# Forest$ in Bhutan:

## *Economic Value of Forest Ecosystem Services in Bhutan*

Watershed Management Division
Department of Forests and Park Services
Ministry of Agriculture and Forests
Bhutan, 2019

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# Executive summary

The Royal Government of Bhutan recognises forests' values and honours it in its Constitution. Ensuring that it remains in the long term to fuel the economy and benefiting local people will require a more strategic approach to target the investment in this sector.

The Watershed Management Division under Department of Forests & Park Services (DoFPS), Ministry of Agriculture & Forests (MoAF) has conducted a series of studies to understand the role of forests in Bhutan's economy.

This document presents the results of an assessment of the economic value of forest ecosystem services to Bhutan's economy, with a focus on direct use values. This study combines the latest biophysical and economic tools to model relations between forests, water and other ecosystem services with economic valuation techniques. The data used in the study includes global climatic data calibrated with local measurements of fog interception, and local and national maps and statistics on hydroelectricity generation, timber, fodder and NWFP. Through the use of models such as Co$tingNature (www.policysupport.org/costingnature), the study assessed the magnitude and direction of benefits from forest ecosystems to the Bhutanese economy. This information will be used as input for modelling the impact of changes in forest cover in the national economy and at watershed level (see report on "*Modelling changes in Bhutan's ecosystems, impacts and trade-offs*").

The re-valuation of the contribution of ecosystem services to the economy has two impacts: 1) to see how the benefits from forest significantly spread across other sectors in the economy – hydroelectricity, tourism, and even health (through better diets and clean water) and also 2) to see a potential increase in the country's perceived wealth, as National Accounts begin to incorporate contributions from ecosystem services. . Previous studies have focused on potential ecosystem services of forests using crude benefit transfer techniques per hectare of land use. This study examines current realised ecosystem services, for which the number, type and distribution of nearby current beneficiaries (people, dams, agriculture for example) is fundamental.

Capacity building and co-creation of results have driven the design, implementation and analysis of this study. The choice of ecosystem services and valuation techniques was linked to national expert consultation, availability of data, the need to generate values that are used as inputs for modelling geographic distribution and land use changes using Co$tingNature, and the need for WMD staff to be able to replicate the study in the future with relatively little external support. The study has also focused on values for Bhutanese people (i.e. avoiding non-use values or benefit transfer estimates from other countries that often result in inflation of estimates) and not considering beneficiaries in downstream countries.

The main results of the study are:

***1) Ecosystem services are many, and are significant***

The economic value of ecosystem services in Bhutan ranges between US$394 million to US$1,269 million per year:

**Economic value of ecosystem services in Bhutan (US$ million per year)**

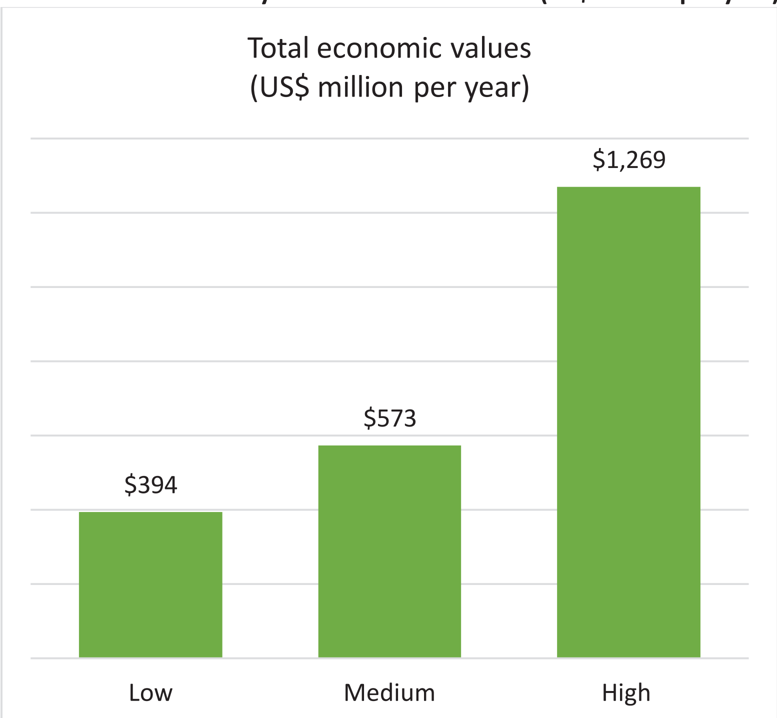


Table 36 presents a range that varies from conservative estimates, for example using national prices, to higher end estimations that try to further remove the effect of national price regulations to get a closer view of real economic values. For all ranges the estimates are nevertheless realistic and are not over-estimations.

Despite the conservative approach to avoid over-estimations, the results are nevertheless impressive and indicate a significant value of forests to Bhutan.

Provisioning services represent the highest values, as nature provides Bhutanese people with inputs for food, timber, water and energy in amounts that range from US$301 million to about US$973 million per year.

Ranging between US$77 and US$216 million per year, cultural and recreation services also play a significant and increasing role in generating wealth in the country. Much of this is driven by the flourishing tourism sector and the flows of investments that support Bhutan's efforts to conserve and protect their natural habitats and biodiversity, which provides stunning backgrounds to the spiritual enjoyment of the country's traditions.

This study also attempted to value some of the benefits from ecosystems for regulation of key functions, which are often unaccounted in traditional economics. The study shows that these values range between US$15 to US$80 million, dominated by the expectation of Bhutan's ability to access international carbon markets. The estimates of regulation of water quality for existing dams and those under construction appear modest after looking at carbon sequestration, ranging between US$1.5 to US$2 million per year), but not insignificant if a proportion of it could be converted into operational costs of managing 'green infrastructure' and be transferred back into watershed management. These water quality regulating benefits also benefit rural households, who do not have access to filtering services.

Taken together, these conservative estimates of multiple values of forest ecosystem services are considerably larger than the existing contribution of timber to the economy, as recorded through its contribution to GDP (US$32 million in 2015).

**Table 1. Economic value of ecosystem services in Bhutan (US$ million per year)**

| | | Economic values | | |
|---|---|---|---|---|
| | GDP (2015) | Low | Medium | High |
| **Provisioning services** | **$344** | **$301** | **$390** | **$973** |
| Timber, total | $32 | $25 | $49 | $94 |
| Timber, softwood | $32 | $17 | $31 | $76 |
| Timber, hardwood | | $8 | $18 | $18 |
| Domestic water | $1 | $2 | $2 | $7 |
| Water Utilities (piped water) | $1 | $0.5 | $1.1 | $5.1 |
| Rural water (mostly unpiped) | | $1.3 | $1.3 | $1.5 |
| Fodder for livestock | $82 | $82 | $99 | $136 |
| NWFP | $7 | $7 | $7 | $8 |
| Energy: | | | | |
| Hydroelectricity | $222 | $183 | $228 | $723 |
| Firewood (total) | $1 | $2 | $6 | $6 |
| Firewood, softwood | $1 | $1 | $2 | $2 |
| Firewood, hardwood | | $1 | $3 | $3 |
| **Cultural services** | $42.6 | $76.8 | $142.5 | $215.7 |
| Tourism, Nature based (International Tourism, receipts, BTC, 2016) | $43 | $43 | $108 | $182 |
| Biodiversity (investment flows) | | $34 | $34 | $34 |
| **Regulating and climate** | $0 | $16 | $40 | $81 |
| Carbon | $0 | $16 | $40 | $80 |
| Water quality (sediment removal) | | $1.54 | $1.59 | $2.07 |
| Disease and pest control (Human Wildlife Conflict) | | -$1.1 | -$1.3 | -$1.3 |
| **Total USD millions/year** | **$387** | **$394** | **$573** | **$1,269** |

Note: These values are an initial approximation of the value of the ecosystem services, with a focus on use values, and focusing on variables where information exists and can be easily updated by WMD.

### *2) Forests ecosystems as assets for wealth*

Because forests cover such a large proportion of the country, values from forest ecosystems represent a large proportion of the total values in the country (about 70%). It is important to highlight that these monetary benefits do not derive entirely from the forests themselves but through the interaction of forests with other components of the ecosystem (e.g. ecosystem, infrastructure and people), as explained in the methodology section (Figure 2 and Table 2).

Traditionally, forests are accounted in economic reports in relation to their contribution to timber, firewood and non-wood forest products (one of the components of the "primary sector", alongside agriculture and livestock, see NSB (2017)). In 2015 its contribution to GDP was approximately US$40 million, representing about 2% of national wealth[1]. For a country with 70% forest cover this may seem small.

This study shows that the contribution of forests and its associated ecosystems is significantly larger, with values that range between 21% to 63% of national GDP, showing the linkages to key emerging economic processes such as hydroelectricity and tourism, but also its importance to local economies in terms of energy, food, and water quantity and quality. This valuation study shows that Bhutanese people benefit highly from nature services, ranging from US$597 to US$1,830 per capita per year.

### 3) *Forest ecosystems benefit rural economies*

Rural communities directly affected by the quality of their surrounding ecosystems. The figure below presents a rough estimate of how some of these values accrue to rural households. The analysis assumes that rural benefits are especially linked to timber, firewood, NWFP, fodder for livestock, and water for domestic uses. It also allocates half of the revenues from nature-based tourism, assuming that local people benefit from jobs, provision of services and access to recreation attractions. The analysis also allocates 20% of hydroelectricity benefits to rural communities[2].

The study finds that, while there may be some overlap (e.g. electricity, firewood) the benefits from nature range between 55% and 96% higher than mean annual household expenditure, as reported in the latest Living Standard Survey (2017). Some of these households are also highly affected by human-wildlife conflict, with significant losses from livestock killings and crop raiding that directly affect food security.

Although many ecosystem services are "free" to the user, or heavily subsidised by the state, this study provides quantitative evidence of their enormous economic importance for rural economies. The costs of degradation of forest ecosystems will be felt by these groups in earnest.

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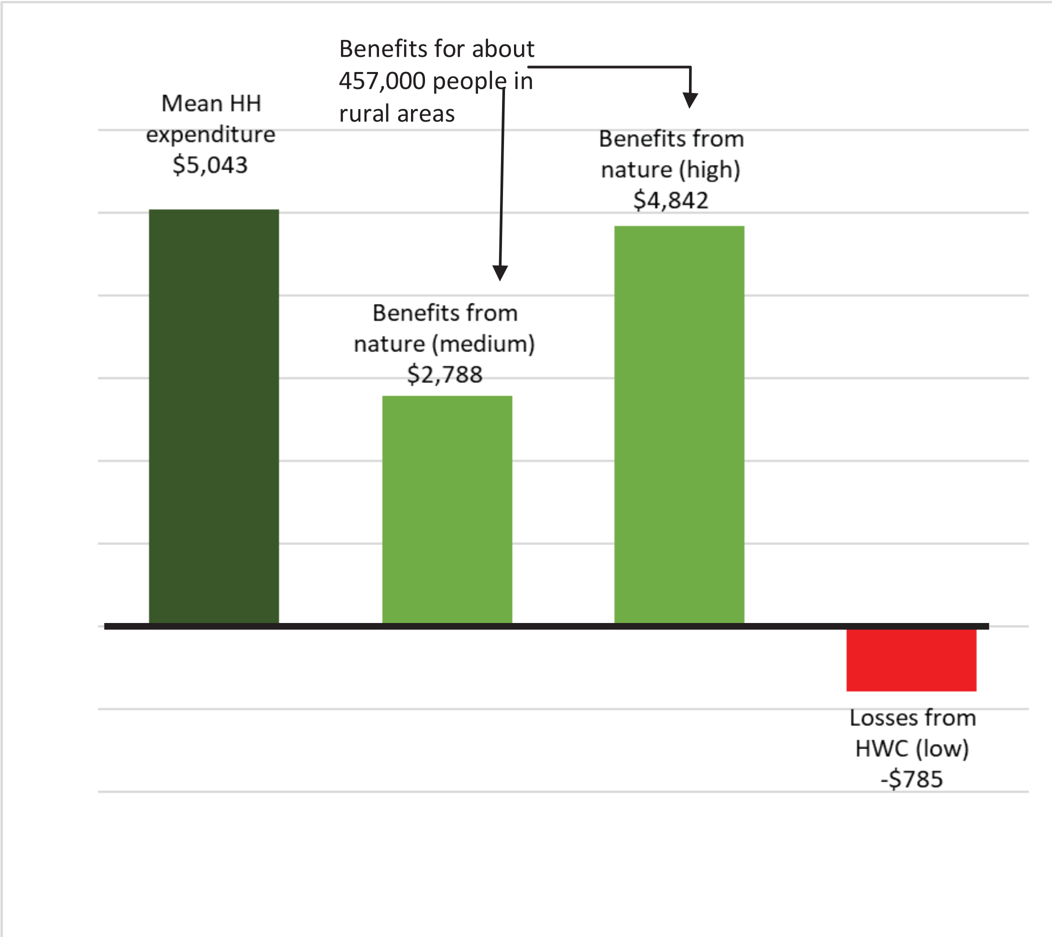
[1] Total GDP in 2015 was approximately US$2058 million and US$2305 million in 2016 (NSB, 2017).

[2] This value was in turned obtained assuming that 30% of all production is for national consumption (DrukGreen, 2016), of which 64% is for rural households (NSB, 2017).

**Per capita benefits (and costs) from ecosystem services (US$ per year)**




**Because of policies affecting the governance of forests and other ecosystems, very few of these values are currently reflected in national accounts or government revenues, often giving the impression of an economically dormant sector. This document clearly demonstrates that this is not the case.**

A better understanding of how ecosystem services interact with the rest of the economy is a first step to truly mainstreaming nature in policy making. The information from this study feeds into a series of studies linking to policies and strategies for sustainable financing of Bhutan's natural ecosystems.

***4) What happens if forest ecosystems disappear or are degraded?***

This study shows total economic values, that is, the benefits that emerge as the combination of forest ecosystems, human assets, infrastructure and technology. The impact of forests degradation or disappearance will have different impacts on each ecosystem service, depending on how heavily they rely on forest. For example, if natural forest disappears and is not replaced with plantations then timber values and most NWFP will dwindle to zero. The quality and part of the quantity of water for hydroelectricity will be affected, but hydropower generation will continue.

The results from this study are used as inputs to develop scenarios of land use change to assess what may happen to economic values within each sector, and as an aggregate to the economy. Two models are used for this: Co$tingNature looks at values across the full range of resources in the country, and WaterWorld is run to specifically focus on the impacts on hydropower.

Modelling these scenario changes helps to understand the marginal contributions of forest to the national economy. The results of this scenario analysis are presented in detail in another report in this series: “Changing Landscapes”.

# Contents

# 1 Introduction

The Royal Government of Bhutan recognises forests' multiple values and honours them in its Constitution. As the country enters middle-income status, ensuring that forest ecosystems continue to fuel the economy and benefit local people in the long term will require a more strategic approach to investment in the sector.

This study provides robust evidence on the values of forest ecosystem services across Bhutan's economy and geography.

# Background

The Watershed Management Division under Department of Forests & Park Services (DoFPS), Ministry of Agriculture & Forests (MoAF) has conducted series of studies to understand the role of forests in Bhutan's economy.

This study combines the latest biophysical and economic tools to model relations between forests, water and other ecosystem services. The data used in the study includes global climate data calibrated with local measurements of fog interception, and local and national statistics on hydroelectricity generation, timber, fodder and NWFP. The study used various economic valuation techniques and models driven by detailed remotely sensed databases such as Co$ting Nature and Water World to assess the magnitude of forest ecosystem services, their trade-offs, and the links to the economy and geography of the country.

The objectives of the overall study are:

1. To assess the contribution of key forest ecosystem services to Bhutan's economy and the geographical distribution of different forest services and the potential impacts of scenarios for deforestation;
2. To assess the existing experiences of PES-type schemes in Bhutan as a potential instrument for promoting sustainable ecosystem management;
3. To elaborate an in-depth analysis of a PES case for the Bhutan Sustainable Hydropower Development Policy, including biophysical and economic valuation and proposed fund mobilization strategy.
4. Based on ground studies and experiences from other countries, to provide policy recommendations to the scaling up and expansion of PES and/or similar instruments in Bhutan, including the assessment of sources of sustainable finance and the use of supporting tools such as Natural Capital Accounting.
5. To support local capacity building within the country, in particular to provide training in ecosystem services mapping, modelling, monitoring and valuation.

This document presents the results of an assessment of the annual economic values of forest ecosystem services to Bhutan's economy. The study focusses primarily on use values: that is, the benefits that accrue mostly to Bhutanese people.

# Methodology

The study used desk-based review of existing documents, consultation with experts, participatory mapping of main forest ecosystem services (providers, beneficiaries and available data), economic valuation using a variety of tools, and modelling biophysical interactions using the Water World and Co$ting Nature tools used in >140 countries for this purpose (see www.policysupport.org).

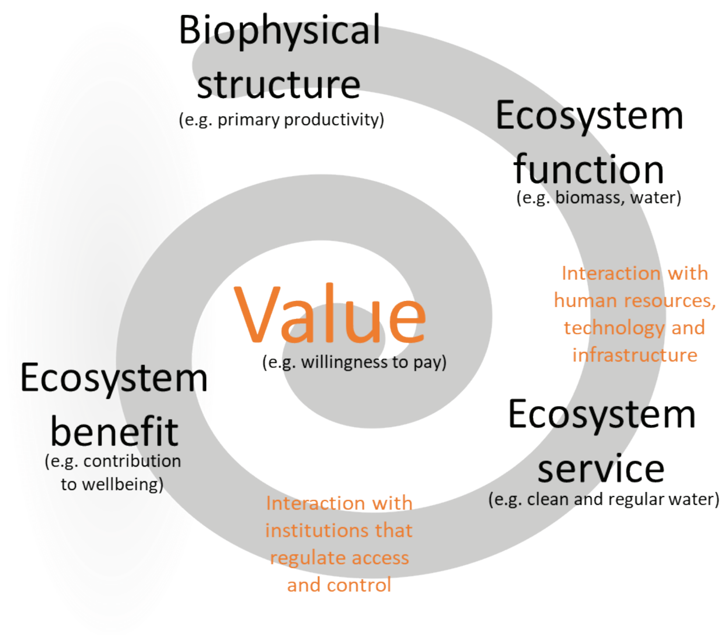
## 1.1.1 Analytical framework: ecosystems, services and values

### Ecosystem functions, services and benefits from nature

Ecosystems are communities of living (people, animals, plants) and non-living organisms (soil, water, air) that interact within a geographic system or biophysical structure. The stock of these ecosystems and their components at a given point of time is often referred to as "natural capital".

The processes that occur within these ecosystems are strongly driven by the number and types of species, supporting and competing. The ensuing balances - and imbalances – affect the ecosystems' functions and their ability to recover from external shocks (their resilience). As ecosystem functions interact with people, technology and infrastructure they generate ecosystem services, which enter economic processes through production functions or by being consumed directly by people. The existence of institutions that regulate access and control in turn determines how these services are distributed across different groups and how each player benefit, generating individual or social values, see Figure 1.

**Figure 1. Ecosystem services conceptual framework**

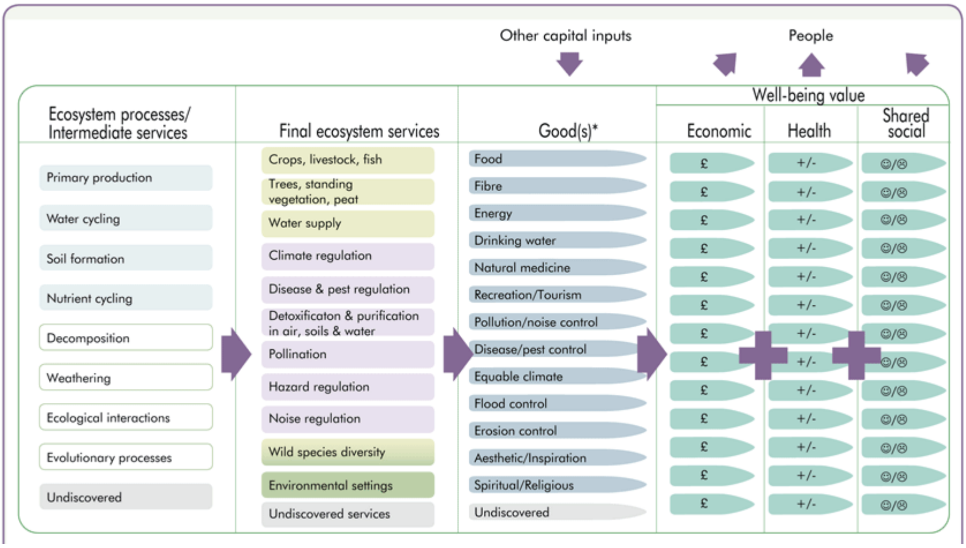



Source: Adapted from Haines-Young and Potschin (2012) and Fisher et al (2014)

The UK National Ecosystem Assessment (UK NEA) provides a useful framework to conceptualise the linkages between these ecosystem processes, services, goods and their impact on people's wellbeing, presented in Figure 2 . Some ecosystem services ("*supporting services*") feed into intermediate processes, while some are more closely linked to production and consumption processes. For example:

- Provisioning services: food, fodder for livestock, water supply for industry and domestic users)
- Cultural services: which includes supporting diversity of wildlife, environmental benefits, recreation and religious spaces;
- Regulating services, for example helping to regulate the climate, reducing hazards and diseases, and contributing to purification of the air, soil and water.
- It is important to recognise that Nature also provides a range of disservices that result in disbenefits to people. These might include crop raiding, human wildlife conflict and pests in the Bhutanese context.

**Figure 2. Ecosystem processes, services, goods and benefits defined in the UK National Ecosystem Assessment**




Source: (UK National Ecosystem Assessment, 2014). Notes: Cultural services (green), provisioning services (yellow), regulating services (purple) and supporting services (blue).

## General context in Bhutan

Covering over 70% of Bhutan, forest ecosystems provide multiple benefits to people, from timber, food, spiritual and recreation to protecting valuable resources that feed into economic processes such as water for hydroelectricity. These physical interactions of forests and ecosystem services are well documented in scientific literature (see for example Bonell and Bruijnzeel (2005) and Bruijnzeel (2010)). Table 2 presents a summary of these linkages, and what would be the expected benefits to people in Bhutan.

This report combines desk-based literature review with a participatory mapping exercise conducted during an international conference on ecosystem services in Paro (WWF and DoFPs, 2017) to establish a theory of change of forest contributions to the economy. Other ecosystem services were discussed, for example hazard mitigation, but for purpose of this study the focus is on ecosystem services presented in Table 2 (though Co$ting Nature provides maps of hazard mitigation services, these are difficult to assign monetary value to). The economic techniques used to identify values varied depending on the ecosystem service and the type of information available, which is discussed in Section 2.

