quarter
11	BIO11	Mean Temperature of Coldest Quarter
12	BIO12	Annual Precipitation
13	BIO13*	Precipitation of Wettest Month
14	BIO14*	Precipitation of Driest Month
15	BIO15*	Precipitation Seasonality (Coefficient of variation)
16	BIO16	Precipitation of Wettest Quarter
17	BIO17	Precipitation of Driest Quarter
18	BIO18	Precipitation of warmest quarter
19	BIO19	Precipitation of coldest quarter
20	Slo*	Slope
21	Asp*	Aspect
22	Eleve*	Elevation
23	LULC*	Land-use land-cover

Note: *The variables marked with asterisk sign are selected for the modelling after running a Pearson correlation coefficient test.*

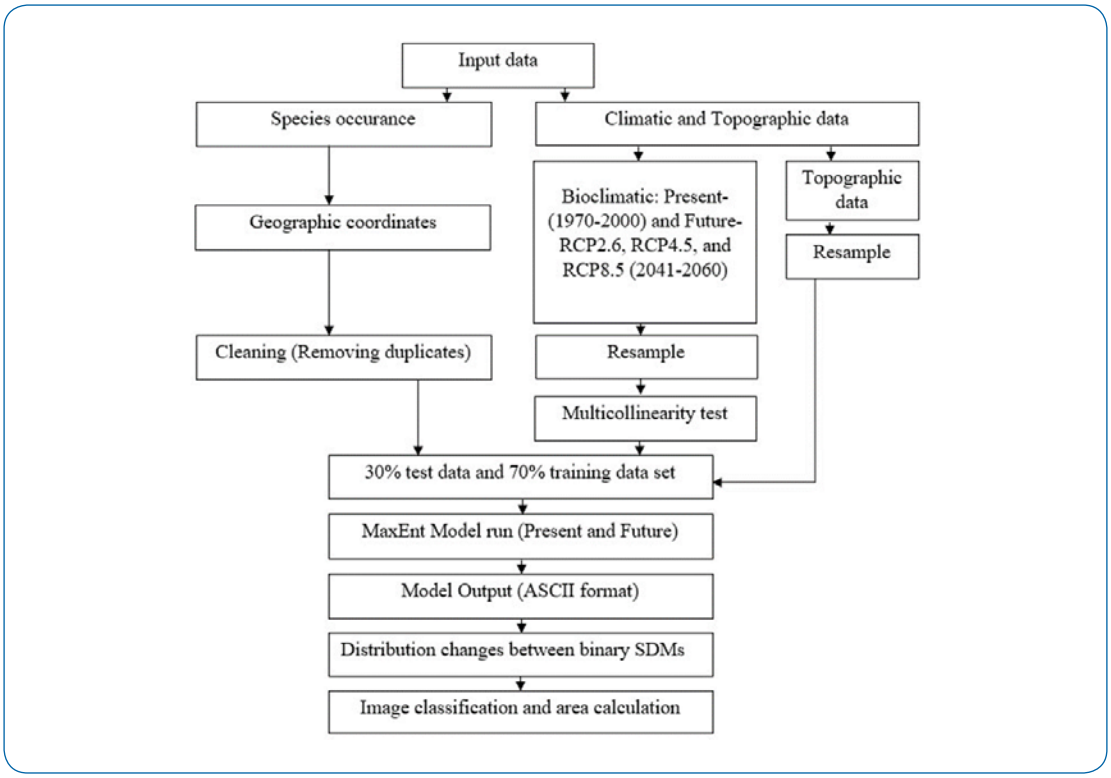


Figure 7.3: *Conceptual framework for distribution of White-bellied Heron*

7.4.2 Analysis of the variable contribution

The relative percentage contribution and permutation importance of environmental and topographic variables generated by the MaxEnt model should be analysed and recorded for triangulation. For example, from all the variables, land-use land-cover has the highest percentage contribution followed by isothermality with 38% and 23% respectively. Such analysis tells us the importance of specific variables (See table 7.5 for details).

Table 7.5: *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

For example, based on "presence" data, the model for the current and future scenarios can be 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 Wangdue Phodrang, Punakha, and Zhemgang district accounts for the highly suitable area where the expansion of suitable area from (1.04%) in RCP2.6 to (1.38%) 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 (See Figure 7.4). However, the interpretation should be made carefully as the current result is based on the past occurrence of WBH sighting data.

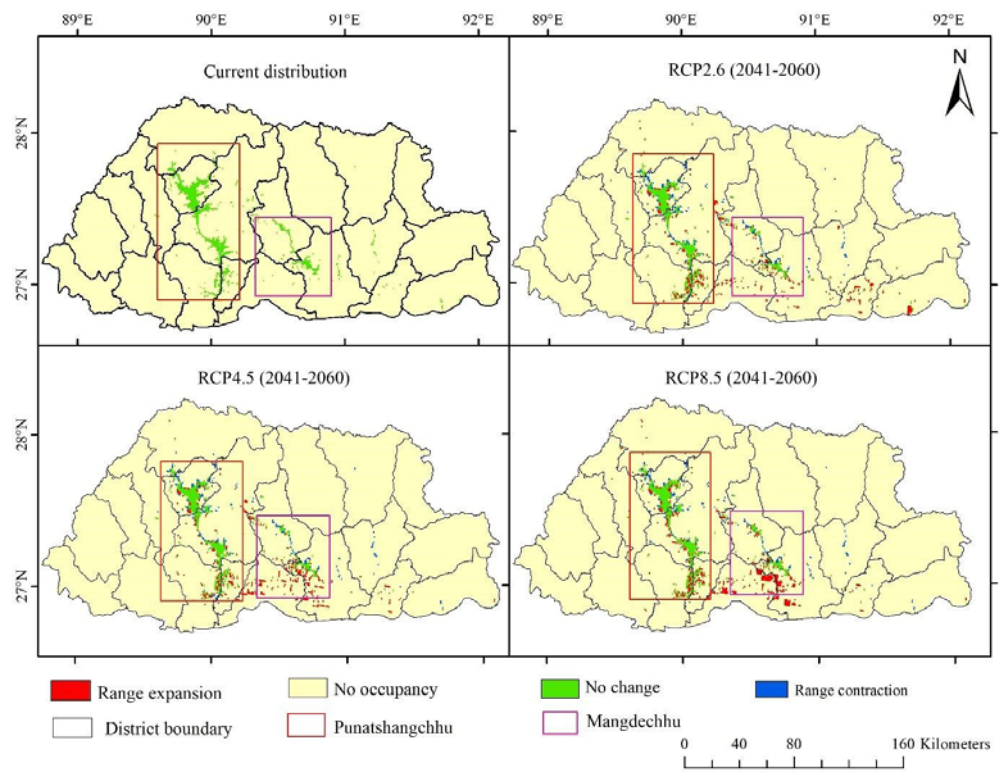


Figure 7.4: *Example of habitat suitability of WBH under climate scenarios (2041-2060)*

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