**Table 2. Forest impacts on selected ecosystem services**

| Ecosystem service | Theory of change | Values to people: main beneficiaries |
|---|---|---|
| **Water quantity (total, and flow regulation)** | Forests generally use more water than shorter vegetation because of higher evapotranspiration, but under sustainable management they are better able to soften hydrological highs and lows (e.g. some degree of floods and droughts) | National: Hydroelectric projects; water users (domestic (urban, rural), industrial, agriculture) using piped water (intakes) |
| **Water quality** | Protecting forests helps improve water quality because it reduces inputs of contaminants such as fertilizers, pesticides, organic manures, litter, etc relative to other land uses (agriculture, urbanisation). This produces water of higher quality with lower risk to health. | Local: unpiped water users relying on surface water sources |
| **Sediment control** | Forests can regulate water and when sustainably managed can reduced erosion and sediment transport. They can result in less input of s sediment to rivers than bare soils. | Local: hydroelectric projects, roads |
| **Carbon** | Forests absorb $CO_2$ as part of their metabolism, acting as a sink of $CO_2$ and further reducing $CO_2$ in the atmosphere as the forest grows. Removal of forests results in releases of $CO_2$, an important greenhouse gas. | National/ international |
| **Nature-based tourism** | Approximately 30% of tourism in Bhutan is nature or adventure based. Forests also provide important scenic background for many of Bhutan's cultural sites. | International: tourists (international and regional) |
| **Timber** | Natural forests in Bhutan currently provide an annual average of 161,008 $m^3$ of timber (softwood and hardwood) | Local and national: households, industry (construction, furniture, etc) |
| **Fuelwood** | Although electrification reaches most of Bhutan, fuelwood is still a major source of energy. Estimations of fuelwood extraction vary, from 85,000 to 160,000 $m^3$/year. | Local: households – especially rural |
| **Fodder** | Livestock in Bhutan traditionally graze in forests for fodder and shelter. | Local: households, especially rural |
| **Non-wood forest products (NWFP)** | Over 75% of Bhutan's rural population collect different types of NWFP to complement their livelihoods. | Local: households, especially rural |
| **Wildlife disservices** | Human-Wildlife Conflict is significant in Bhutan, e.g. crops raiding, and killed livestock. | Households, especially rural |

Source: Bonell and Bruijnzeel (2005), Bruijnzeel (2010), Calder (2006), WWF and stakeholder consultations at DoFPs (2017).

### 1.1.2 Modelling with Co$ting Nature

This study uses the web-based Co$ting Nature policy support system to measure and analyse natural capital and ecosystem services provided by natural environments that benefit people. It can also be used to assess the impacts of human interventions before they are implemented in practice. This policy support system (PSS) incorporates detailed spatial datasets at 1-square km and 1-hectare resolution for the entire world, spatial models for biophysical and socioeconomic processes along with scenarios for climate and land use. The PSS calculates a baseline for current ecosystem service provision and allows a series of interventions (policy options) or scenarios of change to be used to understand their impact on ecosystem service delivery.

Typical applications include ecosystem service assessment, conservation prioritization, analysis of co-benefits e.g. for REDD+ and analysis of pressures and threats on carbon and biodiversity in general or for specific planned agricultural, industrial or extractive interventions.

The model can run with built-in global input data (from remote sensing and other global sources) but it can also accommodate users' own datasets. The quality of the results may vary depending on the availability, level of processing, format and consistency of the input datasets used. The global remote sensing data can be more detailed and accurate than some locally sourced data. All background information on how Co$ting Nature operates, including videos and Users Guides, are available in http://www.policysupport.org/costingnature.

Co$ting Nature provides maps of 12 ecosystem services which include (commercial and domestic) timber and fuelwood (divided as hardwood and softwood), grazing/fodder, non-wood forest products, water provisioning (quantity, quality), (commercial and artesanal) fish catch, carbon, natural hazard mitigation (flood, drought, landslide, coastal inundation), culture and nature-based tourism, environmental and aesthetic quality services, wildlife services (pollination, pest control), and wildlife dis-services (crop raiding, pests).

Table 3 describes the characteristics of maps and variables required to display the geographic distribution and value of these services. They can be calculated in relative (nationally or globally normalised) biophysical units and in economic units (through completion of a valuation matrix of use and non-use values – see Section 2 of this report). The model uses these datasets to map ecosystems and the services they provide to the current distribution of humans and human infrastructure. Scenarios for land cover and use change (and their impact on services and service valuations) can also be run.

This study includes a detailed economic valuation for some of these ecosystem services, using both the global datasets that underpin Co$ting Nature and by replacing these with the available national datasets. The results of using the models for scenario changes are presented in a separate document: "Changing Landscapes".

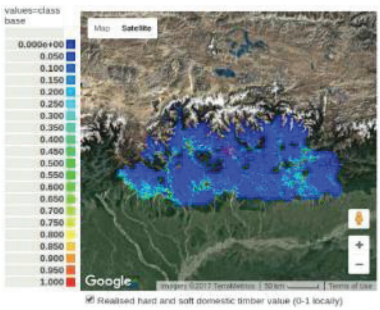
**Table 3. Indicators and values required for Co$ting Nature**

| Service | Mapped variable | Value required: |
|---|---|---|
| **Water (intakes)** [(1)] | map: fractional natural capital footprint upstream of intakes | value: total dam and urban water supply revenue in study area) |
| **Water (rural)** [(2)] | map: per-capita fractional natural capital footprint to rural populated areas | value: amount willing to pay per capita per year |
| **Sediment (intakes)** [(3)] | map: fractional natural capital footprint upstream of intakes | value: annual sediment management cost for all intakes in study area) |
| **Carbon** | map: tonnes per year above ground storage + sequestration for forests only | value: per-tonne carbon market price) recognising that stored carbon also produces benefits annually |
| **Hazard mitigation** | map: GDP/yr at risk of damage | value: protection replacement cost/yr per US$ at risk |
| **Nature based tourism** | map: fractional density of tourists | value: total annual spend of all nature-based tourists in study area) |
| **Environmental quality** | map: Normalised accessible environmental and aesthetic quality | value: hedonic price increase per %s of land at maximum environmental quality) |
| **Fuelwood (hardwood)** | map: tonnes/yr | value: substitute cost per tonne at market price |
| **Fuelwood (softwood)** | map: tonnes/yr | value: substitute cost per tonne at market price |
| **Timber (hardwood)** | map: tonnes/yr | value: market price per tonne |
| **Timber (softwood)** | map: tonnes/yr | value: market price per tonne |
| **Livestock (grazing)** | map: tonnes/yr | value: substitute cost at market price or opportunity cost per tonne of fodder diverted from market sale to cattle) |
| **Cultural/heritage/spiri tual** | map: fractional density of culture-based tourists | value: total annual spend of all culture-based tourists in study area |
| **Non-wood forest products** | map: forests accessible to the poor | value: mean income from NWFP per collector per year) |
| **Wildlife dis-services** | map: crop raiding and other HWC annual probability of damage | value: damage avoidance cost or damage cost/unit area/yr when damaged |
| **Wildlife services** | map: pollination and pest control: annual probability of benefit | value: value/unit area/yr when benefitting total crop value or pesticide cost avoided |
| **Species Richness** | map: fractional species richness | value: indirect use value of all species in study area |
| **Species Endemism** | map: fractional endemism richness | value: indirect use value of endemic species in study area |

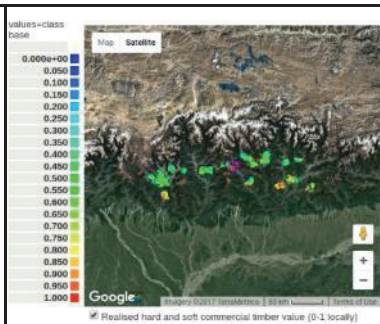
Notes: [(1)] Water (intakes) refers to water that feeds human activities and is distributed primarily through infrastructure such as pipes. [(2)]Water (rural) mostly refers to water used for households directly extracted from natural systems rather than official distribution service. [(3)] Sediment (intakes) are those sediments directly affecting reservoirs for hydroelectricity and urban water treatment plants.

Figure 3 presents the biophysical characterisation of the services in Bhutan and an annotated comparison of the distribution of ecosystem services, as mapped by Co$ting Nature, before any economic values are attached. The maps are normalised on a scale of 0 to 1 (lowest to highest). This normalisation occurs between the 1st and 99th percentile to avoid undue impact of outliers.

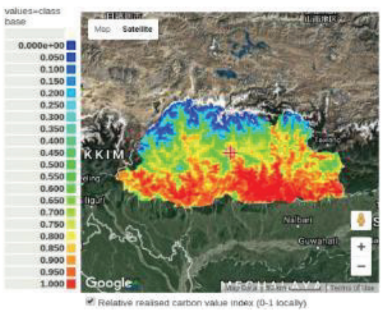
**Figure 3. Services mapped by Co$ting Nature on a scale of 0 to 1 with in Bhutan**



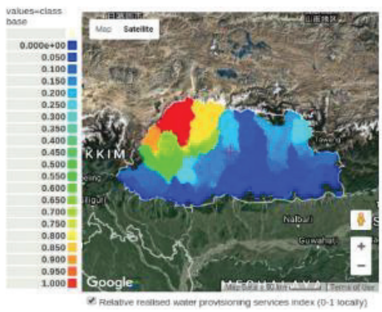

**Domestic timber** is greatest where tree cover is dense and rural populations are present outside of commercial forest management units



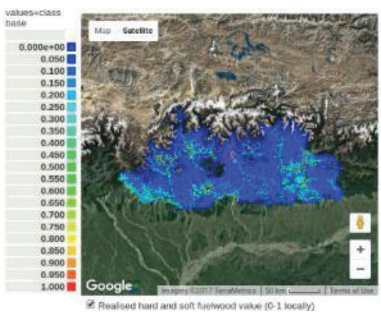

**Commercial timber** is greatest inside those forest management units where the tree cover is densest



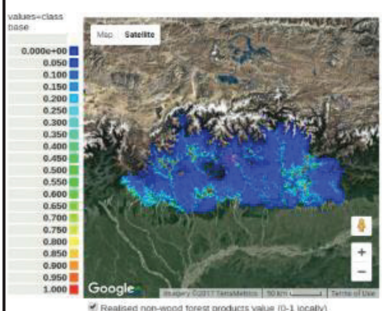

**Carbon values** reflect carbon stock above and below ground as well as carbon sequestration and are highest in the south of the country where forests are more dense and productivity is greater reflecting the warmer, wetter climate.



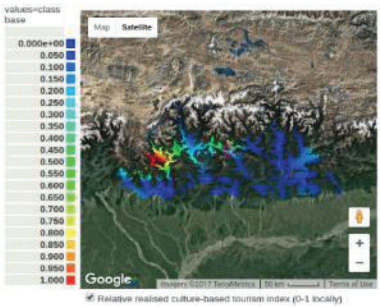

**Water services** reflect the distribution of areas producing volumes of clean water accessible to downstream beneficiaries. They are thus highest in the north-west of the country where significant populations and dams occur downstream.



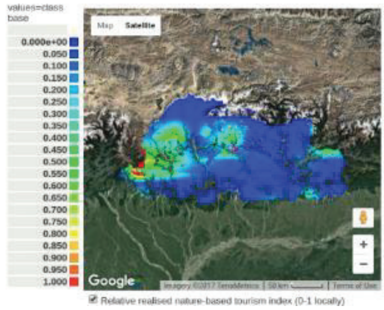

**Fuelwood availability** are greatest where dense forest and significant rural populations combine outside of forest management units



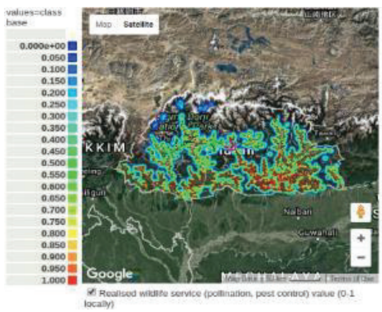

**Non-wood forest products** services are greatest where poor rural populations combine with high forest productivity outside of forest management units



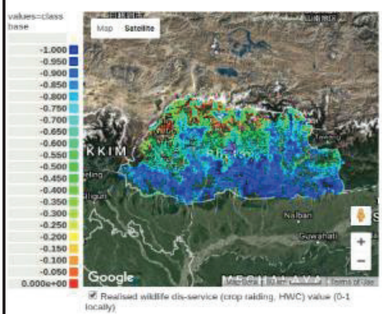

**Culture based tourism** services are greatest close to urban areas where significant numbers of photographs are registered on social media sites geolocated near roads and urban areas. This is likely overestimated because of overestimation of built up cover in the official date set.



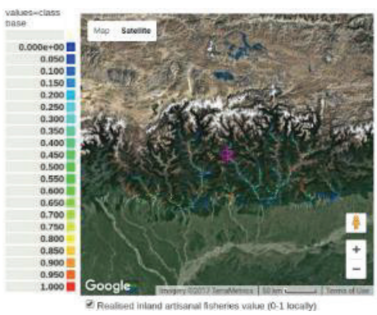

**Nature based tourism** is similarly distributed outside of urban and populated areas where high numbers of photographs are registered on social media sites.



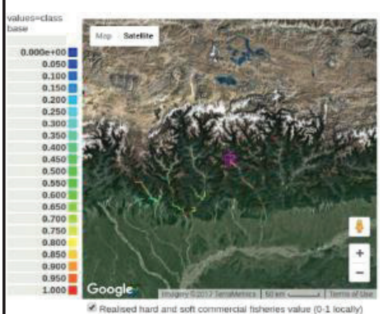

**Wildlife services** can be found at the interface of agricultural land and natural land as seen here. The service decays quickly over distance at this interface. Wildlife services are greatest for the most intensive agriculture.



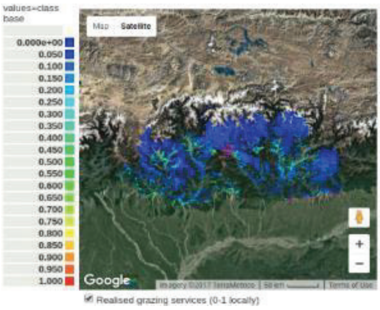

**Wildlife dis-services** also occur at the boundary of agriculture and natural land but are greatest where natural land has the lowest productivity in relation to agriculture, therefore in the north of Bhutan.



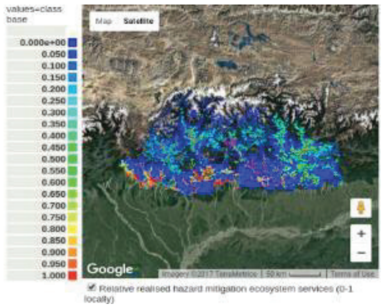

**Artisanal Fisheries** are possible in the significant rivers of Bhutan.



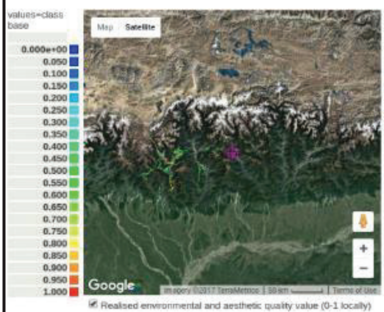

**Commercial fisheries** are clearly only viable in some of the larger lakes and bigger rivers that are to be found in the south of the country




**Grazing services** are greatest where livestock distributions combine with productivity outside of agricultural land




**Multi hazard mitigation** services are highest where the probability of landslide and flood are greatest and where exposure is significant, especially significant in the west and South.




Realisation of **environmental and aesthetic quality** value depends upon proximity to major urban centres. thus this service is mostly to be found in Western Bhutan

Bringing these services together produces the map in Figure 4. This map shows that high levels of service provision across multiple services occur over small areas of dense concentration of beneficiaries along roads and near urban centres, particularly around Thimphu and Paro. Lower levels of provision occur throughout the Bhutanese valleys with the lowest provision of all in the low population areas of the far north and East.

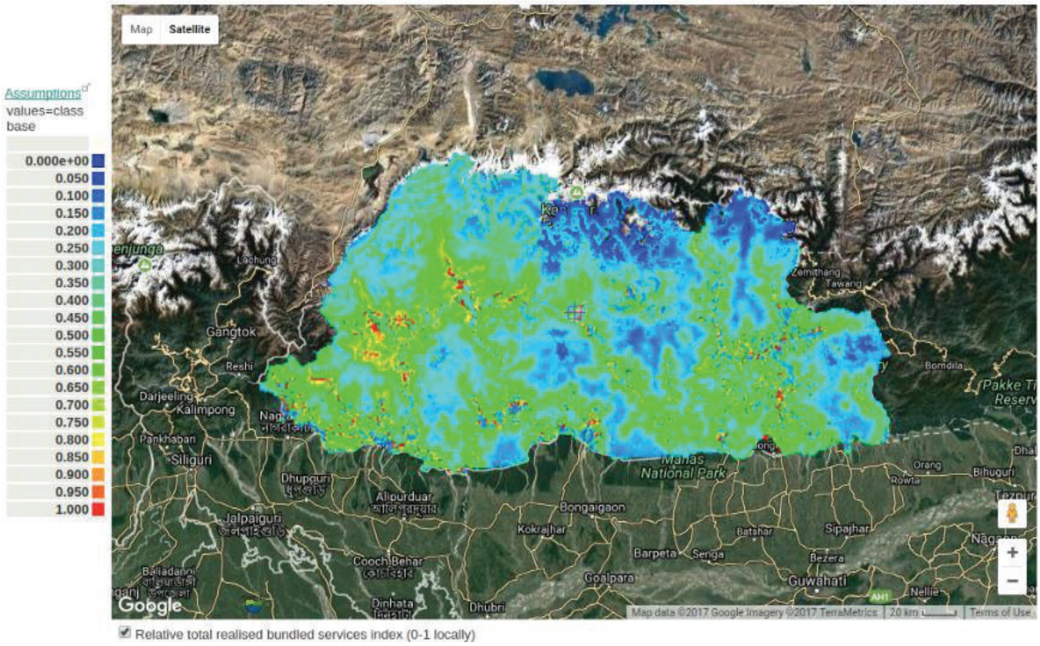



**Figure 4. Bundled ecosystem service provision (non-monetary units)**

Note: Most ecosystem services are concentrated where beneficiaries are nearby, particularly near main cities of Thimphu and Paro

# 2 Economic values

In 2016 logging contributed to 3% of GDP in Bhutan (US$32 million). But because of its high subsidies, it generated only US$885,000 (less than 0.5%) of actual revenues to the government. Given that forests cover more than 70% of the country, these figures suggest an economically stagnant sector.

This section looks beyond timber, mainstreaming forest ecosystem contributions to the economy as inputs to production and as resources for consumption and trade.

# Timber

## 2.1.1 Policies affecting values

The value of timber is highly affected by policies. Bhutan is currently undergoing an in-depth reflection process that seeks to improve the way its forest resources are managed, summarised in the recently published *Drivers of Deforestation* study (WMD, 2017). Key issues emerging include (see also Table 4 for more detail):

- High levels of subsidies often benefit poor people but may dis-incentivise industry;
- Allowing prices to respond to supply and demand can bring better profits to re-invest in the forestry sector (e.g. better sawmills, nurseries, species management, etc) especially given increases in construction.
- Consider revising roles of subsidies through: a) minimising chances of surplus and aligning with real household needs; b) strengthen links with housing association to integrate ideas, structures and materials; c) provide an equivalent cash subsidy that would allow households to purchase the timber from Community Forestry or NRDCL.
- Improve digitalised data collection on requests, approvals, over harvesting, announced audits of sawmills, and other forms of annual surveys and independent evaluation including cross-border controls.

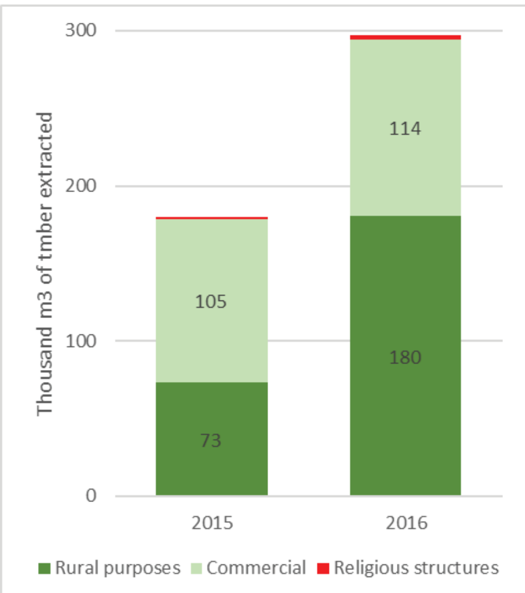



**Figure 5. Timber extraction for commercial and subsidised sectors (thousands of m$^3$)**
Note. Timber extraction has been increasing significantly over the past years. In 2016 the extraction for subsidised timber (rural purposes) saw an increase of more than double its 2015 levels. While subsidised timber undoubtedly benefits poor people, it has the risk of undervaluing the profitability of the timber industry.
Source: Forests Facts and Figures (2015-2016).

**Table 4. Policies affecting the value of timber**

| Commercial Timber Operations | Rural timber supply (subsidised) | Community Forestry Management Groups (CFMG) |
|---|---|---|
| **Description** | | |
| Production and marketing of commercial timber. | Government grant to every household outside the main urban center: 4,000 cft of unprocessed logs (or 2500 cft of sawn timber) to for household construction every 25 years; 1000 cft in unprocessed logs (or 650 cft in sawn timber) for maintenance; also for building fences, cultural and religious ceremonies, fuelwood, etc. | Emerging. Proposed as pilot. |
| **Management** | | |
| NRDCL is responsible to harvest the timber based on the management plans developed by DoFPS and approval of the annual operational Plans by DoFPS. NRDCL only operates in the FMUs. | Management is done by the DoFPS. The Gup verifies the documents and final approval from the DoFPS. Household head writes request, with the Gup having final approval. Instructions are passed to the territorial forest division, which decides which trees are available for harvesting. Although there are written plans most of the decision is discretionary and largely from unmanaged areas. | Members have (conditional lease) rights to manage (plans 5-10 years) and trade NWFP and control timber production and reforestation. |
| **Proportion of the resources** | | |
| Only 17% of forests have potential to be managed as FMU and WS for commercial timber (access/quality/available). Currently uses 8% of forest cover, operates in 16 Forest Management Units (FMUs) and 5 Working Schemes (WS). Generates about 1.9-2.3 million $m^3$ of timber per year. About 10% of this goes to subsidised rural timber. (WMD, 2017) | Some timber comes from FMUs, but the majority comes from areas outside FMUs. 47% of households in Sarpang District complained of insufficient allocations. | 680 CF, accounting for about 2% of the GRF. |
| **Prices** | | |
| Timber sold through fixed prices (auctions banned since 2010, with big impact on prices). | Free. The cost of extraction/ delivery is covered by the household. Most often they use family labour. According to the drivers of deforestation report, subsidised timber is the main cause of forest degradation under REDD+. Although there are no statistics it is presumed that quotas allocation excesses are often re-sold (illegally) in urban areas. US$8333 collected as fines from misuse of rural timber in 2009. | Expected to provide members with timber for house building and domestic uses. Any excess can be commercially sold. Infringements means that DoFPS can take lease away. |

Source: all information in this table is from WMD (2017) Drivers of Deforestation report.

### 2.1.2 Realised values

#### Using GDP for forestry and logging

The first level of valuation is by using national forestry and logging statistics reported by the National Statistics Bureau (Method 1 Table 5). The information on physical timber extraction (i.e. $m^3$) is based on the Forestry Facts and Figures (DoFPS, 2016), with monetary values estimated by the National Statistics Bureau and reported as part of the National Account Statistics (NSB, 2016).

The results are presented at the top of Table 5. The reported contribution of the forestry and logging sector was approximately US$53.5 million. Subtracting the values associated to fuelwood and stone/sand (assumption 60% timber, 40% firewood according to FF&F statistics) the approximate value from forestry operations was US$32.1 million/year. According to Forests Facts and Figures (2016) the extraction in 2015 was 321,780 $m^3$. This suggests that the implicit price of timber of US$100/$m^3$ (not differentiating by hardwood/softwood). Conversations with the National Statistics Bureau suggests a possible overestimation resulting from the use of a high price per ton of timber to calculate value (personal conversation with Ugyen Norbu, NSB). The amounts of timber extracted for this calculation are based on those reported by Drivers of Deforestation study (figure 22).

#### Valuation using reported extraction and corrected timber prices

This section uses corrected market prices to estimate the (existing) value of forest extraction. The assumptions of the analysis are as follow:

- Total timber extracted is 297,230.3 $m^3$ as reported by Forests Facts and Figures 2016. The figure excludes firewood. Assuming a proportion of 36% hardwood - 64% softwood extraction (see Figure 6) this means 190,227.4 $m^3$ of softwood and 107,002.9 $m^3$ of hardwood.

Table 5 presents the valuation analysis using three types of prices:

- Method 2: fixed internal prices retailed by NRDCL in Thimphu, average class A and class B logform: 88.1 US$/$m^3$ for softwood and US$77.1/$m^3$ hardwood. (http://www.nrdcl.bt/uploads/Timber.pdf)
- Method 3: fixed internal prices for sawntimber (as indicator of highest possible value), retailed by NRDCL in Thimphu, average class A and class B:

US$161.95/m$^3$ softwood and US$166.94/m$^3$ hardwood. (http://www.nrdcl.bt/uploads/Timber.pdf)

- Method 4: A final scenario uses Malaysia's average log export prices 2013-2017 (World Bank, 2017), with a price differential of 15% less for broadleaf species (in relation to Bhutan's differential), estimated at US$271.60 for conifer and US$230.9 broadleaf.

The results are presented in Table 5. The estimated market values of (existing) timber extraction vary between US$25.02 to US$76.37 million per year, depending on the prices used.

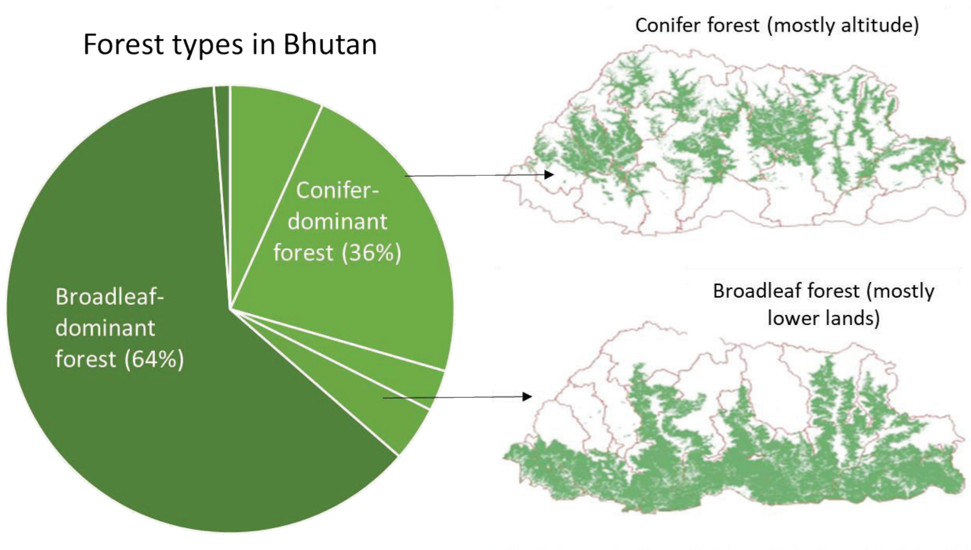



**Figure 6.Proportion of hardwood/softwood extractions**
Source: (DoFPS, 2016) and (MoAF, 2011)

Notes to Figure: Proportions prepared following discussions with experts at WMD in September 2017. Because of terrain, access and species only 17% of the total forest in Bhutan is economically accessible, of which only 10% is currently managed (Watershed Management Division, 2015). The proportion of forests that can be sustainably extracted per year is approximately 25%. This study assumes that the extraction of timber species is generally in line with the forest cover. According to the forest cover maps, forest species can be roughly divided into broadleaf and conifers, and their distribution varies by climate and geographical conditions. Approximately 36% of extraction is for conifer species, and 64% from broadleaf species. Since most timber in Bhutan is from natural forests, we do not distinguish between cultivated (plantation) and natural timber. Cultivated timber would receive a different accounting timber, as their growth is under the control, responsibility and management of institutional units (private or public), and there are statistics for this.

**Table 5. Timber values through corrected market values**

| **Method 1, using GDP for forestry and logging** | Value | Descriptive |
|---|---|---|
| GDP Forestry and logging Million/year (2015) | 53.5 | Million US$ |
| Assumption: 60% timber, 40% firewood | | |
| GDP forestry (no firewood) (million US$/year) | 32.1 | Million US$/yr |
| Total revenues, softwood | 20.6 | Million US$/yr |
| Total revenues, hardwood | 11.6 | Million US$/yr |
| Total timber extraction, 2015 m3 | 321780 | m3 |
| Average price per m3 (*implicit by calculation)* | 100 | US$/m3 |

| **Method 2, using reported m3 extraction and local fixed prices** | Value | Descriptive |
|---|---|---|
| Quantity: Total timber extraction, 2016 m3 | 297230.3 | m3 |
| Softwood extracted | 190227.4 | m3 |
| Hardwood extracted | 107002.9 | m3 |
| Prices (Fixed prices, for log form. For Co$tingNature we use the log value as baseline) | | |
| Fixed price, softwood/conifer (in Thimphu, as retailed by NRDCL, average class A and class B) | 160 | Nu/cft |
| Fixed price, hardwood/broadleaf (in Thimphu, as retailed by NRDCL, average class A and class B) | 140 | Nu/cft |
| Fixed price, softwood/conifer (in Thimphu, as retailed by NRDCL, average class A and class B) | 88.1 | US$/m3 |
| Fixed price, hardwood/broadleaf (in Thimphu, as retailed by NRDCL, average class A and class B) | 77.1 | US$/m3 |
| Conversion factor cft to m3 | 35.31 | 1 m3 to cubic feet |
| Value: total revenue (million US$/year) | 25.02 | US$ |
| Value of total extraction, softwood | 16.77 | US$ |
| Value of total extraction, hardwood | 8.25 | US$ |

| **Method 3, using reported m3 extraction and MAXIMUM price obtainable for timber (sawntimber)** | Value | Descriptive |
|---|---|---|
| Quantity: Total timber extraction, 2016 m3 | 297230.3 | m3 |
| Softwood extracted (36%) | 190227.4 | m3 |
| Hardwood extracted (64%) | 107002.9 | m3 |
| Prices: Maximum prices for timber (sawntimber, to use for Co$tingNature) | | |
| Softwood (294 Nu/cft) | $161.95 | $/m3 |
| Hardwood (303.05 Nu/cft) | $166.94 | $/m3 |
| Value: total revenue (million US$/year) | **48.67** | |
| Value of total extraction, softwood | 30.81 | US$ |
| Value of total extraction, hardwood | 17.86 | US$ |

| Method 4, using reported m3 extraction and international logform Malaysia prices | Value | Descriptive |
|---|---|---|
| Quantity: Total timber extraction, 2016 m3 | 297230.3 | m3 |
| Softwood extracted (36%) | 190227.4 | m3 |
| Hardwood extracted (64%) | 107002.9 | m3 |
| Prices: Maximum prices for timber (sawntimber, to use for Co$tingNature) | | |
| Softwood (294 Nu/cft) | $271.60 | $/m3 |
| Hardwood (303.05 Nu/cft) | $230.90 | $/m3 |
| Value: total revenue (million US$/year) | **76.37** | |
| Value of total extraction, softwood | 51.67 | US$ |
| Value of total extraction, hardwood | 24.71 | US$ |

### 2.1.3 Potential timber values, using Co$ting Nature

This section looks at the potential value of timber extraction using Co$ting Nature. The use of spatially defined units helps to map the geographic input of where most of these ecosystem services are located. The mapped variables and required input for modelling are presented in Table 3 in the methodology section. The main inputs from the valuation exercise in the previous section are the prices of timber (softwood and hardwood). The model then allocates potential revenues from domestic (mostly rural) and commercial timber values – presented in Figure 7.

The results, presented in **Error! Not a valid bookmark self-reference.** suggest that actual use values range between US$25 and US$76 million per year. The potential extraction level, modelled through Co$tingNature, is approximately US$189 per year (using all FMUs). Co$tingNature also provides a figure for all forests accessible from roads (US$387 per year)

The results suggest that potential extraction values could be significantly higher if the forestry industry was allowed to expand operations -provided suitable infrastructure and governance – in ways that increases the revenues of the sector without largely compromising the ecosystem functions. The trade-offs from its extraction need to be carefully considered. At low extraction rates it is sustainable and can continue to be provided. At high extraction rates it is consumptive of the ecosystem and damages the co-benefits for other services provided by forests.

**Table 6. Summary of realised and potential timber values, US$ million/year**

| | National Statistics | Economic Values | | |
|---|---|---|---|---|
| | | low | med | high |
| Estimated value of timber | 32.1[(a)] | 25.02[(a)] | 48.67[(a)] | 76.37[(a)] |

(a) Represents the total estimated values for softwood (conifers) and hardwood (broadleaf) using different prices.

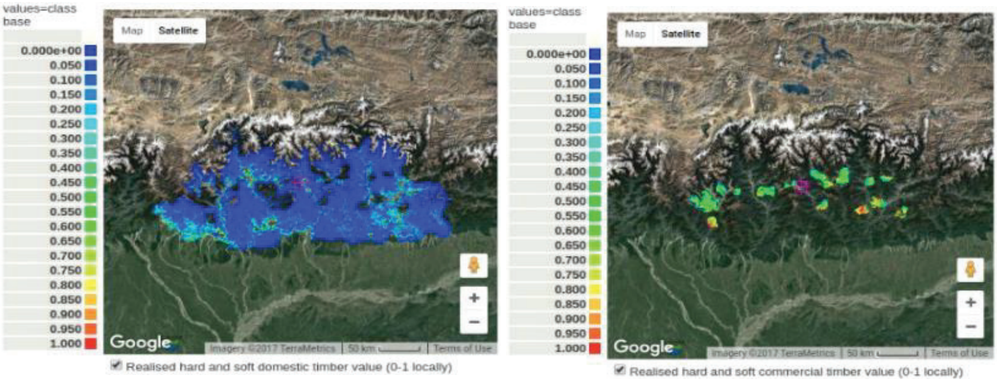



**Figure 7. Distribution of values for domestic (left) and commercial (right) potential timber values, using Co$ting Nature**

Notes: Scale 0-1, with 1 the highest. For output in relative units (0-1 in the study area) the potential and realised values (tonnes) are normalised between the first and 99th percentile. Domestic timber is spread out throughout the country wherever there are forests and people while commercial timber is confined to forest management units.

Methodology to estimate timber in Co$ting Nature: The potential mass of timber (the potential service) is estimated from the above ground carbon stock map (Ruesch and Gibbs, 2008; Saatchi S *et al.*, 2011). The proportion of carbon coming from trees in a pixel is calculated as the product of carbon stock and fractional tree cover (DiMiceli, 2011) for rural areas (Schneider *et al.*, 2009) only (urban trees are considered not to be usable for timber).

The realised service (the timber accessible) is calculated as potential timber within 6 hours of a population centre of >50K people (Uchida and Nelson, 2009) and on slope gradients <31.5 degrees (70%) (Lehner *et al.*, 2008) considered to be workable for logging (Greulich, 1999). Timber mass defined as accessible is constrained by slope to reflect the enhanced cost of removal (and increased wastage) on steeper slopes with a linear decrease in timber availability (from complete availability to zero) as slope increases from 0 to 90 degrees. This is the realised timber service in tonnes.

The spatial distribution of hardwood and softwood is calculated according to the work of Box and Fujiwara (2005) in which mean annual temperature and a cold index are calculated from mean monthly temperature (Hijmans *et al.*, 2005) as the sum of temperature for months where temperatures are less than 5 degrees. Hardwood distributions are calculated as those with a mean annual temperature >20C and a cold index >-10C. Softwood areas are calculated as all other areas.

For output in relative units (0-1 in the study area) the potential and realised values (tonnes) are normalised between the first and 99th percentile. For output in economic units both use values and non-use values are used and are specified separately for hardwood and softwood fractions of the timber mass. The economic value is thus the product of baseline use and non-use values (US$) for the realised service and inflation, where inflation is: $1+f^{-years}$ where f=discount rate and years= years from baseline to time horizon. For this analysis only use values were specified.

# Water

Ecosystems provide important benefits in terms of water -quantity, quality and regulation of flows. Water is the main natural input to several economic processes. This section focuses on the economic values for hydroelectricity and domestic water users.

**Underlying theory of change:** Forest ecosystems provide important functions in terms of water (MEA, 2005). Because of their high altitude and constant exposure to clouds, forests in Bhutan intercept fog that would otherwise remain in the atmosphere and have low evaporative demand because of cool temperatures and frequent cloud cover, thereby increasing flows available during the dry season. During the monsoon season, the cover and variety of trees and layers within the forest help to soften the impact of monsoonal rains, supporting natural soil and water conservation processes, including improved water quality (Bruijnzeel *et al.*, 2010; Calder and Aylward, 2006). Forests tend also to have lower human occupancy and thus reduced loads of agricultural and human pollution

By interacting with people and infrastructure, these ecosystem functions become "ecosystem services": the benefits that people derive from nature. The economic values associated are in turn affected by the existing capacity to create economic returns (e.g. access to technology and markets), and its distribution by prevailing governance systems (e.g. property rights, prices).

The objective of this section is to estimate the economic value of the contribution of forests to water ecosystem services in Bhutan, in particular hydroelectricity and water for domestic uses. This information is then used in models to understand potential co-benefits of forests for other ecosystem services across the country (Co$ting Nature) and benefits for water ecosystem services under current conditions and under land use change (Water World). The modelling component is presented in a separate document: Mulligan, Porras and Burke: "*Modelling changes in Bhutan's ecosystems, impacts and trade-offs*".

Methodology:

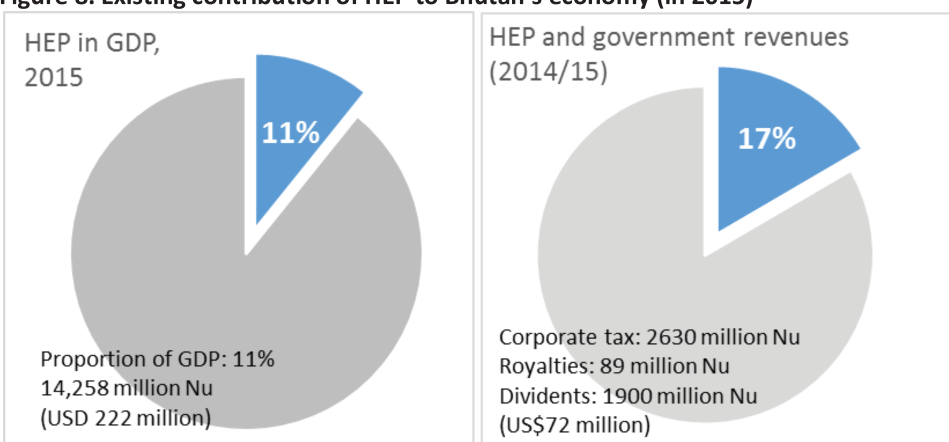
- Estimate economic value of key water-related industries:
    a. Economic value of water for hydroelectricity
    b. Benefits in terms of sediment control (using lost production due to sediment removal)
    c. Economic value of water for domestic use (piped and unpiped) in urban and rural areas
- Modelling water benefits across the landscape:
    a. At national (1km resolution) and catchment level (1 hectare resolution), using Water World.
    b. Assessing co-beenfits of forests at national level, using Co$ting Nature

### 2.1.4 Hydroelectricity

Recent studies by WWF explore in depth the links of Bhutan's hydropower to other sectors, including the environment (WWF, 2016). For example, affordable electricity helps to position the industrial sector to compete in the region. Reported values using national statistics

Hydroelectricity is a very important source of income in Bhutan. In 2015 it contributed to 11% of GDP (NSB, 2016). With prices fixed both for domestic and export markets, revenue levels are heavily affected by water inflow. For 2015 DrukGreen reported total revenues of 14,258 Nu (~US$223 million). Accounting for corporate income tax, royalties and dividends back to the government, hydroelectricity provided 17% of the declared government revenues in 2015 (Department of Revenue & Customs, 2017).

**Figure 8. Existing contribution of HEP to Bhutan's economy (in 2015)**




Source: Royal Government of Bhutan (2016) and DrukGreen(2016)

HEP project can be flexible in their design, considering geography, water flows and investment capacity. The economic analysis in this section uses market prices following three steps: 1) estimating annual generation (divided by wet and dry season); 2) assigning different prices to correct for market distortions, for example due to subsidies; and 3) estimating total value by multiplying quantity by prices. The value of hydroelectricity is then estimated as a function of generation and price, where generation is itself a function of water available and a fixed level of infrastructure.

**Table 7. Details of main hydroelectric plants**

| | Basochhu | Chhukha | Kurichhu | Tala |
|---|---|---|---|---|
| **Catchment area** | 226 km2 | 3,108 km2 | 9,135 km2 | 4,028 km2 |
| **Net Head** | 356/459 m for Upper/ Lower Stage | 435 m | 32 m | 819 m |
| **Installed Capacity** | 24/40 MW for Upper/ Lower Stage | 336 MW | 60 MW | 1,020 MW |
| **Number of Units** | 2x12/2x20 MW for Upper/ Lower Stage | 4x84 MW | 4x15 MW | 6x170 MW |
| **Mean Annual Generation** | 291 GWh | 1,800 GWh | 400 GWh | 3,962 GWh |

Source: Druk Green Annual report 2015

***Step 1. Estimating quantities of hydroelectric generation in one year***

Hydroelectric plants can be designed to meet base-load demand, peak demand, or a combination of both. The production varies throughout the year, depending on water flows available during the wet and dry seasons. Table 8 presents reported generation by the four existing hydropower plants (as per 2016 annual report). The Sustainable Hydropower Policy in 2008 proposed a target of building additional 10,000 MW of hydropower capacity by 2020. The 12$^{th}$ Five-Year National Plan, which is being finalised now, features this expansion.

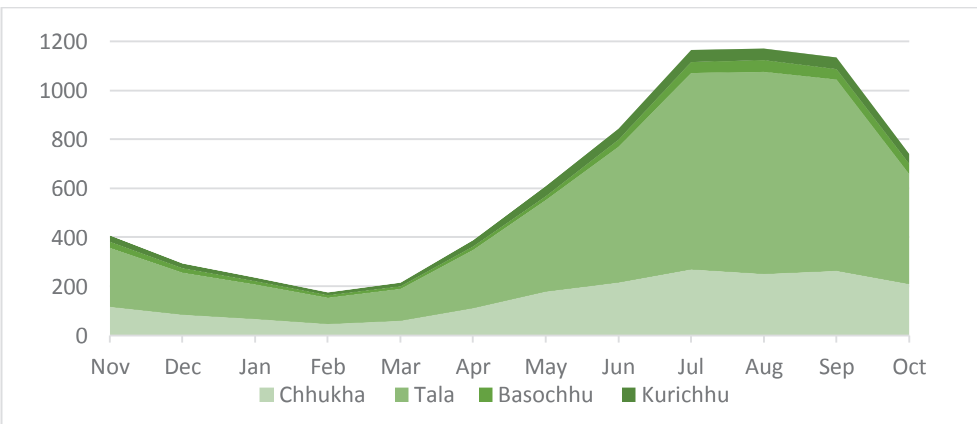
Table 8. Total Generation Million units, 2015 (GWh)

| Monthly Energy Generation, (MU) 2015 | Season | Chhukha (CHP) | Tala (THP) | Basochhu (BHP) | Kurichhu (KHP) | Total |
|---|---|---|---|---|---|---|
| **Nov** | Dry | 116.2 | 241.3 | 24.8 | 25.1 | 407 |
| **Dec** | Dry | 83.8 | 172.2 | 18.2 | 18.7 | 293 |
| **Jan** | Dry | 66.3 | 141.8 | 13.4 | 13.8 | 235 |
| **Feb** | Dry | 46.0 | 107.8 | 10.3 | 10.9 | 175 |
| **Mar** | Dry | 59.1 | 130.9 | 10.6 | 14.2 | 215 |
| **Apr** | Dry | 110.7 | 238.7 | 14.2 | 24.9 | 389 |
| **May** | Wet | 178.3 | 374.7 | 15.6 | 41.0 | 610 |
| **Jun** | Wet | 215.4 | 555.1 | 28.9 | 44.8 | 844 |
| **Jul** | Wet | 269.0 | 802.6 | 44.8 | 49.3 | 1166 |
| **Aug** | Wet | 250.4 | 825.9 | 47.6 | 47.7 | 1172 |
| **Sep** | Wet | 263.1 | 781.7 | 42.6 | 47.7 | 1135 |
| **Oct** | Wet | 209.1 | 449.8 | 41.6 | 40.7 | 741 |
| **Total effective generation (Million KWh, or MU)** | | 1867.4 | 4822.5 | 312.7 | 379.0 | 7382 |

Source: (DrukGreen, 2016)

Figure 9 shows the pattern of generation across wet and dry season. The economic importance of water increases during the dry season when water flows are lower, and decreases in the wet season, when the monsoon rains significantly increase the water available.

**Figure 9. Annual generation of hydroelectricity, by month and by plant**




Source: Drukgreen (2016)

***Step 2. Selecting different prices levels to correct for market imperfections***

Market price valuation requires correcting prices for subsidies, by theoretically removing barriers to trade. The price of electricity in Bhutan is subsidised for national consumption. Export prices have their own distortions as well, as they are part of a political negotiation between the Government of Bhutan and India (where the energy is exported to).

This analysis uses several price levels, presented in Table 9 and discussed below.

1. Cost of production: 1.59Nu/KWh, which is a fixed level established by the government. It does not include distribution cost or revenues.
2. Export price: 1.98 Nu/KWh, which is a price also fixed from agreements.
3. Commercial rates of electricity in India: 6 Nu/KWh.

Prices 2 and 3 also include distribution costs (i.e. grid). The prices are not disaggregated to reflect the additional distribution cost linked for example to changes in voltage for export or domestic markets. For the scope of this study, using more general figures provide sufficient information in terms of magnitude and direction of change. When applying the models for scenario changes, the assumption is that all existing infrastructure does not change.

The model also introduces an element to account for scarcity. Because prices are fixed throughout the year, they do not vary to reflect higher/lower demand (i.e. night, day rates) and seasonal scarcity (i.e. lower flows in dry season). To introduce this element of scarcity the model adds an artificial 20% price increase for dry season generation for the three previous prices considered. This 20% scarcity price is only applied during dry months (November to April) to reflect water scarcity -as shown in Figure 9 above. All results are presented with and without this artificial scarcity "premium".

**Table 9. Prices for electricity, wet and dry season**

| Price | Average price (Nu/KWh) | Corrected by seasonality (20% for dry season flow), Nu/KWh |
|---|---|---|
| **Price 1: Production cost** | 1.59 | 1.91 |
| **Price 1: Export price** | 1.98 | 2.376 |
| **Price 2: Indian commercial rate** | 6 | 7.2 |

***Step 3. Estimating annual values of hydroelectricity generation***

Table 10 and Figure 10 present the estimates using the different prices, with and without the scarcity premium. For existing generation, the values range between approximately US$183.1 million /year to US$723 million per year when using commercial rates and accounting for scarcity. The impact of the "scarcity premium" is approximately a 5% increase in economic values when included. These values are used as input for Co$tingNature.

**Figure 10. Ranges for economic values for hydroelectricity (US$ millions per year)**

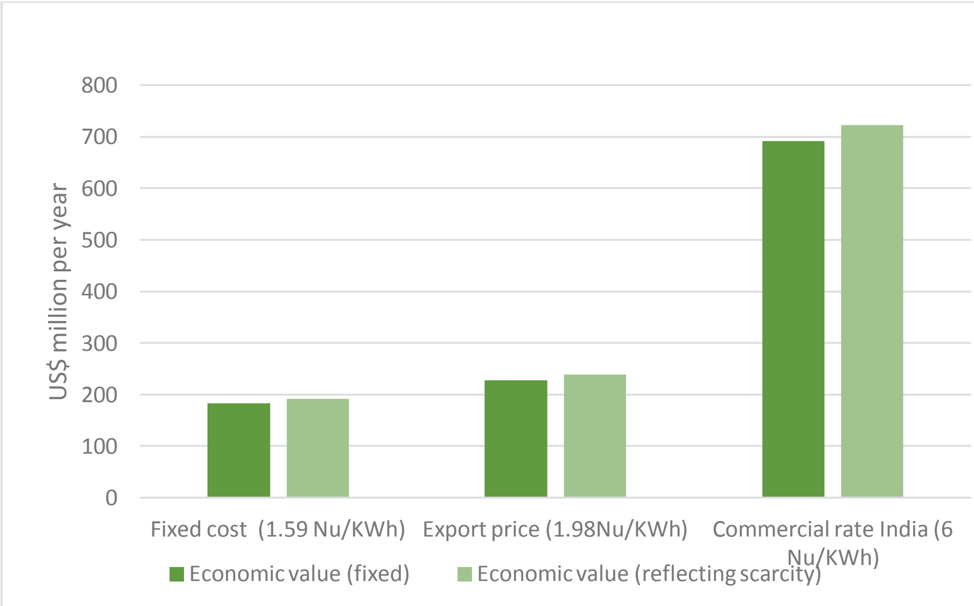



**Table 10. Total annual income from hydroelectricity**

| Month | Total generation (2015) | Price 1: cost of production 1.59 Nu/KWh **Revenues (US$ million per year)** | | Price 2: Export price 1.98 Nu/KWh **Revenues (US$ million per year)** | | Price 3: Commercial rate 6 Nu/KWh **Revenues (US$ million per year)** | |
|---|---|---|---|---|---|---|---|
| | | Fixed | With Scarcity added | Fixed | With Scarcity added | Fixed | With Scarcity added |
| **Nov** | 407 | 10.1 | 12.1 | 12.6 | 15.1 | 38.1 | 45.8 |
| **Dec** | 293 | 7.3 | 8.7 | 9.1 | 10.9 | 27.4 | 32.9 |
| **Jan** | 235 | 5.8 | 7.0 | 7.3 | 8.7 | 22.0 | 26.4 |
| **Feb** | 175 | 4.3 | 5.2 | 5.4 | 6.5 | 16.4 | 19.7 |
| **Mar** | 215 | 5.3 | 6.4 | 6.6 | 8.0 | 20.1 | 24.1 |
| **Apr** | 389 | 9.6 | 11.6 | 12.0 | 14.4 | 36.4 | 43.6 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **May** | 610 | 15.1 | 15.1 | 18.8 | 18.8 | 57.1 | 57.1 |
| **Jun** | 844 | 20.9 | 20.9 | 26.1 | 26.1 | 79.0 | 79.0 |
| **Jul** | 1166 | 28.9 | 28.9 | 36.0 | 36.0 | 109.1 | 109.1 |
| **Aug** | 1172 | 29.1 | 29.1 | 36.2 | 36.2 | 109.7 | 109.7 |
| **Sep** | 1135 | 28.2 | 28.2 | 35.1 | 35.1 | 106.3 | 106.3 |
| **Oct** | 741 | 18.4 | 18.4 | 22.9 | 22.9 | 69.4 | 69.4 |
| **Total** | 7382 | 183.1 | 191.6 | 228.0 | 238.6 | 690.9 | 723.0 |

Note: Dry season months depicted in red

### 2.1.5 Sediment removal and water quality in HEP

Sediments can be a major problem in hydroelectric dams worldwide. Sediment have two costs for hydropower: 1) in terms of flushing cost sediments and 2) the cost due to wear and tear of runners. The monetary figures provided below are low estimates of the impact of sediments for the hydroelectric operations.

All existing hydroelectric projects in Bhutan are run-of-river schemes. in CDCL. Druk Green established the Bhutan Hydropower Services for reclamation of runners and allied underwater hydro-mechanical components that are prone to wear and tear, for example from sediments. According to DrukGreen Annual Report for 2015, the approximate expenses in R&M for civil structures, and electro mechanical were approximately US$4 million in 2015. Assuming that one-third of these expenses[3] were linked to maintenance of runners gives a rough estimate linked to wear-and-tear of **about US$1.35 per year**.

The cost of lost generation when flushing sediments is estimated as a 3-step approach: 1) estimating the number of hours the dams are out of operation; 2) estimating the actual generation per hour for each of the projects; and 3) assigning the value of lost energy using the prices described in the section above (Nu. 1.59, Nu. 1.98, and Nu.6 per KWh).

*Step 1. Estimating number of hours out of operation.* DGPC's strategy to deal with sediments is by opening the gates of the dam and "flushing them out" during the dry season. Detailed data from dam scouring was provided for Chukkha Dam by DGPC in September 2017. Advice from plant engineers suggest that the figures are representative for the other dams. According to this table, the plants are out of operation for about 16.2 hours during the dry season every year.

[3] Expert recommendation from Tashi Choeden and Thinley, Deputy Manager DHPS during Punakha workshop June 03-08 2018.

**Table 11. Dam Scouring, Chukkha Dam**

| Year | Frequency in a year | Type of Dam scouring | | Remarks |
|---|---|---|---|---|
| | | For flushing sediment | Duration in Hours | |
| 1999 | 1 | 1 | 9Hrs | Scheduled Scouring |
| 2000 | 1 | 1 | 10Hrs | Scheduled Scouring |
| 2001 | 1 | 1 | 6.50Hrs | Scheduled Scouring |
| 2002 | Scouring details not available | | | |
| 2003 | Scouring details not available | | | |
| 2004 | Scouring details not available | | | |
| 2005 | Scouring details not available | | | |
| 2006 | 1 | 1 | 7Hrs | Scheduled Scouring |
| 2007 | Scouring details not available | | | |
| 2008 | 1 | 1 | 12.35 | Scheduled Scouring |
| 2009 | 1 | 1 | 10 | Ad-hoc due to flash flood |
| | 1 | 1 | 4.75 | |
| 2010 | 1 | 1 | 11.32 | Scheduled Scouring |
| 2011 | Scouring details not available | | | |
| 2012 | 1 | 1 | 9.3 | Scheduled Scouring |
| 2013 | 1 | 1 | 11.83 | Scheduled Scouring |
| 2014 | 1 | 1 | 20.5 | Scheduled Scouring |
| 2015 | 1 | 1 | 23 | Scheduled Scouring |
| **Average 2012-2015** | | | 16.2 | |

Source: Data provided by Druk Green, September 2017.

Step 2. Estimating the generation lost in each plant. Assuming all plants are out of operation for about 16.2 hours, the generation lost is estimated in relation to the efficiency of each plant. Step 3 presents the approximate energy lost per year for each plant, and in total: 6.41 million KWh in a year.

**Table 12. Total generation lost while flushing out sediments per year and per plant**

| | Chukkha (from data) | Tala | Basochhu | Kurichhu | Total |
|---|---|---|---|---|---|
| Total generation dry season months (million GWh) | 482 | 1033 | 92 | 108 | |
| Number of hours working | 4320 | 4320 | 4320 | 4320 | |
| Generation per hour (million GW) | 0.11 | 0.24 | 0.02 | 0.02 | |
| Total energy lost during the year: (million KWh) | 1.80 | 3.86 | 0.34 | 0.40 | **6.41** |

Step 3. Estimating values. The previous section discussed the different prices used for estimating economic values of hydroelectricity. This section applies the same prices (recovery, export, commercial) and a 'scarcity premium' element. The results are shown in Table 13

**Table 13. Value of removing sediments, in terms of lost generation, US$ million per year**

| | Fixed | With 20% Scarcity premium |
|---|---|---|
| **Price 1: Fixed cost of generation Nu.1.59** | 0.16 | 0.19 |
| **Price 2 (Export Nu. 1.98)** | 0.20 | 0.24 |
| **Price 3 (commercial: Nu.6)** | 0.60 | 0.72 |

According to this analysis, the total economic cost of sediment removal varies between US$1.5 million and US$2 million per year, which takes into account the lost energy during flushing, and the cost of repairing and cleaning the runners.

**Table 14. Total cost of removing sediments: lost generation and repairs, US$ million per year**

| | Low | Medium | High |
|---|---|---|---|
| **Annual cost (USD million: includes cost of runners, and lost generation)** | 1.54 | 1.59 | 2.07 |

* Note: the values presented here include the 20% economic 'scarcity premium', to reflect that flushing takes place during the period when water is more scarce, even if the market rates remain fixed.

## 2.1.6 Water for domestic uses

This section looks at the total value of water for piped and unpiped households using two methods:

For households connected to piped systems:

1) Method 1: baseline, using national accounts
2) Method 2: estimating the value by looking at total number of households connected to piped connections.

Estimates of values for households in rural areas not connected is based on results from a Willingness to Pay (WTP) for improved service.

### Urban piped users, national statistics

The first method is straightforward. According to the National Accounts Statistics, the contribution of water utilities to the country's GDP was 31.99 million Nu, equivalent to approximately half a million US$ per year (NSB, 2016).

**Box 1. Domestic water in Bhutan**

Water distribution in Bhutan is done through public water utilities in the 20 districts across the country. According to the latest household survey, approximately 87% of urban households and 73% of rural households have improved piped water supply within their households. Sewage and sanitation is mostly present in large cities like Thimphu, Phuntsholing and Gelephu (National Statistics Bureau, 2013). The 2017 Census will shed more up-to-date light on the state of water provision in the country. A better understanding of who benefits and how can help unlock potential revenues to invest not only in better service delivery but in continuing the protection of ecosystems that affect water quantity and quality

Good quality piped water is accessible by most households in urban areas. But as cities grow rapidly this will affect the utilities' capacity to deliver. Photo I Porras.

## Economic values, using corrected prices and WTP

Corrected market values. The value provided by GDP (above) may be lower than the real value, as it reflects subsidies and potential inefficiencies in collecting fees. As before, the economic analysis follows the three steps of 1) estimate quantities, 2) estimate prices, and 3) estimate total value.

**Step 1: Estimating quantity.** Table 15 presents an estimation of the total number of households with piped connection within their homes. This information is obtained from the Living Standards Survey (National Statistics Bureau, 2013). According to this survey, 76% of urban households and 29% of rural households have piped connections within their dwelling. This means that there is a total of 74,966 households connected to pipes. These pipes may come from water treatment plants (in urban areas) but in rural areas are more likely to extract directly from streams and river.

**Table 15. Estimating number of households with piped connections**

| Number of households (urban) | 59,044 |
|---|---|
| Number of households (rural) | 104,967 |
| % people with piped water into dwelling (urban) | 76% |
| % people with piped water into dwelling (rural) | 29% |
| Number of households with piped into dwelling (urban and rural) | 74,966 |

**Step 2: Estimating prices.** Water prices are progressive: they increase according to the amount of water used by the household. The average bill for water per household is estimated in two ways:

- According to Thimphu City Corporation[4], the average consumption for a household is approximately 20m$^3$/month. This is roughly equivalent to 75 Nu/household/month, or US$ 1.2.
- A Hedonic Study conducted in Bhutan (Ngawang and Kuenzang, 2015) estimated the Willingness to Pay for good service piped water for rural and urban areas in Bhutan, by comparing the property values or rents between connected and unconnected houses after controlling for other factors that also affect prices. The resulting value is 362 Nu/household/month (approximately US$ 5.6). Full details on how these values were obtained are available on their report in the bibliography.

[4]http://bhutanobserver.bt/2921-bo-news-about-water_tariff_to_be_increased.aspx

**Step 3. Estimated revenue from sales, for different prices.** Total revenue is estimated by multiplying the number of households with piped connections by the two prices. The results present ranges between US$1.05 and US$5.08 million per year (Table 16).

**Table 16. Total revenue from piped water collection, corrected market prices**

| Estimation of value | Indicator |
|---|---|
| **Number of HH with piped into dwelling (urban and rural)** | 74,966 |
| **Tariff 1, 75 Nu/hh/mont, in USD** | 1.17 |
| **WTP, 362 Nu/hh/month in USD** | 5.65 |
| **Annual revenue, Tariff 1 (Nu75/month), in million US$/year** | 1.05 |
| **Annual revenue, using WTP as tariff (Nu 362/hh/month) in million US$/year** | 5.08 |

## Economic values for unimproved water supply (rural)

Because of their remoteness, many rural households remain unconnected to piped water. They collect water directly from rivers or storage tanks, which is rarely treated besides boiling water for infants[5], even piped water in these areas often extracts direct from streams, with only basic filtration of sediments. These households do not pay any fee for water, water is therefore considered free and its contributions to the economy fail to be reflected in the books. Unpiped and untreated households are even more dependent on the services provided by ecosystems than piped households. Exposure to contaminated sources for example has direct impact on health, like diarrhoea, especially on children and vulnerable adults.

There are different ways to value water for unpiped households. For example, the costs in terms of health (e.g. number of days people are off-work because of diarrhoea), or the investments individual households make to procure their own water (e.g. the cost of digging wells or building protective fences around water springs).

This study combines information from the Living Standards Survey (2013) and the results of the hedonic model prepared by Ngawang and Kuenzang (2015), who estimated willingness to pay for improved water connections within the households by comparing rental prices and controlling for external factors.

[5] Focus group with community group and local forestry officers, in Chukhha watershed, 16/09/2017.

**Table 17. Economic values of rural (unpiped) water**

| | | |
|---|---|---|
| **1. Quantity** | | |
| **Number of HH (rural)** [a] | 104,967 | pp |
| **2. (Price)** | | |
| **WTP for inside piped connection (rural)** [b] ***equivalent to Nu 66/hh/year*** | 12.4 | US$/hh/year |
| **Using existing piped minimum tariff of Nu.75/hh/month** | 14 | US$/hh/year |
| **Average HH size** | 4.2 | Persons per household |
| **WTP per person using price Nu.66/hh/month** | 2.92 | US$/pp/year |
| **WTP per person using price Nu 75/hh/month** | 3.32 | US$/pp/year |
| **3. Value** | 70.52 | millions Nu/year |
| **With price of Nu.66/hh/month** | 1.3 | US$ million /year |
| **With price of Nu.75/hh/month** | 1.47 | US$ million /year |

Sources: [a]Living Standard Survey 2017; [b]Ngawang and Kuenzang (2015), which shows 66 Nu/HH/month for rural areas and Nu362 for urban areas.

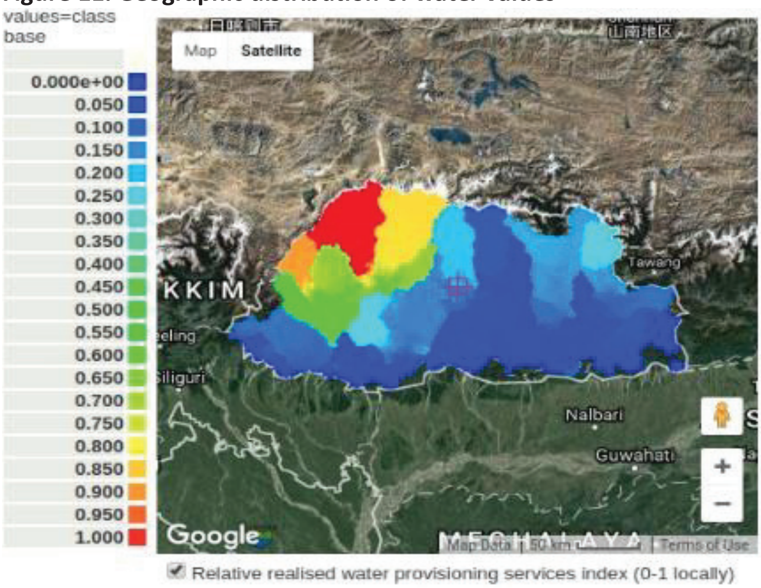
Water treatment plants are only available for urban areas. This study assumes that all rural households are exposed to lesser quality of water, and whose quality is heavily dependent on the health of the ecosystem in the basins. For prices this study uses two values for ranges: 1) the Ngawang and Kuenzang's WTP study suggests that households in rural areas are willing to pay approximately 66 Nu per month for improved water within their household; and 2) applying the same tariff of Nu.75/household/month. The estimated values range between US$1.3-US$ 1.47 million per year.

### 2.1.7 Modelling water potential across the landscape, Co$ting Nature

The information from this section is entered into Co$ting Nature to estimate the potential realisable economic values of water ecosystem services. The mapped variables and values required are presented in Table 3 in the methodology section.

A more in-depth description of these values in relation to country values is presented in a separate document. The model estimates the water runoff available in the watersheds where major dams or cities are located. It also looks at the location of rural populated areas to estimate rural water values. It is important to remember that water benefits reflect the distribution of upstream areas producing *clean* water for different classes of beenficiary (for hydroelectricity and other intakes (eg urban water use) and for rural domestic use) and is thus affected by the distribution of water, natural landscapes providing clean water and the distribution of downstream beneficiaries. Economic values therefore are highest in the north-west of the country where significant volumes of clean water are produced and significant populations and dams occur downstream.

**Figure 11. Geographic distribution of water values**




## Tourism

Tourism is an important economic activity in Bhutan, with fast growing market trends every year (35% increase in visitors between 2015 and 2016, and about 20% between 2016-17). It generates significant amounts of revenue and foreign currency, as well as catalysing new jobs in the economy. The government understands the importance of the sector and is developing plans to facilitate infrastructure and improve benefit-sharing strategies. Mass tourism is expected to face rapid expansion in coming years, especially from growing middle-income regional visitors from India. However, most of the benefits for those involved (hotels, restaurants) are in urban areas (including hotel, restaurants and tour operators), with rural people not receiving major benefits (Bhutan Tourism Council, 2016). According to the annual report of 2017, over 60% of international tourists spent more than US$250 per day during their stay in the country.

Tiger's Nest in Bhutan. Forests and natural ecosystem play a key role in the attraction of Bhutan's main cultural sites. Photo I Porras.

### 2.1.8 Reported economic values

#### Values reported in national statistics

Approximately 210,000 people visited Bhutan in 2016. The gross earnings from tourism towards GDP in 2016 were US$73.7 million. Additionally, the industry generated other revenues such as visa fees, taxes, etc, with an annual earning of US$ 147 million in 2015. According to exit surveys, approximate 29% of all visitors are nature-based tourists. This suggests that nature-based tourism (which includes forests, wetlands, glaciers etc) generates an annual income of at least US$42.6 million – see Table 18.

**Table 18. Reported revenues from nature-based tourism, from national statistics (US$ million/year)**

| Indicator | Value |
|---|---|
| Gross Earning | 73.74 |
| Royalty | 20.28 |
| Visa Fees from tourists | 2.15 |
| 2 percent Tax Deduction at Source | 1.02 |
| Tour Operators' Net | 49.75 |
| Baseline earnings from tourism | **147.0** |
| Of which 29% nature-based | **42.6** |
| And 61% is culture based | 89.7 |

Source: Data from Bhutan Tourism Council

## Economic valuation using travel cost

This analysis uses information collected by the Bhutan Tourism board to estimate a quick Travel Cost Analysis for tourism in Bhutan(Bhutan Tourism Council, 2016). Travel cost is a revealed preferences technique which assumes that people are willing to incur in expenses to access a site. This estimated "price" is used as an approximation of the value of the ecosystem service value for recreation.

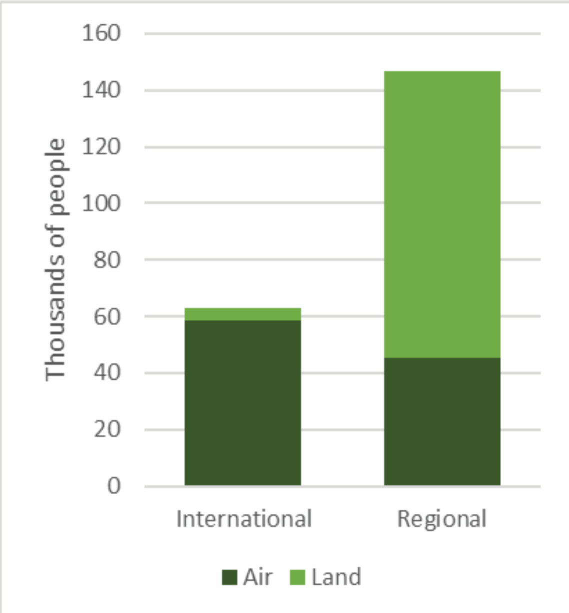
The travel cost analysis considers:

> **1) Market segments**: Visitors are grouped as "international" (Asia-Pacific, Europe and North America principally) and "regional", mostly from India but also from Bangladesh. The tourist council provides statistics on the number of visitors for each of this group.
>
> **2) Average expenses** per individual include personal expenses (as reported by the tourism council, equivalent to US$1,735/trip for international tourists and US$583/trip for regional visitors). Information on these expenses includes accommodation, transport, food and beverages, personal shopping, entertainment, guide services, communications, tipping and donations.
>
> **3) Travel costs** (see Table 19) for air-based travel are estimated using an average ticket from Drukair plus the cost of the international connection from port of origin (Asia-Pacific, Europe and North America). Travel costs for land travellers are estimated using the average return journey cost[6] from three main routes into Thimphu: Kolkata, Dhaka and Kathmandu, using a rough cost of US$0.60 per mile.

[6]http://www.theaa.com/driving/mileage-calculator.jsp

**Figure 12. Type of visitor and mode of entry**

Most visitors (70%) are regional, arriving mostly from India and Bangladesh. Of this, 30% were "international" (e.g. Europe, North America). The mode of transport is very linked to the type of visitor: 93% of international visitors arrive by air, while 70% of regional visitors travel by car.




Source: prepared with data from Bhutan Tourism Council

**Table 19. Average transport costs for regional and international travel**

| | Return |
|---|---|
| Average RETURN car journey cost | 582 US$ |
| Kolkata to Thimphu, 542miles, $0.60/mile | 650.4 US$ |
| Dhaka to Thimphu, 415 miles | 496.8 US$ |
| Kathmandu to Thimphu, 500 miles | 600 US$ |
| Average airfare | |
| Average DRUK airways ticket into Bhutan | 600 US$ |
| Connection to DRUK | |
| Asia- Pacific (connection to Druk airways) | 300 US$ |
| Europe | 1000 US$ |
| North America | 1500 US$ |
| Others | 1800 US$ |

**4) The nature component of visitors** is estimated based on two factors: the proportion of visitors coming for leisure (87% international and 83% regional) and the proportion visitors reporting nature, environment and adventure as the main reason for the visit. Two values are obtained in that way: a) using values of nature-based tourism only (29% international, 31% regional), and b) assuming that 50% of all leisure visitors enjoy the forested landscape beauty while visiting cultural sites.

The results are presented below. The economic value of tourism (cultural, nature, leisure) in Bhutan is approximately US$426 million per year, and increasing at a fast rate. Within this, the contribution of forest landscapes to tourism ranges from US$108 to US$182 million per year.

**Table 20. Economic value of forests for tourism in Bhutan (US$ million/ year)**

| | Number of visitors | | Expenses pp/trip | | Total expenses |
|---|---|---|---|---|---|
| | Air, persons | Land, persons | Air ($/pp/trip) | Land ($/pp/trip) | US$ million/ year |
| International | | | | | |
| Asia- Pacific | 32,567 | 4377 | 2,635 | 2,318 | 148.7 |
| Europe | 15,183 | | 3,335 | | 50.6 |
| North America | 9,343 | | 3,835 | | 35.8 |
| Others | 1,302 | | 4,135 | | 5.4 |
| Subtotal international visitors | 58,396 | | | | 240.5 |
| Regional Visitors (India, Bangladesh) | 45140 | 101657 | 1,483 | 1,166 | 185.5 |
| Total tourism (annual) | 103,536 | 106,034 | | | 426 |
| Economic values of leisure travel tourism[(a)] | | | | | |
| International (87% of group) | | | | | 209 |
| Regional (83% of group) | | | | | 154 |
| Of, which the following reported nature-based tourism as main reason of visit: | | | | | |
| International 29% | | | | | 61 |
| Regional 31% | | | | | 48 |
| Value 1: Economic value of forests in Bhutan from nature-based tourists: | | | | | 108 |
| Value 2: Economic value, assuming 50% of all tourists enjoy the benefits of forest surrounding cultural sites[(b)] | | | | | 182 |

Source: Data from Bhutan Tourism Council (2016). Notes: (a) the remaining percentage is business or official travellers. (b) This estimate assumes that even if people do not declare they visit as 'nature-based' tourists the still enjoy the beauty of the forests as part of the cultural sites they visit.

## 2.1.9 Modelling tourism potential with Co$ting Nature

The information from annual economic values is used as input for Co$ting Nature following the methodology outlined in Table 3. Co$ting Nature estimates the value of nature-based tourism taking into account the annual expenses form tourists and maps of fractional density of tourists. The estimates of value range between US$43 million -as currently reported by national statistics, to US$182, which reflects a true estimation of the value people place in willingness to pay to travel to Bhutan.

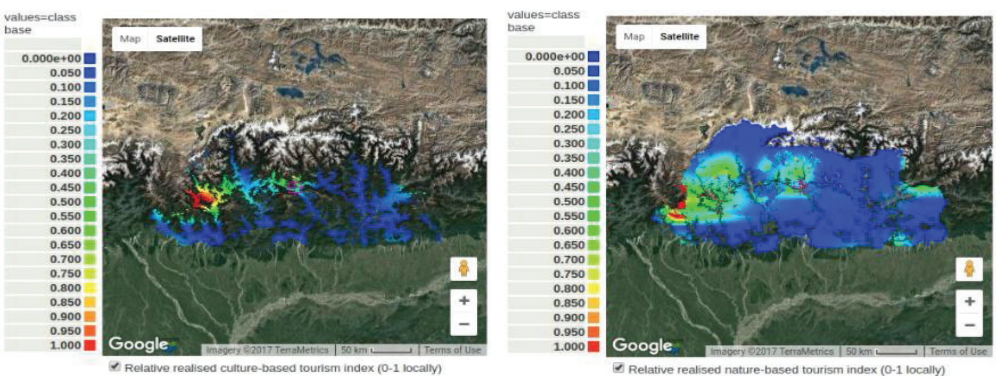
**Table 21. Summary of realised tourism?? economic values**

| Variable in Co$tingNature | Variable in Economic analysis | National Statistics | Economic Values | | | Co$tingNature model results | |
|---|---|---|---|---|---|---|---|
| | | | low | med | high | Global datasets | National datasets |
| Nature-based tourism | | 42.6 | 73.7 | 108.4 | 181.96 | 182.0 | 182.0 |

Using Co$ting Nature it is possible to geographically distribute the main regions where tourism takes place. The model also differentiates between culture-based tourism and nature-based tourism:

- **Culture-based tourism** (Figure 13, left) services are greatest close to urban areas and roads where significant numbers of photographs are registered on social media sites and are associated with access to cultural sites. The extent here is likely overestimated because of overestimation of built up cover in the official date set.
- **Nature-based tourism** (Figure 13, right) is similarly distributed outside of urban and populated areas where different numbers of photographs are registered on social media sites.

**Figure 13. Distribution of values for culture-based tourism (left) and nature-based tourism (right) using Co$ting Nature** (scale 0-1, with 1 the highest)



# Fuelwood

While almost 100 % of the country is electrified, wood is still an important source of energy in rural areas. According to the *Drivers of Deforestation* study, fuelwood supplies 90% of Bhutan's energy demand, and provides important benefits to local people (WMD, 2017).

Economic values of fuelwood are estimated using two methods:

1) Using national reported statistics on fuelwood from DoFPS and the National Statistical Bureau (NSB);
2) Estimating the opportunity cost of collecting fuelwood, in terms of time.

## Values using national statistics

Information to estimate extraction of fuelwood is limited, and the total amount estimated depends on the method used. The table below uses national statistical data from a) national accounts, and b) data from estimates from the drivers of deforestation study. The main difference is on the reported fuelwood figures, which is substantially higher for the *Drivers of Deforestation* estimations. This section only uses data from the NSB to avoid over estimation but highlights the importance of revising official estimates with the newer data from the WMD (2017) study.

Production of fuelwood is estimated in terms of number of backloads (rural) and truck loads (urban). This study assumes that the precedence of this fuelwood is distributed following the pattern 64% broadleaf:36% conifer forest cover across the country. Prices of fuelwood (softwood and hardwood) are published annually by NRDCL (see Figure 6 in timber values section).

Using national statistics from the NSB, the estimated annual value of fuelwood is approximately US$2.16 million (Table 22).

**Table 22. Value of fuelwood from national statistics**

| Method 1: | National statistics (NSB) | Units |
|---|---|---|
| Quantity: Total fuelwood reported [(a)] | 131,295 | $m^3$ |
| Softwood (36% total supply) | 47,266 | $m^3$ |
| Hardwood (64% of total supply) | 84,029 | $m^3$ |
| Prices of fuelwood, fixed [(b)] | | |
| Softwood (at 1002 Nu/$m^3$) | 15.63 | US$/$m^3$ |
| Hardwood (at 1082 Nu/$m^3$) | 16.88 | US$/$m^3$ |
| **Value** | | |
| Softwood | 0.74 | US$ million/year |
| Hardwood | 1.42 | US$ million/year |
| **Total: Annual value of fuelwood extracted (total** | **2.16** | **US$ million/year** |

Source [(a)] (DoFPS, 2016). [(b)] Published rates by NRDCL, http://www.nrdcl.bt/news.php?id=47.

## Economic value of firewood, using replacement time

Much of the fuelwood collected by rural households is "free". However, people spend significant time collecting fuelwood. This section uses the economic value of this time as estimate for the value of fuelwood.

According to UNDP[7], collecting and using fuelwood takes about three hours per day – a labour usually done by women. According to expert consultation within WMD (September 2017), most rural households are more likely to spend the equivalent of one hour per day at this task. This study assumes an 8-hour workday, and collection time of 4 days/week over 50 weeks of the year. It also assumes that 80% of rural households collect fuelwood, which is not likely an over-estimation because fuelwood is the main source of heating for most Bhutanese rural households. Using a minimum daily wage of 215 Nu for unskilled rural worker, the estimated value of fuelwood is US$5.61 million per year. This is significantly higher than the reported values found in national statistics of US$2.6 million per year.

[7]http://www.undp.org/content/bhutan/en/home/ourwork/ccmenergy/successstories/smoke-free-kitchens-for-rural-bhutan.html

**Table 23. Economic value of fuelwood estimated as time spent collecting, US$ million/year**

| Indicator | Value | Notes |
|---|---|---|
| **Quantity**: time spent collecting | | |
| Collection of fuelwood (1 hour HH/day) | 1 | Hours/day |
| Proportion of working day spent collecting (8 hours working day) | 0.125 | % of labour day |
| **Price**: average cost of time for unskilled workers | | |
| Minimum wage/day, unskilled (8 hours) | 215 | Nu/day, Minimum wage[8] |
| Proportion of wage spent collecting | 26.875 | Nu/day collecting |
| Extrapolation | | |
| Annual costed time per HH , 4 days/50 weeks | 5375 | Nu/HH/year equivalent |
| Number of rural HH | 83560 | Living Standard Survey 2012 |
| Assume 80% collect fuelwood | 66848 | Focus group WMD September 2017, using Population Census 2005 |
| **Value: of time spent collecting fuelwood** | | |
| Total spent collecting fuelwood (Nu) | 359 | Million Nu/year in Rural Bhutan |
| **Total spent collecting fuelwood (US$)** | **5.61** | **US$/year** |
| Of which | | |
| Softwood (40%) | 2.24 | US$/year |
| Hardwood (60%) | 3.36 | US$/year |
| Total fuelwood collected | 131,295 | $m^3$ |
| **Implicit price, for Co$tingNature** | 42.69 | US$/$m^3$ |

### 2.1.9.1 Modelling with Co$ting Nature

Co$tingNature maps the tonnes of fuelwood per year and estimates values in terms of substitute cost per tonne at market prices (see Table 3 in methodology).

Fuelwood availability as an ecosystem service are greatest where dense forest and significant rural populations combine outside of forest management units. As with timber values (see Section 2.1.3) the relative realised fuelwood provision services is estimated as a fractional cover of the above ground carbon stock. The estimated values range between US$ 13 and US$ 38 million dollars depending on the dataset used (global in which areas accessible by road are all reserved for commercial timber or national in which commercial timber extraction occurs only in forest management units) Where there is commercial timber extraction, there can be no domestic fueldwood access. Details of the estimation process is described below Table 24.

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[8] www.bhutannewsnetwork.com/2016/03/minimum-wage-rate-increased/

**Table 24. Summary of realised water economic values**

| Variable in Co$ting Nature | Variable in Economic analysis | National Statistics | Economic Values | | | Co$tingNature model results | |
|---|---|---|---|---|---|---|---|
| | | | low | med | high | Global datasets | National datasets |
| **Fuelwood** | | 1.4 | 2.2 | 5.6 | 5.6 | 38 | 13 |

**<u>Co$ting Nature relative realised fuelwood provision services index</u>.** Like with timber all above ground carbon stock represented by tree cover is considered a potential fuelwood service or supply, so the potential fuelwood service is the product of above ground carbon stock (Ruesch et al, 2008; Saatchi et al, 2011) and fractional tree cover (di Miceli et al., 2011) for rural areas (Schneider et al., 2009) only (urban trees are considered not to be usable for fuelwood). Fuelwood use is considered to scale with rural population (LandScanTM, 2007) and per capita use 3.65 tonnes/person/year (OECD, 2006) but also with slope gradient with a linear decrease in fuelwood extraction (from baseline demand to zero) as slope increases from 0 to 90 degrees, reflecting the difficulty in extraction and transport. The realised fuelwood service (tonnes) is thus equal to the fuelwood demand (where supply >= demand) or is constrained to the supply where (supply < demand).

For output in relative units (0-1 in the study area) the potential and realised values (tonnes) are normalised between the first and 99th percentile. For output in economic units both use and non-use values are used and are specified separately for hardwood and softwood fractions of the fuelwood mass. The economic value is thus the product of baseline use and non-use values (US$) for the realised service and inflation, where inflation is: $1+f^{-years}$ where f=discount rate and years= years from baseline to time horizon. In this analysis only use values are used.

Livestock activities are very important to Bhutan's economy. In 2015 it represented about US$82 million of the GDP[9] (NSB, 2016). Beyond the impact on GDP, livestock husbandry is also the main economy for subsistence farmers. Livestock is used as sources of food (milk, meat), fertilizers, materials for clothing (wood, leather), rearing and transportation. As for many rural economies, livestock rearing is an important way for asset creation, with relatively fast liquidity.

# Fodder for livestock

Livestock activities are very important to Bhutan's economy. In 2015 it represented about US$82 million of the GDP[10] (NSB, 2016). Beyond the impact on GDP, livestock husbandry is also the main economy for subsistence farmers. Livestock is used as sources of food (milk, meat), fertilizers, materials for clothing (wood, leather), rearing and transportation. As for many rural economies, livestock rearing is an important means of asset creation, with relatively fast liquidity.

Natural ecosystems in Bhutan provide important benefits for livestock, which traditionally graze and find fodder in forests – a practice known as *tsamdrog* -see Box 2. This practice in turn affects the composition of the forest quality, by browsing tree seedlings, compacting soil, and extraction of fodder supplies such as pine-needle or oak-leaf for bedding in sheds.

This section looks at the values of livestock within the Bhutanese economy. Using a replacement cost technique, it estimates the proportion of this value that comes directly as a provisioning ecosystem service from forest, assessing the cost of food if livestock was not to roam and forage in forests and grasslands. The estimation process is similar to the other ecosystem services in this report: 1) Estimate quantities; 2) estimate prices; and 3) estimate value.

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[9] This value includes the total value of stock and products traded (animals, meat, wool, milk, etc), with no information on the values of inputs for the activity.

[10] This value includes the total value of stock and products traded (animals, meat, wool, milk, etc), with no information on the values of inputs for the activity.

**Box 2. Livestock strategies in Bhutan**

There are over 406,000 hectares of *Tsamdrog* in Bhutan (MofAF, 2009), with pastures often providing fodder for yak in winter and cattle in summer. Grazing density (cattle heads per $km^2$) is very high in provinces like Samtse and Trashigang -well above the national average, but very low in provinces like Zhemgang and Trongsa. Most of the livestock are grazed in nearby forests during daytime, and sometimes enclosed in sheds at night (a practice that has implications on human-wildlife conflict, see next Section). Farmers have an average of 6 animals. Because of Buddhist traditions farmers seldom kill their stock for meat and end up owning as many as 20 animals (Tshering and Thinley, 2017).

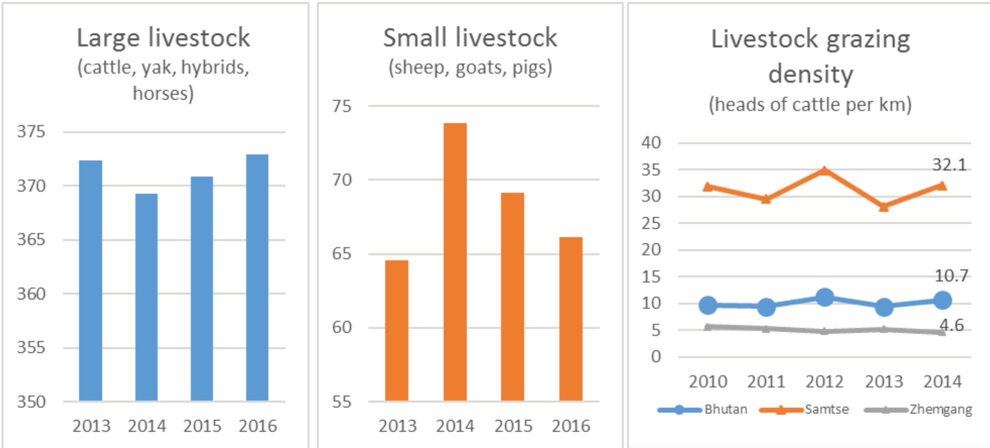
Photo I Porras.

### *Step 1: Estimating quantities of food required*

The amount of food required in terms of nutritional content is linked to the type of cattle; the average food requirements per animal, and the total number of livestock units in the country.

The government has been promoting different policies which affect the size and type of herd composition, and the grazing densities (see Figure 14). In 2016 there were approximately 440 thousand livestock units in the country, 70% of which were cattle kept for dairy or meat, 9% was yaks, 9% goats and the remaining a mix of traditional breeds (mithun, zo-zoms, bufalos), horses, sheep and pigs (MOaF, 2016). Table 25 presents a short description of the livestock units, which includes average weight and an approximation of the nutritional requirements by type of animal.

**Figure 14. Livestock herds in Bhutan (thousands of animals)**




Source: (MOaF, 2016)

**Table 25. Main types of livestock species in Bhutan**

| Specie | Description |
|---|---|
| **Yak** | Semi-nomadic specie, found mostly in mountain plateaus. Average height 1.3 metres at shoulder, weight 250-550 kg for males and 180-350 kg for females. Useful for riding and as pack animals and can be used for ploughing. Milk fat percentage ranges from 5.7% to 6.8%. |
| **Mithun (Bosfrontalis)** | Domestic breed of animal, widely used for crossbreeding. Milk fat content 6.8-7.8%. Average height 1.3 metres at shoulder, and about 540 kg (cows shorter). Used for fieldwork and draft animals as well as meat supply. The offspring of mithuns and Siri cows (Jatsha/male, and Jatsham/female) are highly profitable. |
| **Dairy breeds: Brown swiss, Jersey, Holstein,** | Imported species, often used in cross-breeding. Adult males weight about 700-800 kg and females 500-600 kg. Jersey cows are smaller than Brown Swiss: 500kg cows and 600-700 kg bulls. Holstein weight about 500-750kg. |
| **Buffalo (murrah,** | Water buffalo are important species in Bhutan, used both for meat and milk (especially ghee). Breed is one of the most efficient milk producers and bulls are used for upgrading inferior stock. Weight is about 550 kg bull and 450kg cow. |
| **Equine** | Local horses are pony-like type of horses, sturdy pack animal, well adapted to hard topography of the country. Haflinger breed introduced from Europe, larger in size to local horses. |
| **Pigs** | Consumption of pork raising but often met with (cheap) imports, rearing not culturally common. Indigenous breeds about 68% of total pig population. Farmers are required to fence pigs but many are free-ranging. |

Source: Prepared with information from Tshewang (no date).

This study assumes that forest fodder values are replaced by average quality hay rather than improved (e.g. corn) silage. The proportion of food intake is also relative to animal weight[11]:

- Cattle: 2.25%
- Equine: 2%
- Sheep, goats: 1.7%
- Pigs: 4%

***Step 2: Estimating prices of fodder***

Most of the fodder plants in Bhutan belong to the family of legumes and grasses, including those grasses grown for grain (wheat, paddy, barley and maize). Legumes are highly digestible and protein-rich fodder, and some species are found in the natural flora of the country although most are introduced for enriching pastures - e.g. white clover. Forage crops are also used as seasonal plants to fill the gaps between main crops, and produce additional forage for lean season. The main kinds of fodder crops in Bhutan are maize, turnips (most widely used) and oats.

Two sets of prices are used for the valuation:

1) Legume/grass hay price, at 7Nu/kg (RNR 2017 extension manual), similar to fodder price in India (wheat/bajra straw), at Rs 6.7/kg
2) Wholesale corn mean animal feed in China, which ranges from $300 to $800 per Ton[12]. This study uses the lowest value in the range.

***Step 3: Estimating economic value of nutritional replacement***

Table 26 presents the results of the economic values. The lower range of prices suggests an annual replacement cost of 198 US$ million/year, using grass hay from Bhutan, and a higher replacement cost importing cornmeal from China (US$544 million/year). To prevent over-estimation, the analysis assumes that half of the herd roams in the forests for food, resulting in an estimation of the **value of fodder ranging from US$ 99 to US$ 136 million per year.**

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[11] Cattle: http://beef.unl.edu/cattleproduction/forageconsumed-day; Equine: www.msdvetmanual.com/management-and-nutrition/nutrition-horses/nutritional-requirements-of-horses; Sheep/goats: www.sheep101.info/201/nutritionreq.html; Pigs: www.thepigsite.com/stockstds/18/daily-feed-intake/

[12] http://puretop.en.made-in-china.com/product/kydmhrBHhJWn/China-Corn-Meal-Animal-Feed-for-Cattle-Pig-Chicken-Corn-Gluten-Meal-60-.html

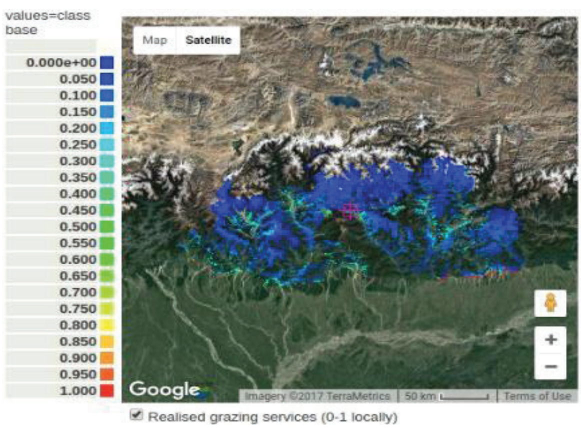
**Table 26. Replacement costs for fodder, livestock**

| | Quantities (estimation of nutritional requirements) | | | | | Nutritional value (as replacement cost) US$ million/year | |
|---|---|---|---|---|---|---|---|
| | Number of units 2016 | Average weight per unit (kg) | Day (kg/unit) | Year (kg/unit) | Bhutan (Mtons /year) | Grass hay | Cornmeal feed (China) |
| **Cows** | 303297 | 600 | 13.5 | 4927.5 | 1494496 | 163 | 448 |
| **Mithun** | 577 | 500 | 11.25 | 4106.3 | 2369 | 0 | 1 |
| **Yaks** | 40438 | 400 | 9 | 3285.0 | 132839 | 15 | 40 |
| **Zo-zoms** | 9179 | 500 | 11.25 | 4106.3 | 37691 | 4 | 11 |
| **Buffallo** | 532 | 500 | 11.25 | 4106.3 | 2185 | 0 | 1 |
| **Equine** | 18890 | 500 | 10 | 3650.0 | 68949 | 8 | 21 |
| **Sheep** | 11277 | 35 | 0.595 | 217.2 | 2449 | 0 | 1 |
| **Goats** | 39513 | 15 | 0.255 | 93.1 | 3678 | 0 | 1 |
| **Pigs** | 15324 | 300 | 12 | 4380.0 | 67119 | 7 | 20 |
| **Total** | 439,027 | | | 28,872 | 1,811,774 | | |
| **Assumption 1: all forest fodder is replaced** | | | | | | 198 | 544 |
| **Assumption 2: 50% of livestock roams in forests** | | | | | | 98.9 | 135.9 |

Notes: all data sources are described in the text above.

## Modelling distribution with Co$ting Nature

**Figure 15. Spatial distribution of grazing/fodder values (0-1, 1 highest)**




The estimated values are used in Co$ting Nature to estimate the realisable values from Bhutan's forests in terms of fodder. The model maps the tonnes per year of potential fodder and applies a substitute cost at market price. **The estimated benefits from Co$ting Nature range between US$ 92 and 193 million**, depending on the spatial dataset used (National and Global, respectively). Spatial mapping of the results show that grazing services are greatest where livestock distributions combine with productivity outside of agricultural land.

# Non-wood forest products

Bhutan has prioritised development for about ten types of non-wood forest products (NWFP). The most valuable products are *cordyceps* sp., matsutake mushrooms and bamboo. Collection and management is done by local rural people, with technical support from the DoFPS and other relevant agencies. Collectors are required to pay a minimum royalty. The type and economic importance of NWFP varies geographically. Over 50% of collectors in the highlands comes from cordyceps, while collection and trade of chirata is very important for local livelihoods in the Eastern part of the country. This study uses data from the DoFPS, Department of Indigenous Medicine, Department of Agriculture Marketing (DAMC).

## Values from national statistics

Information on NWFP in readily available national statistics is limited to a few key species. The RNR statistics yearbook (2016) reports very high values for exports of *cordycepssinensis* at Nu 259 million (about US$4 million), which is collected by DoFPS approved NWFP management groups. There are many other NWFP collected for 'free' in Bhutan's forests, including cane shoots, *rubiacordifolia*, bamboo, leaves, mushrooms, grass, resins and pine needles, many of which are not sold but consumed within the household. The royalties realised by the Government are however very low, reported at approximately US$30,000 in 2016.

Table 27 reports more detailed statistics for official NWFP collector groups and income for 2016. There are 6674 collectors organised in groups, who are allowed to freely collect NWFP in the forests. The total income reported by these groups was US$6.8 million in 2016.

This value is however skewed because of by collection of cordyceps, in particular in the Wangdue Dzongkhag. The figures reported for 2016 suggest that a group of 105 collectors obtained over US$6.6 million for cordyceps collection with an average of almost $8,000 per collector per year. These values significantly inflate the economic value of NWFP, when looking at national totals, and it is good to see the disaggregated information in terms of:

- Income from NWFP excluding cordyceps and matsutake: US$114,841/year
- Income including cordyceps and matsutake, but excluding Wangdue: US$1.9 million
- Income from all NWFP, including Wangdue: US$6.73 million.

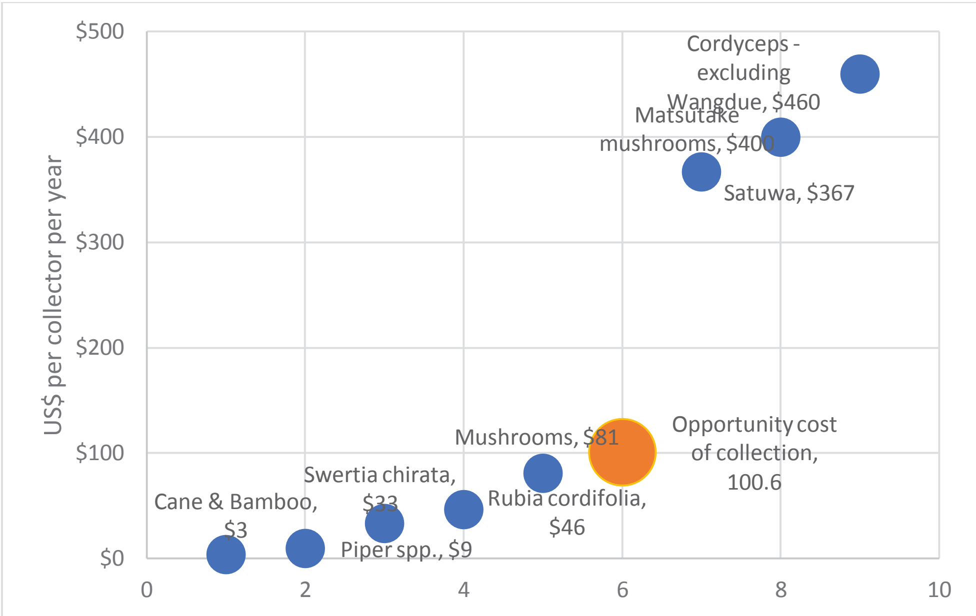
The average income per collector varies widely, from as low as US$ 3/person/year for cane and bamboo, with an average of US$42.6 for NWFP other than cordyceps and matsutake, and about US$294 including all NWFP (but excluding Wangdue).

**Table 27. Reported income per NWFP collector, 2016**

| NWFP Species | #collectors | Income 2016 (Nu) | Income (USD) | Average income per collector/year |
|---|---|---|---|---|
| ***Swertia chirata*** | 423 | 895,200 | 13,966 | US$33 |
| ***Rubia cordifolia*** | 715 | 2,116,752 | 33,023 | US$46 |
| ***Piper spp.*** | 387 | 230,669 | 3,599 | US$9 |
| **Mushrooms** | 229 | 1,183,500 | 18,463 | US$81 |
| **Cane & Bamboo** | 827 | 185,165 | 2,889 | US$3 |
| **Satuwa** | 117 | 2,750,000 | 42,902 | US$367 |
| **Matsutake mushrooms** | 122 | 3,124,960 | 48,751 | US$400 |
| **Cordyceps** excluding Wangdue | 3749 | 113,403,398 | 1,769,164 | US$460 |
| Including Wangdue | 3854 | 424,972,308 | 6,629,833 | US$7,991 |
| Bumthang | 1923 | 24,580,191 | 378,157 | US$196.6 |
| Gasa | 1005 | 64,381,066 | 990,478 | US$985.6 |
| Paro | 31 | 968,222 | 14,896 | US$480.5 |
| Thimphu | 678 | 22,581,034 | 347,401 | US$512.4 |
| Trashiyangtse | 112 | 892,885 | 13,737 | US$122.6 |
| Wangdue | 105 | 311,568,910 | 4,793,368 | US$45651.1 |
| **Totals** (excluding Wangdue) | 6569 | 123,889,644 | 1,932,756 | US$294 |
| Including Wangdue | 6674 | 435,458,554 | 6,793,425 | US$1,018 |
| Excluding cordyceps and matsutake | 2698 | 7,361,286 | 114,841 | US$42.6 |

Source: Ms. Sonam Peldon, Social Forestry & Extension Division, Department of Forests & Park Services.

**Figure 16. Average income per collector for NWFP, by main type of product (US$ per year)**




## Economic values by opportunity cost of time spent collecting

Because NWFP are 'free' to collect, the reported values collected by national statistics not always reflect the real contribution to the household economy. As an alternative valuation, this study also uses time spent collecting NWFP as an estimate of opportunity cost, similar to the model used for fuelwood. The estimation follows the same process (see Table 28):

1) Estimating quantity, or amount of time spent collecting NWFP;
2) Estimating the price of time spent collecting, using minimum wages
3) Estimating economic value by multiplying quantity by price.

The resulting values are double-checked with other information provided by the DoFPS on data for NWFP.

***Step 1: estimating time collecting NWFP***

Similar to the discussion of how much time households spend collecting fuelwood, this estimation assumes that collectors spend 15% of their household time collecting NWFP, based on focus group discussion with WMD experts in September 2017.

***Step 2: estimating price***

The estimation uses the minimum wage as an approximation of the opportunity cost of time for unskilled workers, reported at 215 Nu/day. Assuming that the proportion of time spent collecting NWTP this results in a value of 32.25 Nu/day (about 50 US cents).

***Step 3: estimating value***

The total number of days that a person collects is estimated assuming that a person collects four times in a week, 50 weeks of the year. Assigning the proportion of minimum wage this results in approximately USS$100.6 per collector/year.

The Living Standard Survey 2012 reports a total of 83,560 rural households in the country, and according to the expert opinion of WMD staff, approximate 90% of rural households collect NWFP. This generates a national estimate of the economic value of NWFP of approximately US$7.6 million per year.

**Table 28 Estimating the value of NWFP in Bhutan's**

| Method: Opportunity cost: Time spent collecting multiplied by average cost of time | Indicator | Units |
|---|---|---|
| **Quantity: time spent collecting** | | |
| Collection of NWFP (15% of HH time/day) | 1.2 | Hours/day |
| Proportion of working day spent collecting (8 hours working day) | 0.15 | % of labour day |
| **Price: average cost of time for unskilled workers** | | |
| Minimum wage/day, unskilled (8 hours) | 215 | Nu/day, Minimum wage: http://www.bhutannewsnetwork.com/2016/03/minimum-wage-rate-increased/ |
| Proportion of wage spent collecting | 32.25 | Nu/day collecting |
| **Value: of time spent collecting NWFP** | | |
| Annual costed time per HH , 4 days/50 weeks (NU) | 6450 | Nu/HH/year equivalent |
| Annual costed time per HH , 4 days/50 weeks (US$) | **100.6** | US$/collector per year |
| **Total revenues/ country** | | |
| **Extrapolation 1: same value across** | | |
| Number of rural households in Bhutah | 83560 | Living Standard Survey 2012 |
| Of which about 90% collect NWFP | 75204 | Focus group of experts at WMD in September 2017 |
| Total revenue/country (Nu, million) | 485.1 | Million Nu/country |
| Total revenue/country (US$/ million) | 7.6 | Million US$/year/country |

In summary, the economic values of NWFP in Bhutan vary between US$0.1 and US$7.6 million USD:

- Opportunity cost of time collecting NWFP: US$7.57 million;
- Reported revenues from collection, including cordyceps: US$6.8 million;
- Reported revenues from collection, excluding cordyceps and matsutake: US$0.11 million.

## Carbon

Bhutan made a commitment under its NDC to adopt a legally binding agreement under UNFCCC to remain carbon neutral, by committing that the emission of GHGs does not exceed the sink capacity of its forests (Kingdom of Bhutan, 2015).

**Carbon stocks:** This study uses two calculations of carbon stocks: 1) from the REDD feasibility study conducted in 2010 (van Noord, 2010), and 2) the more recent REDD+ estimate of carbon by the WMD study.

**Method 1: A previous methodology to estimate the potential of carbon stock for Bhutan is presented below**. The authors use growing stock volume to estimate national above ground biomass - (van Noord, 2010). Their figures suggest an average stock increase of 3.4 million metric tons per year.

**Table 29. Estimated carbon stock in Bhutan's forest, REDD feasibility study 2010**

| million metric tonnes | 1990 | 2000 | 2005 | 2010 |
|---|---|---|---|---|
| Carbon in above-ground biomass | 216 | 228 | 236 | 245 |
| Carbon in below-ground biomass | 80 | 85 | 88 | 91 |
| Sub-total: Living biomass | 296 | 313 | 324 | 336 |
| Carbon in dead wood | n.a. | n.a. | n.a. | n.a. |
| Carbon in litter | 49 | 55 | 58 | 60 |
| Sub-total Dead wood and litter | 49 | 55 | 58 | 60 |
| Soil carbon | 212 | 218 | 223 | 226 |
| **Total** (million metric tonnes) | 557 | 586 | 605 | 622 |
| **Change** | | 5% | 3% | 3% |

Source: (van Noord, 2010).

**Method 2. Using results from the REDD+ 2018 study.** Using the results from the REDD+ study, the average carbon capture (above and below ground) is approximately 8 million tCO2 per year.

Using the REDD+ feasibility study and assuming carbon prices of US$2, $5, and US$10 per tCO2 the estimated value of carbon stock in Bhutan ranges between US$6.7 and US$ 33.7 million. Studies elsewhere have used prices as high as

US$25/tCO2, which would suggest revenues from carbon of approximately US$84 million per year. For carbon prices see for example internal carbon estimate for private companies from CDP (2013), and the Forest Trends annual reports of carbon markets, the latest found in Hamrick and Gallant (2017). These values are applied to both studies and the results are presented below.

**Table 30. Range of values for carbon sequestration in Bhutan, US$ million per year**

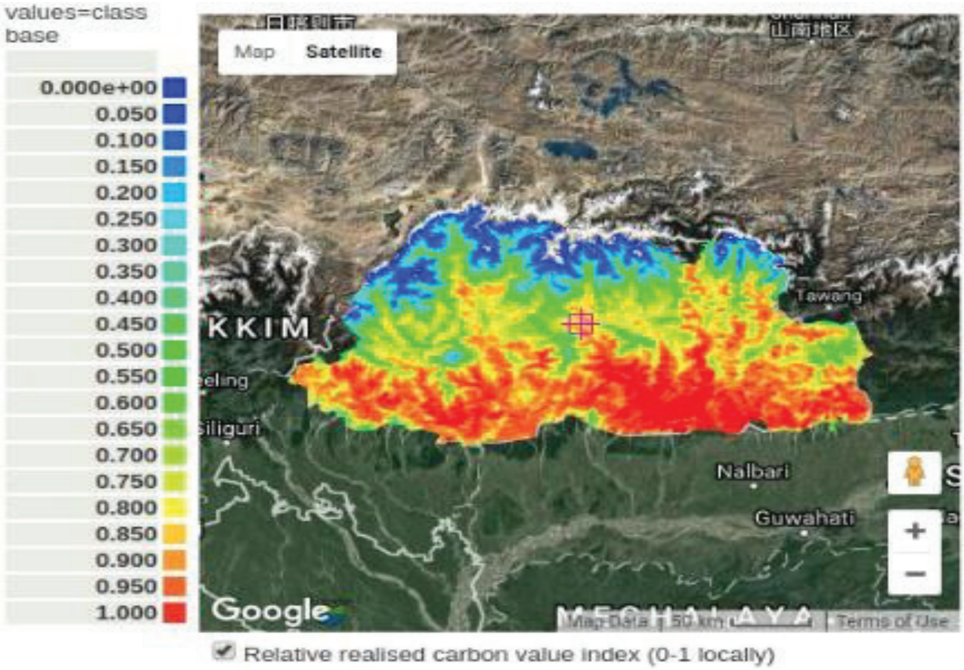
| | Low ($2/tCO2) | Medium ($5/tCO2) | High ($10tCO2) |
|---|---|---|---|
| **REDD Feasibility** | 7 | 17 | 34 |
| **REDD+ (2018) study** | 16 | 40 | 80 |

This study recommends a cautionary approach to values and focus on those that are more likely to take place. Carbon markets internationally have been volatile and unreliable (Hamrick and Gallant, 2017). The latest report on the State of Carbon Markets suggests carbon prices as low as 50 cents/tCO2 from wind and hydroelectric projects, while forestry and land use projects sold at an average of US$5.1/tCO2. However, the tendency shows prices decreasing and significant amounts of stock unsold (about 25% of offsets in the market last year did not sell). This stagnation may change as the Paris Agreement comes into practice but the experience so far has been limited in terms of price levels and scale of action.

### 2.1.10Co$ting Nature for carbon

This study also uses Co$ting Nature to determine carbon baselines and distribution in the country. The model uses information on above ground carbon stock map (Ruesch and Gibbs, 2008; Saatchi S *et al.*, 2011) but also carbon sequestration and soil carbon. The proportion of carbon coming from trees in a pixel is calculated as the product of carbon stock and fractional tree cover (DiMiceli, 2011) for rural areas (Schneider *et al.*, 2009). Application of the model is presented in (Figure 17).

**Figure 17. Relative realised carbon value map, using Co$ting Nature (scale 0-1, 1 highest)**




# Biodiversity (investment flows)

Bhutan's wildlife is rich and diverse. Recognising this, the country's National Biodiversity Strategies and Action Plan 2014 (MoAF, 2014) categorizes biodiversity under:

- Ecosystem diversity (Forest diversity, Aquatic ecosystem, Agricultural ecosystem)
- Species diversity (Vascular plants, Non-vascular plants, Fungus, Insect Fungi, Lichens and Lichenicolous fungus, mammals, Avifauna, Herpetofauna, Invertebrates, Fish fauna)
- Domestic biodiversity (Crops, Livestock).

The government has been actively promoting conservation through formal programmes and regulations since the 1960s. It features strongly in the philosophy of the Gross National Happiness, with an average allocation of 7% of government expenditures linked to environment-related policy (MoAF, 2014), as well as important flows of international investments supporting forests and biodiversity conservation in the country. More than the economic value that accrues from biodiversity through its interaction with certain ecosystem services, the GNH sees one of the four pillars as: *"in addition to providing critical services such as water* *and energy, the environment is believed to contribute to aesthetic and other timulus that can be directly healing to people who enjoy vivid colours and light, untainted breeze and silence in nature's sound"[13].*

The rise in forested area and successful wildlife policies also generate conflict with humans, especially in rural areas, such as crop raiding and livestock attacks from wild animals. On the other hand, the degradation of existing natural habitats also pushes predators outside their natural boundaries giving new spaces for conflict. This section looks at economic values of the benefits of biodiversity protection, and the costs this has in terms of human wildlife conflict.

### 2.1.11 Biodiversity services: investment flows supporting positive action

A recent valuation of ecosystem services in Bhutan (Kubiszewski *et al.*, 2013) suggests that the economic value of biodiversity protection in Bhutan's temperate forests could be, on average US$2,795 million per year. Kubiszewski's study used value transfer method from other countries and settings, which leads to a substantial over estimation of the realised values for the country. To put it in context, Kubiszewskis's estimate of biodiversity values is 36% higher that the country's GDP in 2015 (US$2,060 million, according to NSB (2016)).

Erring on the cautionary side, this study looks at realised values of biodiversity, focusing on the more visible interest from the international community for biodiversity conservation that results in flows of revenues into the country (apart from nature-based tourism, which is accounted for in a different section). This study then looks at the average investments made in the country in relation to biodiversity and climate change adaptation and mitigation over the past three years, including new projects like *Bhutan for Life* (http://www.bfl.org.bt/).

Table 31 summarises some of the main investments, with information from the forthcoming BIOFIN expenditure report. The investment flows are divided into two groups:

- A set of projects between 2011-2013 to 2015-16 for biodiversity or climate change, with an approximate investment flows of US$31.1 million per year.
- The recently launched Bhutan for Life project, with international investment of US$40 million and a matching national investment from the

[13] http://www.gnhcentrebhutan.org/what-is-gnh/the-4-pillars-of-gnh/

Government for US$25 million in new funding. Supported by WWF, this is a transition fund until 2030 to help the Government build up and effectively manage a network of protected areas and wildlife corridors.

The estimate of international flows supporting biodiversity is approximately US$34.1 million per year.

**Table 31. Summary of international projects for biodiversity and climate change in Bhutan (US$ million)**

| Detail | Investment flows | | |
|---|---|---|---|
| **Set 1: Projects 2011-12 to 2015/16 (3 years),** | Biodiversity only | Climate Change investments | Total investment |
| Project 1 | 15 | 14 | 30 |
| Project 2 | 16 | 14 | 29 |
| Project 3 | 14 | 12 | 26 |
| Project 4 | 16 | 12 | 28 |
| Project 5 | 23 | 20 | 42 |
| Total millions over period | 84 | 72 | 155 |
| Number of years | | | 5 |
| Annual investment, US$ million, Set 1 | | | 31.1 |
| **Set 2: Bhutan for Life** | | | |
| Total investment flow | | | 40 |
| Years | | | 13 |
| Average per year, Bhutan for Life | | | 3.1 |
| **Approximate annual BD investment in a year** | | | **34.1** |

Source: BIOFIN expenditure report (draft, 2017).

## 2.1.12 Wildlife dis-services: human-wildlife conflict

Human-wildlife conflict (HWC) in Bhutan is an important issue that must be considered when looking at benefits and costs from natural ecosystems.

### The issues

Bhutan is a society based around agriculture and forestry. Rural areas are the home of 69% of Bhutan's population, and 73% of the country's workforce. Agriculture and forestry provide jobs for 78% of the rural workforce. In Gasa, 95% of the workforce depend on agriculture and forestry activities (Ministry of Labour and Human Resources, 2015). Disruptions to this activity, especially human wildlife conflict, have significant consequences on rural people's livelihoods who are already poor and vulnerable. According to the several studies, human-wildlife conflict has increased because of several reasons including:

1. The success and expansion of the conservationist discourse, with a focus on charismatic species such as tigers and leopards, which are common predators of livestock (Blench, 2013; Wildlife Conservation Division, 2013).
2. The religious and cultural belief on the sanctity of life which discourages wildlife hunting (NPPC and WWF-Bhutan, 2016);
3. The growth of protected areas and legislation curbing retaliatory killing (Blench, 2013; Wildlife Conservation Division, 2013).
4. Livestock herding systems, where cattle roam free in the forests for grazing (Blench, 2013) .
5. Migration from rural to urban areas, with fewer people available for herding animals (nomadic and within forests) and work the land. This is leading to abandoned farmlands, and reduced grazing from nomadic herds are reverting grassland to shrubland and forest. This creates new habitats for wildlife closer to agricultural lands (Blench, 2013).
6. Unintended effects from previous policies to cull predators' population, for example extensive poisoning of wild dogs in previous years by the Forestry Department (Wildlife Conservation Division, 2013), which led to fast expansion of wild pigs (Blench, 2013) which are now a pest in croplands, costing farmers losses of 30-40% of their crops (NPPC and WWF-Bhutan, 2016)

Most of the livestock losses are cattle (50%, followed by 33% horses), killed mainly by large predators such as leopards (70%), tigers (19%) and bears (8%) (Tshering and Thinley, 2017). Livestock is more vulnerable during summer and early autumn when they are usually released in the forest. In winter and early spring, they are kept in sheds or near farms. Indigenous cattle are more susceptible to wildlife attacks, as imported breeds, usually more expensive, are kept indoors and are stall-fed Like livestock conflicts, crop raiding is seasonal and geographically affected, e.g. tapioca is raided by wild pig in lower elevation areas, and elephants appear during the harvest time of paddy.

Despite traditional strategies to cope with wildlife (throwing fireball, watchtowers, shouting and group chasing), human-wildlife conflict has been recognised as a major constraint to food security, and the government is beginning to take steps to build a strategy that includes prevention, mitigation and compensation (NPPC and WWF-Bhutan, 2016). Agriculture and livestock products are the main source of cash income for most rural households, and this is constantly under threat by a variety of wildlife including wild pigs, monkeys, elephants, bears and different species of felines (Wildlife Conservation Division, 2013).

The magnitude of the human-wildlife conflict in Bhutan cannot be ignored, especially as it is born by the poorest segments of the population.

## Methods to assess human-wildlife conflict

There are several methods to assess human-wildlife conflict, for example damage assessment, preventive costs and mitigation costs, described below with some examples of how it has been used in Bhutan

**Table 32. Methods to assess HWC**

| Valuation technique | Description | Indicators |
|---|---|---|
| **Damage assessment of the impacts of wildlife raids** | Market-based assessment of the value of crops and livestock lost. | Average price of crop (paddy, wheat), average price of traditional cattle, compensation paid for cattle loss (Nu1000-Nu2000), % of people affected. |
| **Preventive costs: to stop or prevent HWC before it occurs** | • Barriers: e.g. electric fencing (currently in operation in some places), fences, trenches, etc.<br>• Changing practices: greater vigilance during grazing (people, guard dogs), proper penning and tethering of livestock, switching to more secure and productive stall-fed cattle, and avoidance of grazing in predation hotspot (Rajaratnam *et al.*, 2016).<br>• Early warning systems, watch towers<br>• Education and community awareness to avoid grazing in predation hotspots. | • Installation and maintenance costs of electric fencing.<br>• Cost of building corrals/sheds for animals;<br>• Time spent in herding and watching cattle (using minimum non-skilled wage of 215Nu/day for people and cost of maintaining guard dogs).<br>• Changing breeds of cattle that prefer roaming to those that can be stall-fed.<br>• Cost of stall-food to replace forest-grazing. |
| **Mitigation costs: to reduce impact of HWC after event** | • Compensation for losses (which should include transaction costs to access compensation);<br>• Insurance | • Price per animal or crop area lost<br>• Transaction costs to access compensation or claim insurance (proof of attack, contact with local authorities etc)<br>• Cost of accessing community-based insurance schemes, currently trialled in Bhutan (Rajaratnam *et al.*, 2016) |

Bhutan has implemented various strategies at different times. These measures have been relatively successful, but lack sufficient funds to continue or expand. For example:

- Fencing: Impact assessments conducted by the Research Development Centre (RDC) in Wengkhar showed that the use of electric fence in the sites has reduced HWC from 100% to 10% after fencing. This has increased food sufficiency between 30% to 40%.
- Community-based insurance (Rajaratnam *et al.*, 2016): the government provided a small amount of seed money (US$4800) to invest in a fund, which generates interest to make insurance payments. Members pay a nominal membership fee of US$3, and an additional premium of US$1.6- $2.4 per livestock owned (Rajaratnam *et al.*, 2016). In practice, this seed amount may be too small to be meaningful, and the price per livestock may be too high for farmers, especially since most of the roaming livestock is traditional varieties of cattle with relatively low market (cash) value.
- Gewog Environmental Conservation Fund [14], initiated in 2012 in seven gewogs with Nu 30,000 which was later increased to Nu 50,000 for compensation to be made to the affected households. Bjenagewog in Wangduephodrang has 400 households, 40 of which are members of the Trust Fund. They contribute Nu 50 a year as insurance for a breed and they receive Nu 1,000 as compensation for loses of that breed to the wild animals. Similarly, Nu200 for breed is paid for which farmers receive Nu 5,000 in compensation.

## Assessment of economic cost of HWC

This section assesses HWC using replacement costs and two sources of data: national statistics (method 1) and statistics reported by field studies.

***Method 1: Replacement cost using national statistics and average compensation***

National statistics on HWC are limited, but they provide a rough approximation to the extent of the problem. According to the RNR Statistics Report, in 2015 most of the HWC were linked to livestock predation, crop and property damage (to the house or compound) and human casualties.

[14] http://www.kuenselonline.com/wildlife-compensation-trust-fund-in-56-gewogs/, http://thebhutanese.bt/tiger-attacks-leads-to-dwindling-livestock/

**Table 33. Reported HWC incidents, 2013-2015**

| | Production lost (kg) | Households affected | Reported incidents Livestock predation | Property damage | Human casualties |
|---|---|---|---|---|---|
| **2013** | 369,891 | 796 | 90 | 8 | 5 |
| **2014** | 1,480,195 | 306 | 61 | 6 | 4 |
| **2015** | 1,154,330 | 1376 | 202 | 7 | 4 |

Source: (MoAF, 2016)

Information on crops raided is obtained from RNR statistics 2016, and the prices used are an average for paddy and wheat, from the RNR extension manual 2016 (60 Nu/kg). **The results suggest that the average costs of HWC is US$ 1.1 million per year**, mostly through crop damage and a small part from killed livestock (see Table 34). These values are likely underestimations: as limited resources hinder providing compensation to all HWC cases and when distances are large, farmers do not usually report HWC situations.

***Method 2: Replacement cost using field studies and market livestock value***

Sangay and Vernes (2008) conducted an in-depth study of livestock losses by predators, as a way to analyse the performance of the Tiger Conservation Fund (TCF) looking at reported incidents. Their regression analysis suggests that on average, households lost between 1.18 and 1.88 livestock units per year. Their study also provides average market prices for main livestock types, which feeds into the price information in Table 34, which provides the US$233 used to estimate market losses from predation attacks. The economic cost of HWC, adding the losses from crop, are approximately **US$1.3million per year.**

**Table 34. Economic cost of human-wildlife conflict, million US$/year**

| Indicator | Units |
|---|---|
| **Method 1: Baseline analysis, using RNR statistics 2016 and average compensation** | |
| **Quantity:** | |
| Crops of production lost (kg), 2015[a] | 1,154,330 |
| Number of reported cases of livestock predation [a] | 202 |
| **Prices** | |
| Average price (60Nu/kg paddy, wheat), in US$ [a] | $0.9 |
| Compensation for killed animal (average Compensation fund) | $47 |
| **(payment between 1000 to 2000, up to 5000)** | |
| **Total cost** | |
| Total cost of production lost (Q*P) | $1.1 |
| Total cost of animals lost | $0.009 |
| **Total cost crops and animals (US$ million)** | **$1.1** |
| **Method 2: using Sangay and Vernes stats for livestock predation and market prices of lost animals** | |
| **Quantity** | |
| Production lost (kg) [a] | 1,154,330 |
| Livestock | |
| Livestock head lost per household over one year (for 2003)[b] | 1.88 |
| Number of HH that reported losses over one year[b] | 564 |
| **Prices** | |
| Average price (60Nu/kg paddy, wheat), in US$[a] | 0.94 |
| Average price of livestock (cattle local breed, female) [b] | $233 |
| **Value (cost)** | |
| Value of crops lost (US$ million) | $1.1 |
| Livestock losses, lower range | $0.2 |
| **Total cost crops and animals (US$ million)** | **$1.3** |

Notes and sources: (a) Information from (MOaF, 2016), see Table 33. (b) Detailed study by Sangay and Vernes (2014) for the period of 2003-2005, which reports average loss of 1.88 heads of cattle in 2003, and an average of 1.32 over the 3-year period. Their study also presents various estimates of market prices for livestock, as well as the number of households that were compensated over three years (1233, averaged to 564 per year).

While on aggregate the cost of human-wildlife conflict does not seem a large figure, the impact felt locally on rural households is very significant as it affects their immediate prospects for expenditure and has greater impacts on the poorest. HWC often means replacing raided crops by buying grain and vegetables in local markets and having to purchase animals that have been killed.

Table 35 shows how the very heavy impact of these losses in the household economy. Losing and having to replace 1.88 units of livestock can represent a cost of US$438 in a year, which is about 10% of the mean rural annual expenditure in food, clothing, transport and health. And the average cost of crop raiding is US$785 per household, or about 16% as much as the mean annual rural expenditure. These costs are completely born by rural, poor farmers and represent forced additional costs if they need to replace lost food or cattle. For a country with a very small area available for agriculture, this has significant impacts on its ability to secure food.

**Table 35. Impact of HWC on rural household economies**

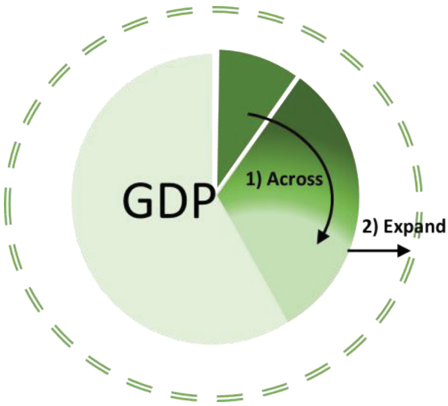
| | Livestock | Crop raiding |
|---|---|---|
| **Average quantity lost per HH (head of livestock, kg of crops)** | 1.88 | 838.90 kg |
| **Average price** | $233 | $0.94 |
| **Estimated cost per household**[(a)] | $438 | $785 |
| **Mean annual HH expenditure, rural areas (Nu 26,937 per month)**[(b)] | $5043 | $5043 |
| **% of HWC in HH expenditure** | 9% | 16% |

Notes and source: [(a)]The number of incidents reported in 2015 was 1376 (see Table 33). [(b)] From the recent Living Survey (NSB, 2017)

# 3 Conclusions

This study unequivocally demonstrates the economic importance of forest ecosystem services to Bhutan's current and future well-being.

This assessment has two impacts: it helps to mainstream the economic importance of forest ecosystems beyond timber and across the economy, and it shows how natural assets contribute to increase Bhutan’s total wealth.




This section summarises the economic values of ecosystem services in Bhutan, prepared following the framework of nature and ecosystem services presented in Figure 2 in the introduction.

Capacity building and co-creation of results have driven the design, implementation and analysis of this study. The choice of ecosystem services and valuation techniques was linked to national experts' consultation, availability of data, the need to generate values that are used as inputs for modelling geographic distribution and land use changes using Co$tingNature, and the ease to replicate the study in the future by WMD staff with relatively little external support. With the exception of carbon, the study has also focused on the current realised values for Bhutanese people (i.e. avoiding non-use values or benefit transfer estimates from other countries that often result in inflation of estimates).

## Ecosystem services are many and are important

The economic value of ecosystem services in Bhutan ranges between US$394 million to US$1,269 million per year.

Table 36 presents a range that varies from conservative estimates, for example using national prices, to higher end estimations that try to further remove the effect of national price regulations to get a closer view to real economic values. For all ranges the estimates are nevertheless realistic and not over-estimations.

Despite the conservative approach to avoid over-estimations, the results are nevertheless impressive. Provisioning services represent the highest values, as nature provides Bhutanese people with inputs for food, timber, water and energy in amounts that range from US$301 million to US$973 million per year.

Ranging between US$77 and US$216 million per year, cultural and recreation services also play a significant and increasing role in generating wealth in the country. Much of this is driven by the flourishing tourism sector and the flows of investments that support Bhutan's efforts to conserve and protect their natural habitats and biodiversity, which provides stunning backgrounds to the spiritual enjoyment of the country's traditions.

This study also attempted to value some of the benefits from ecosystems for regulation of key functions, which are often unaccounted in traditional economics. The study shows that these values range between US$15 to US$80 million, dominated by the expectation of Bhutan’s ability to access international carbon markets. The estimates of regulation of water quality for existing dams and those under construction appear modest after looking at carbon sequestration, ranging between US$1.5 to US$2 million per year), but not insignificant if a proportion of it could be converted into operational costs of managing ‘green infrastructure’ and be transferred back into watershed management. These water quality regulating benefits also benefit rural households, who do not have access to filtering services.

Taken together, these conservative estimates of multiple values of forest ecosystem services are considerably larger than the existing contribution of timber to the economy, as recorded through its contribution to GDP (US$32 million in 2015).

Table 36. Economic value of ecosystem services in Bhutan (US$ million per year)

| | | Economic values | | |
|---|---|---|---|---|
| | GDP (2015) | Low | Medium | High |
| **Provisioning services** | **$344** | **$301** | **$390** | **$973** |
| Timber, total | $32 | $25 | $49 | $94 |
| Timber, softwood | $32 | $17 | $31 | $76 |
| Timber, hardwood | | $8 | $18 | $18 |
| Domestic water | $1 | $2 | $2 | $7 |
| Water Utilities (piped water) | $1 | $0.5 | $1.1 | $5.1 |
| Rural water (mostly unpiped) | | $1.3 | $1.3 | $1.5 |
| Fodder for livestock | $82 | $82 | $99 | $136 |
| NWFP | $7 | $7 | $7 | $8 |
| Energy: | | | | |
| Hydroelectricity | $222 | $183 | $228 | $723 |
| Firewood (total) | $1 | $2 | $6 | $6 |
| Firewood, softwood | $1 | $1 | $2 | $2 |
| Firewood, hardwood | | $1 | $3 | $3 |
| **Cultural services** | $42.6 | $76.8 | $142.5 | $215.7 |
| Tourism, Nature based (International Tourism, receipts, BTC, 2016) | $43 | $43 | $108 | $182 |
| Biodiversity (investment flows) | | $34 | $34 | $34 |
| **Regulating and climate** | $0 | $16 | $40 | $81 |
| Carbon | $0 | $16 | $40 | $80 |
| Water quality (sediment removal) | | $1.54 | $1.59 | $2.07 |
| Disease and pest control (Human Wildlife Conflict) | | -$1.1 | -$1.3 | -$1.3 |
| **Total USD millions/year** | **$387** | **$394** | **$573** | **$1,269** |

Note: These values are an initial approximation of the value of the ecosystem services, with a focus on use values, and focusing on variables where information exists and can be easily updated by WMD.

## Forests ecosystems as assets for wealth

Because forests cover such a large proportion of the country, values from forest ecosystems represent a large proportion of the total values in the country (about 70%). It is important to highlight that these monetary benefits do not derive entirely from the forests themselves but through the interaction of forests with other components of the ecosystem (e.g. ecosystem, infrastructure and people), as explained in the methodology section (Figure 2 and Table 2).

Traditionally, forests are accounted in economic reports in relation to their contribution to timber, firewood and non-wood forest products (one of the components of the “primary sector”, alongside agriculture and livestock, see NSB (2017)). In 2015 its contribution to GDP was approximately US$40 million, representing about 2% of national wealth[15]. For a country with 70% forest cover this may seem small.

However, the current study shows that the contribution of forests is significantly greater, with values that range between 21% to 63% of national GDP (see Figure 18) showing the linkages to key emerging economic processes such as hydroelectricity and tourism, but also its importance to local economies in terms of energy, food, and water quantity and quality. This valuation study shows that Bhutanese people benefit highly from nature services, ranging from US$568 to US$1,832 per capita per year.

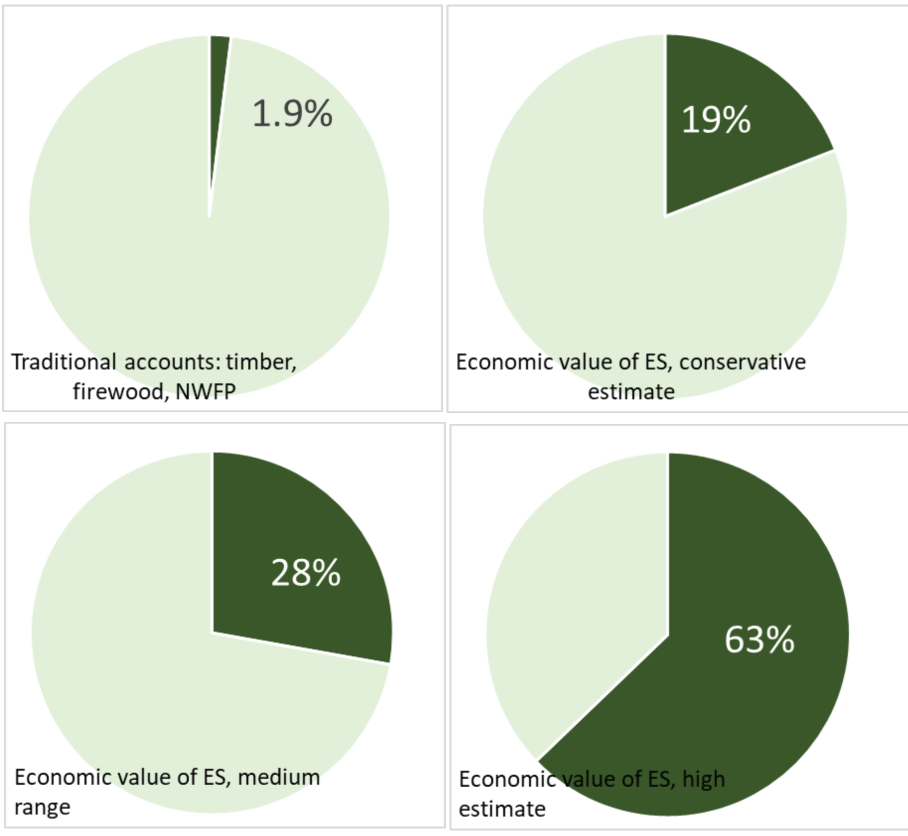



**Figure 18. Participation of forests and its ecosystems in GDP**

[15] Total GDP in 2015 was approximately US$2058 million and US$2305 million in 2016 (NSB, 2017).

# Forest ecosystems benefit rural economies

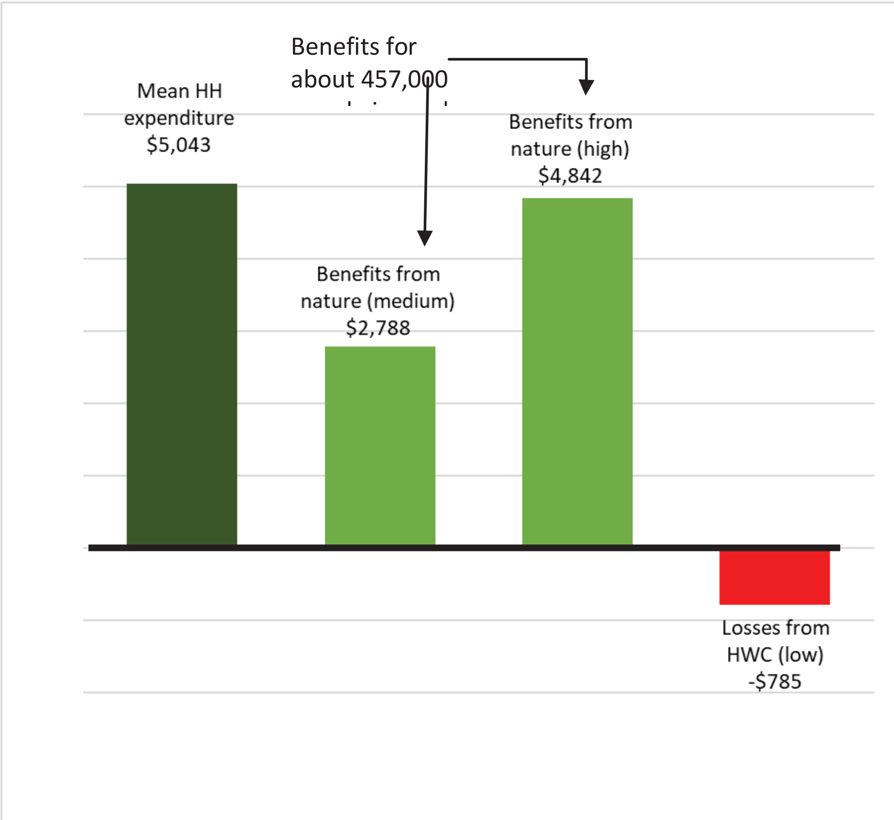
Rural communities directly affected by the quality of their surrounding ecosystems. Figure 19 presents a rough estimate of how some of these values accrue to rural households. The analysis assumes that rural benefits are especially linked to timber, firewood, NWFP, fodder for livestock, and water for domestic uses. It also allocates half of the revenues from nature-based tourism, assuming that local people benefit from jobs, provision of services and access to recreation attractions. The analysis also allocates 20% of hydroelectricity benefits to rural communities[16].

The study finds that, while there may be some overlap (e.g. electricity, firewood) the benefits from nature range between 55% and 96% higher than mean annual household expenditure, as reported in the latest Living Standard Survey (2017). Some of these households are also highly affected by human-wildlife conflict, with significant losses from livestock killings and crop raiding that directly affect food security.

Although many ecosystem services are "free", or heavily subsidised, this study provides quantitative evidence of their enormous economic importance for rural economies. The costs of degradation of forest ecosystems will be felt particularly by these groups. The results also show that healthy forest ecosystems support rural economies and strengthens the proposal for stronger and more active coordination between environmental and social institutions.

[16] This value was in turned obtained assuming that 30% of all production is for national consumption (DrukGreen, 2016), of which 64% is for rural households (NSB, 2017).

**Figure 19. Per capita benefits (and costs) from ecosystem services (US$ per year)**




Because of policies affecting the governance of forests and other ecosystems, very few of these values are currently reflected in national accounts or government revenues, often giving the impression of an economically dormant sector. This document clearly demonstrates that this is not the case.

A better understanding of how ecosystem services interact with the rest of the economy is a first step to truly mainstreaming nature in policy making. The information from this study feeds into a series of studies linking to policies and strategies for sustainable financing of Bhutan's natural ecosystems.

## What happens if forest ecosystems disappear or are degraded?

This study shows total economic values, that is, the benefits that emerge as the combination of forest ecosystems, human assets, infrastructure and technology. The impact of forests degradation or disappearance will have different impacts on each ecosystem service, depending on how heavily they rely on forest. For example, if natural forest disappear and is not replaced with plantations then timber values and most NWFP will dwindle to zero. The quality and part of the quantity of water for hydroelectricity will be affected, but hydropower generation will continue.

The results from this study are used as inputs to develop scenarios of land use change to assess what may happen to economic values within each sector, and as an aggregate to the economy. Two models are used for this: Co$ting Nature looks at values across the full range of resources in the country, and Water World is run to specifically focus on the impacts on hydropower.

Modelling these scenario changes helps to understand the marginal contributions of forest to the national economy. The results of this scenario analysis are presented in detail in another report in this series: “Changing Landscapes”.

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# Appendixes

## Appendix 1: Co$ting Nature V3 Methods

Ecosystem services can be divided into ***potential, realised, and realisable***.

**Relative realised timber services index.** Timber provision is considered an ecosystem service. At low extraction rates it is sustainable and can continue to be provided. At high extraction rates it is consumptive of the ecosystem and damages the co-benefits for other services provided by forests. Realised timber services thus need to be considered carefully in this regard.

The potential mass of timber (the potential service) is estimated from the above ground carbon stock map (Ruesch and Gibbs, 2008; Saatchi S *et al.*, 2011). The proportion of carbon coming from trees in a pixel is calculated as the product of carbon stock and fractional tree cover (DiMiceli, 2011)for rural areas(Schneider *et al.*, 2009)only (urban trees are considered not to be usable for timber). The realised service (the timber accessible) is calculated as potential timber within 6 hours of a population centre of >50K people (Uchida and Nelson, 2009)and on slope gradients <31.5 degrees (70%) (Lehner *et al.*, 2008)considered to be workable for logging (Greulich, 1999). Timber mass defined as accessible is constrained by slope to reflect the enhanced cost of removal (and increased wastage) on steeper slopes with a linear decrease in timber availability (from complete availability to zero) as slope increases from 0 to 90 degrees. This is the realised timber service in tonnes.

The spatial distribution of hardwood and softwood is calculated according to the work of Box and Fujiwara (2005) in which mean annual temperature and a cold index are calculated from mean monthly temperature(Hijmans *et al.*, 2005)as the sum of temperature for months where temperatures are less than 5 degrees. Hardwood distributions are calculated as those with a mean annual temperature >20C and a cold index >-10C. Softwood areas are calculated as all other areas.

For output in relative units (0-1 in the study area) the potential and realised values (tonnes) are normalised between the first and 99th percentile. For output in economic units both use and non-use values are used and are specified separately for hardwood and softwood fractions of the timber mass. The economic value is thus the product of baseline use and non-use values (US$) for the realised service and inflation, where inflation is: 1+f^-years where f=discount rate and years= years from baseline to time horizon.

**Relative realised fuelwood provision services index.** Like with timber all above ground carbon stock represented by tree cover is considered a potential fuelwood service or supply, so the potential fuelwood service is the product of above ground carbon stock (Ruesch et al, 2008; Saatchi et al, 2011) and fractional tree cover (di Miceli et al., 2011) for rural areas (Schneider et al., 2009) only (urban trees are considered not to be usable for fuelwood). Fuelwood demand is considered to scale with rural population (LandScanTM, 2007)and per capita use 3.65 tonnes/person/year(OECD, 2006)but also with slope gradient with a linear decrease in fuelwood demand (from baseline demand to zero) as slope increases from 0 to 90 degrees. . The realised fuelwood service (tonnes) is thus equal to the fuelwood demand (where supply >= demand) or is constrained to the supply where (supply < demand).

For output in relative units (0-1 in the study area) the potential and realised values (tonnes) are normalised between the first and 99th percentile. For output in economic units both use and non-use values are used and are specified separately for hardwood and softwood fractions of the fuelwood mass. The economic value is thus the product of baseline use and non-use values (US$) for the realised service and inflation, where inflation is: 1+f^-years where f=discount rate and years= years from baseline to time horizon.

# Appendix 2: Co$ting Nature V3 Ecosystem services indices

| | Service | Explanation |
|---|---|---|
| | **Provisioning** | |
| 1 | Relative realised timber services index | Relative realised provision of hardwood and softwood timber services |
| 2 | Relative realised fuelwood provision services index | Relative realised provision of hardwood and softwood fuelwood services |
| 3 | Relative realised grazing and fodder services index | Relative realised provision of grazing and fodder services for livestock |
| 4 | Relative realised non-wood forest product services index | Relative realised non-wood forest products accessible to the poor |
| 5 | Relative realised water provisioning services index | Relative realised volume of clean (not human impacted) water available t |
| 6 | Relative realised economic value of inland fish catch | Relative realised catch of inland fisheries |
| | **Regulating** | |
| 7 | Relative potential and realised carbon services index | Relative realised carbon sequestration and relative carbon stock (from living plant biomass and soil) services (all potential is realised) |
| 8 | Relative realised natural hazard mitigation index | Relative realised hazard mitigation services for flood/drought, landslide/erosion, inundation/tsunami/cyclone according to relative risk protected against |
| | **Cultural/Aesthetic** | |
| 9 | Relative realised culture-based tourism services index | Relative realised culture-based tourism services measured as relative density of Panoramio photos in non-urban areas |
| 10 | Relative realised nature-based tourism services index | Relative realised nature-based tourism services measured as relative density of Panoramio photos in non-urban areas |
| 11 | Relative realised environmental and aesthetic quality services index | Relative realised benefits provided by environmental and aesthetic quality |
| | **Other** | |
| 12 | Relative realised wildlife services index | Relative realised benefits provided by wildlife (pollination, pest control) |
| 13 | Relative realised cost of wildlife dis-services index | Relative realised cost of wildlife dis-services (human-wildlife conflict) |

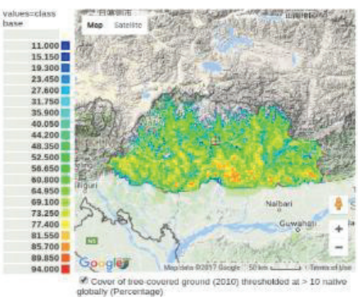
# Appendix 3: Forest baseline maps according to different definitions

### Definition of forests and comparison of forest datasets

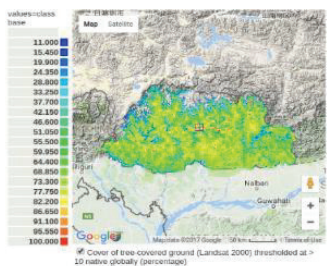
In calculating the ecosystem services provided by forests, it is important to first define “forests” and to map their distribution. There are many ways to do this. Forests can be defined as “tree cover >10%” according to the FAO, although some may argue that 11% tree cover hardly defines a closed canopy forest and some would consider 10% forest cover to be non-forest. Other approaches commonly used include using a 40% threshold. In addition, these thresholds can be applied in binary classification in which a pixel is considered forest or non-forest or using a continuous fields approach where the actual forest cover in each pixel is accounted for and mapped. Both continuous fields and classified datasets are available for Bhutan. Most of the continuous fields approaches are global, remote sensing products, whereas the national land cover map uses a classification approach.

Figure 20 shows forest cover according to different datasets and thresholds using classification and continuous field approaches and indicates the variety of pattern as well as overall forest cover that is produced by using different datasets and different thresholds for the definition of forest.

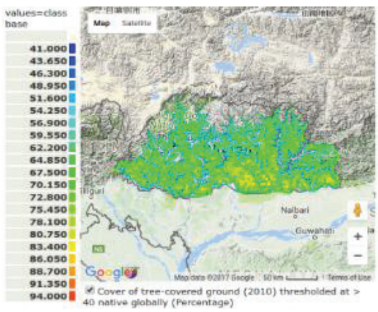
**Figure 20. Bhutan forest cover maps (various methodologies)**



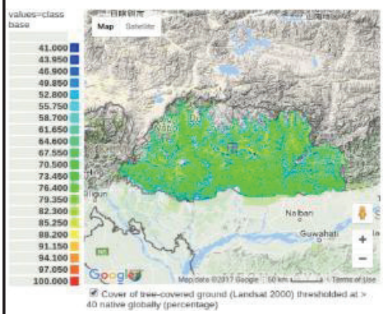

(a) MODIS VCF (2010, continuous fields) Tree >10%: 47.8% Based on 500m MODIS satellite sensor data



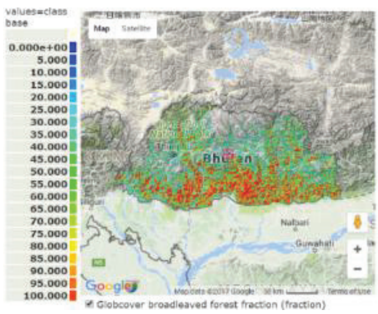

(b) LANDSAT VCF , cont fields Tree >10%: 54.1%, Based on 30m Landsat satellite sensor data



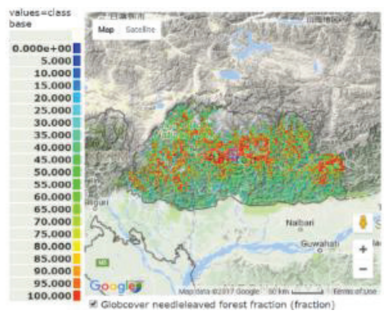

(c) MODIS VCF Tree (2010, continuous fields) >40%: 43.8%. Based on 500m MODIS satellite sensor data



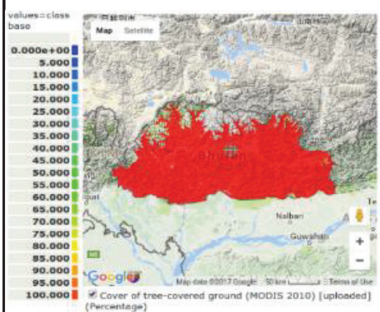

(d) LANDSAT VCF , continuous fields Tree >40%:50.66. Based on 30m Landsat satellite sensor data




(e) Globcover broadleaved forests, continuous fields: 35.4%. Based on 300m ENVISAT satellite sensor data

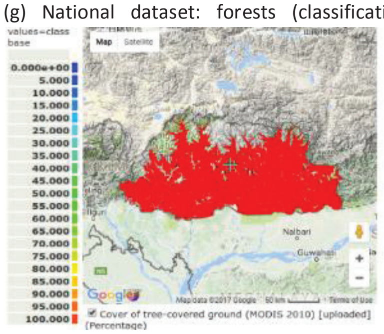



(f) Globcover needle leaved forests, continuous fields: 38.5%. Based on 300m ENVISAT satellite sensor data




(g) National dataset: forests (classification 1km, Tree>0) 85.3% based on supervised classification of 30m Landsat data

(g) National dataset: forests (classification 1km, mode of 1ha cover) 74.8%




Note. Forest cover maps for Bhutan from a variety of datasets and approaches indicating a range of patterns of forest cover and of total forest cover for different sources of data and different processing methods.

Table 37 shows that different data sources (for example MODIS, Landsat) produce different national forest covers by a few percent, and that changing the threshold tree cover defining forest has much greater impact (reducing estimated national tree cover as we go from 0 to 40% threshold).

**Table 37. Total forest cover for Bhutan from a variety of datasets and approaches.**

| Tree cover >= (%) | National tree cover (%) | MODIS (2010) Continuous | Landsat 2013 Continuous | MODIS 2010 Classification >0 | Landsat 2013 Classification> 0 |
|---|---|---|---|---|---|
| 0 | 84.6 | 48.65 | 54.3 | 98.6 | 98.7 |
| 10 | Mode of 1ha cover: 74.8% | 47.8 | 54.1 | 83.7 | 83.7 |
| 40 | | 43.8 | 50.66 | 67.6 | 67.6 |

Continuous-fields approaches (those that account for the actual cover of trees in a pixel rather than converting any cover within a pixel to 100% cover through a classification approach) produce much lower forest cover values than classification approaches. Classification of the same input data produces very high forest cover (98.7%) if all tree covers are considered as forest (>0%) but declines to 67.6% with a threshold of 40% Tree cover (at a 1km resolution).

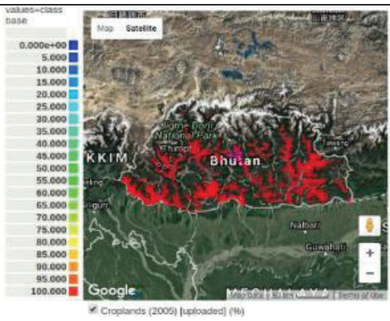
Using the classification approach on the Bhutanese official land cover vector map produces a cover of 84.6%, which is higher than the official national forest cover of 71%. An approach which converts forest cover polygons to a raster map at 1ha resolution and then calculates the modal cover at 1km resolution produces a cover close to the official national figure (74.8) and is used here as the official forest cover map at 1km resolution. This approach will still overestimate the contribution of forests to ecosystem services given the low tree density in parts of this classified map, as seen from comparison with IKONOS imagery (Figure 21). A continuous-fields approach would be more appropriate but are not available as an official national data set.

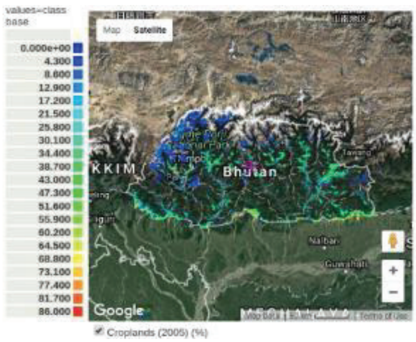
**Figure 21. Forest cover as classified from Landsat imagery in the national cover map (white areas) compared with variable density of tree cover from IKONOS imager, underneath.**

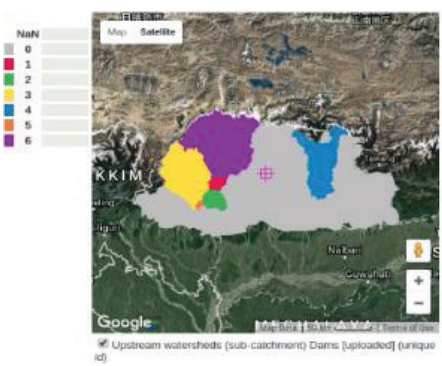
## Comparison of national official and global datasets

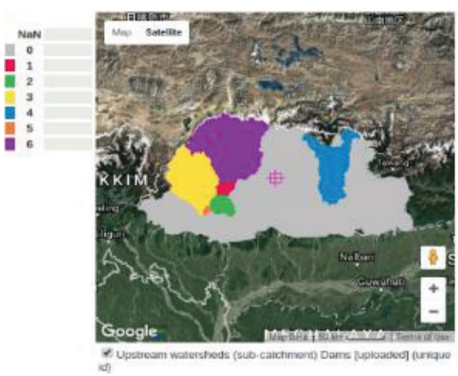
Below is a comparison of spatial datasets sourced from official national data and their equivalent from Co$ting Nature's global database. Figure 22 provides comparative images for each map and clearly indicate that some datasets differ between the national dataset and the global dataset. Though spatial patterns may be similar, the magnitudes are sometimes different because the global datasets use continuous fields and the national data sets are classified data sets. In several cases this means that the national total cover can be different. Both the global and the official national data may not represent the real magnitude and distribution perfectly.

**Figure 22. Comparison of Bhutanese national datasets with equivalent global datasets from Costing Nature. In each case a figure representing total cover in Bhutan is also given.**

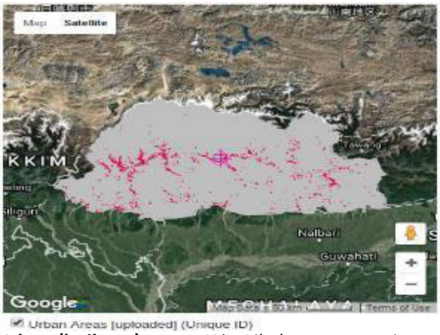
<table>
<tr><th>Bhutanese dataset</th><th>Global dataset</th></tr>
<tr><td>



**Croplands**: 18.6%.<br>Likely an overestimate, possibly misclassification of bare soils or sparse cover
</td><td>



**Croplands**: 3.8%
</td></tr>
<tr><td>


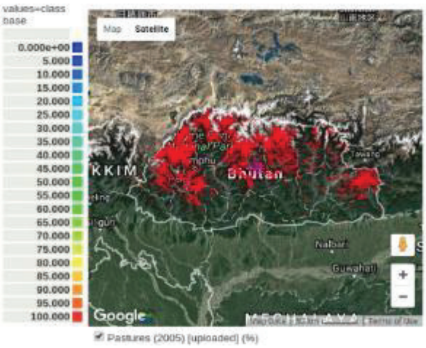

**Watersheds of dams**: 6 dams 36% of area
</td><td>



**Watersheds of dams**: 6 dams 36% of area
</td></tr>
</table>

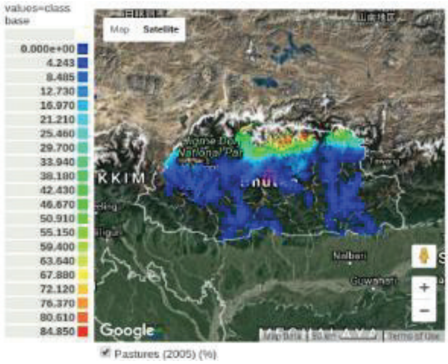



**Urban (built-up)** areas 4%. Likely an overestimate, possibly misclassification of bare soils or sparse cover

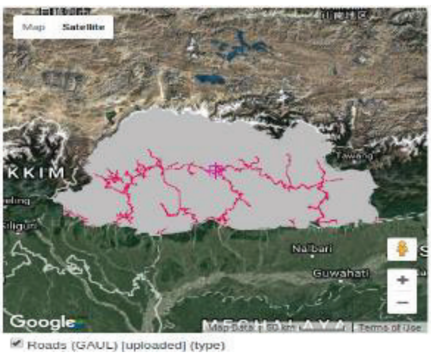

**Urban (built-up)** areas 0.05%



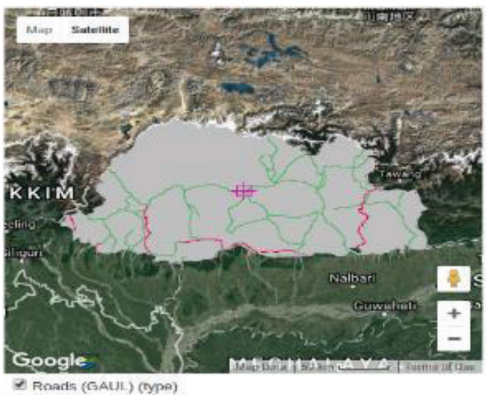

**Pastures**: 19%. Likely an overestimate of the continuous field.



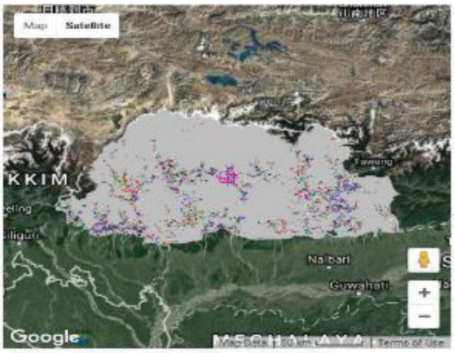

**Pastures**: 3.6%




**Roads** 4.95 % of pixels. More detailed but fewer roads than the global dataset.

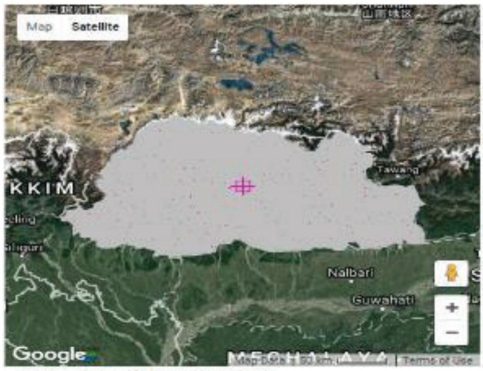



**Roads** 5.37 % of pixels



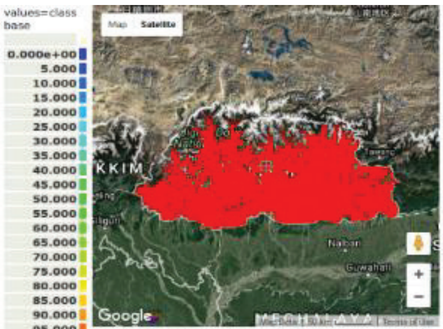

Rural populated places [uploaded] (Unique ID)

**Populated places** 17% of pixels. Likely an overestimate based on misclassification or overrepresentation as a classification at 1km resolution.



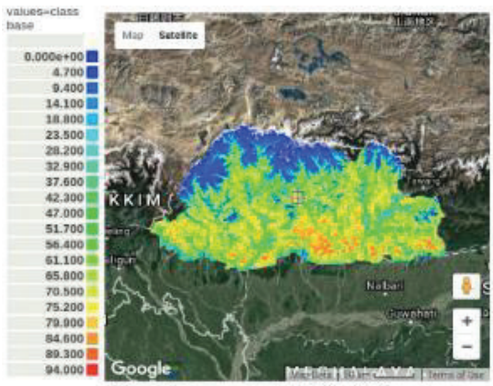

Rural populated places (Unique ID)

**Populated places** 0.4% of pixels



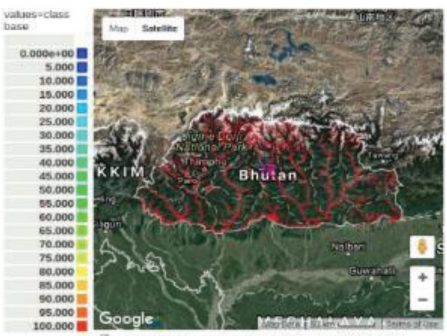

Cover of tree-covered ground (MODIS 2010) [uploaded] (Percentage)

**Forests** (classification 1km) 74.8%. Likely an overestimate given the sparse cover of some forest types, reflected better in the continuous field global dataset



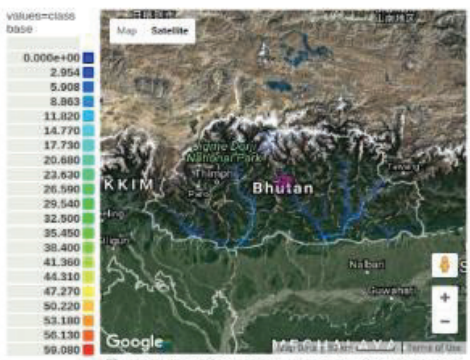

Cover of tree-covered ground (MODIS 2010) (Percentage)

**Forests** (continuous fields 1km) 48.6%



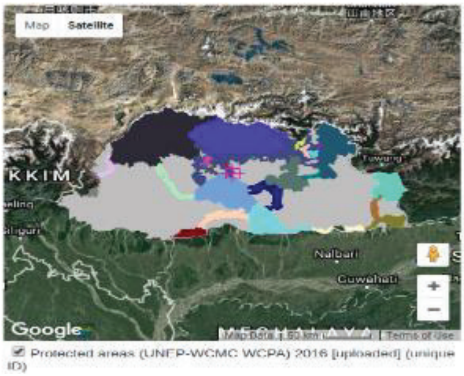

Landsat water mask (Hansen/UMD/Google/USGS/NASA) [uploaded] (% of pixel)

**Water** 9.8%

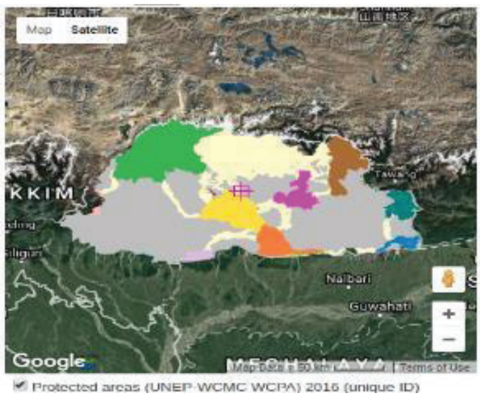



Landsat water mask (Hansen/UMD/Google/USGS/NASA) (% of pixel)

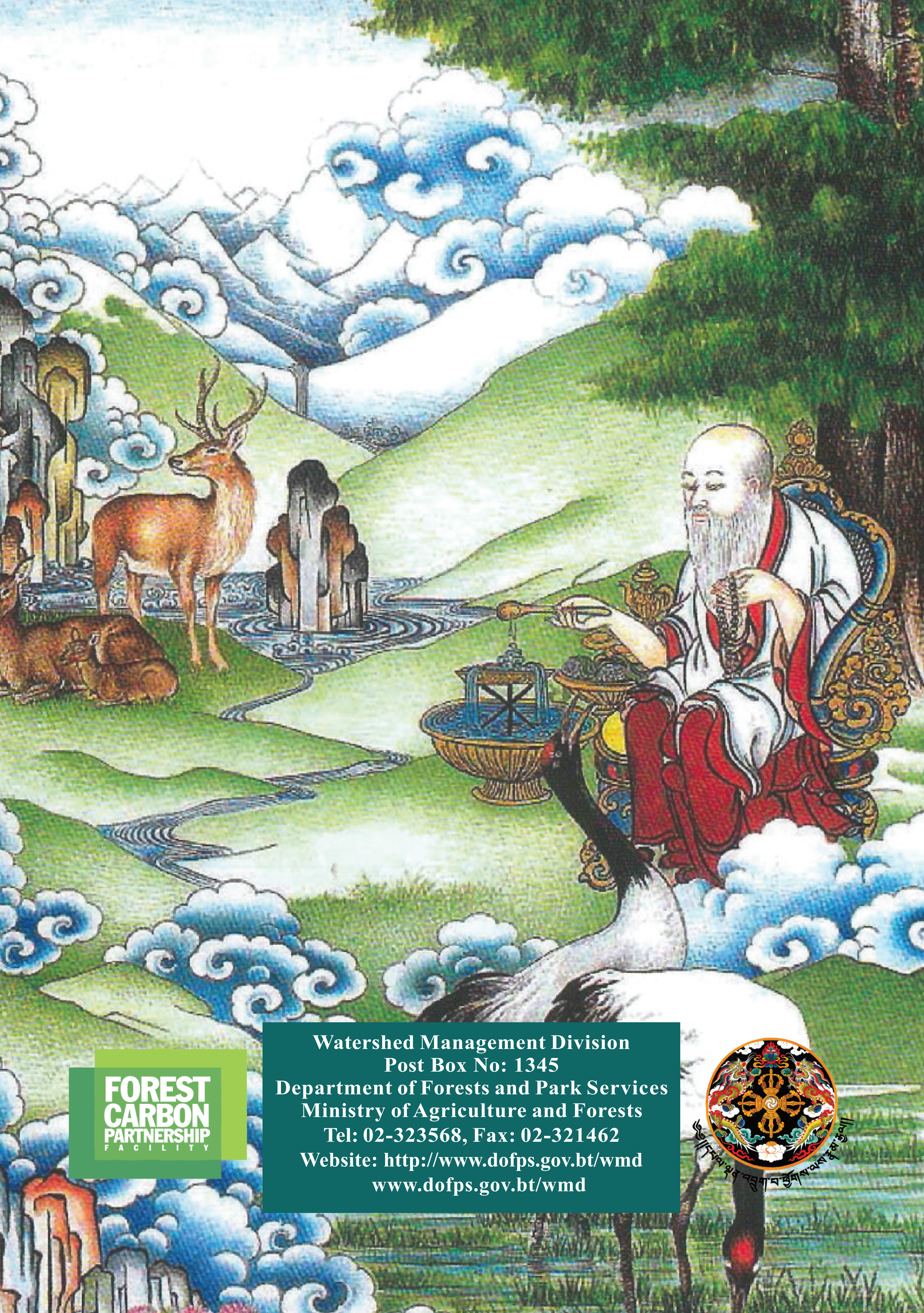
**Water** 2.85%. Likely an underestimate.




**Protected areas** [50.7%]




**Protected areas** [47.4%]

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