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Mapping and Valuing Ecosystem Services in Mondulkiri: Outcomes and Recommendations for Sustainable and Inclusive Land Use Planning in Cambodia

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1. EXECUTIVE SUMMARY AND POLICY RECOMMENDATIONS

Cambodia is a country rich in natural resources that sustain the wellbeing of the nation's population and contribute to the country's economy. It has the largest areas of contiguous and intact forests in mainland Southeast Asia. Millions of people in Cambodia, many rural and poor, depend directly on the natural environment for their daily basic food, water, energy needs and income generation. All Cambodians depend on the country's forests to: regulate the water and soil cycles; provide protection against floods; storm protection; recreational benefits and tourism revenues. All of these benefits are known as ecosystem services which are the goods and services nature provides us for free and are essential for life support processes (Millennium Ecosystem Assessment 2005). These services however are threatened by continued deforestation driven by large-scale infrastructure projects, timber production, illegal logging, mining projects, and other development activities.

Economic growth is essential for the country to develop. However, economic growth at the expense of natural resources and ecosystem services is unsustainable, weakening the functioning of the country's ecosystems and increasing vulnerability among the poorest communities. WWF Cambodia therefore recommends an ecosystem approach to land use planning to ensure that development projects take place outside of areas of critical ecological importance thus preventing economic activities from undermining the functioning of ecosystems. With the generous support of the European Union and USAID and in collaboration with the Royal University of Phnom Penh, WWF Cambodia has conducted a study in the densely forested province of Monduliri to highlight the location and value of the province's key ecosystem services with a view to integrate ecosystem services into land use and spatial planning decisions.

The Royal Government of Cambodia's (RGC) National Spatial Planning Policy aims to address land use challenges and ensure that land and natural resources are used and managed in a sustainable, effective and equitable manner to support socio-economic development, food security, national defense and natural balance (RGC 2011). Without effective land management planning and integrated land use plans, it is likely that: encroachment into Protected Areas (PAs); unsustainable exploitation of forests and fisheries; and poor water management, will become exacerbated. The poorest are likely to be most severely affected (Diepart 2008) however, Cambodia's economy too is also likely to be impacted as the country depends on natural resources for economic development and tourism.

As recognized in the National Strategic Development Plan (NSDP) 2014-18 (RGC 2013a), there is a need to better manage Protected Areas and a need for more information on biodiversity and natural resources. The RGC has demonstrated its willingness and commitment to work towards sustainable development, as evidenced in the National Policy and Strategic Plan on Green Growth (2013b), the National Green Growth Roadmap (2013c) and the current efforts to develop an Environmental Code (in development, 2016). Ecosystem-based management and planning can contribute to achieving sustainable development, defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987; Cohn and Lerner 2003).

A set of tools called InVEST (which stands for Integrated Valuation of Ecosystem Services and Tradeoffs) was used to spatially map and economically value different ecosystem services in the Monduliri province as part of a ecosystem services assessment and valuation undertaken from June 2014 to September 2016. The overall objective of the project was to support policymaking and provide information useful for land use and spatial planning decisions. The specific objectives were to:

1. Produce baseline maps demonstrating the areas with the most priority ecosystem services (or 'hotspots' of priority ecosystem services) and areas with the least;
2. Assign an economic value to priority ecosystem services by carrying out an economic valuation of these ecosystem services; and
3. Provide insights on how priority ecosystem services could be affected by different interventions (policies / actions) in the future, by producing maps of these ecosystem services in 2030 according to different future scenarios.

The team produced maps, in pixels and by sub-watershed, of the following ecosystem services: carbon storage; non-timber forest products (NTFPs); habitat quality of wildlife; annual water yield; avoided nutrient pollution (or nutrient retention); and avoided sediment pollution (or sediment retention).

The following ecosystem services were also assigned an economic value: carbon storage, NTFPs and annual water yield. The remaining ecosystem services were either too small to be valued (as in the case of sediment and nutrient retention) or required primary valuation studies that were not available (as in the case of habitat quality).

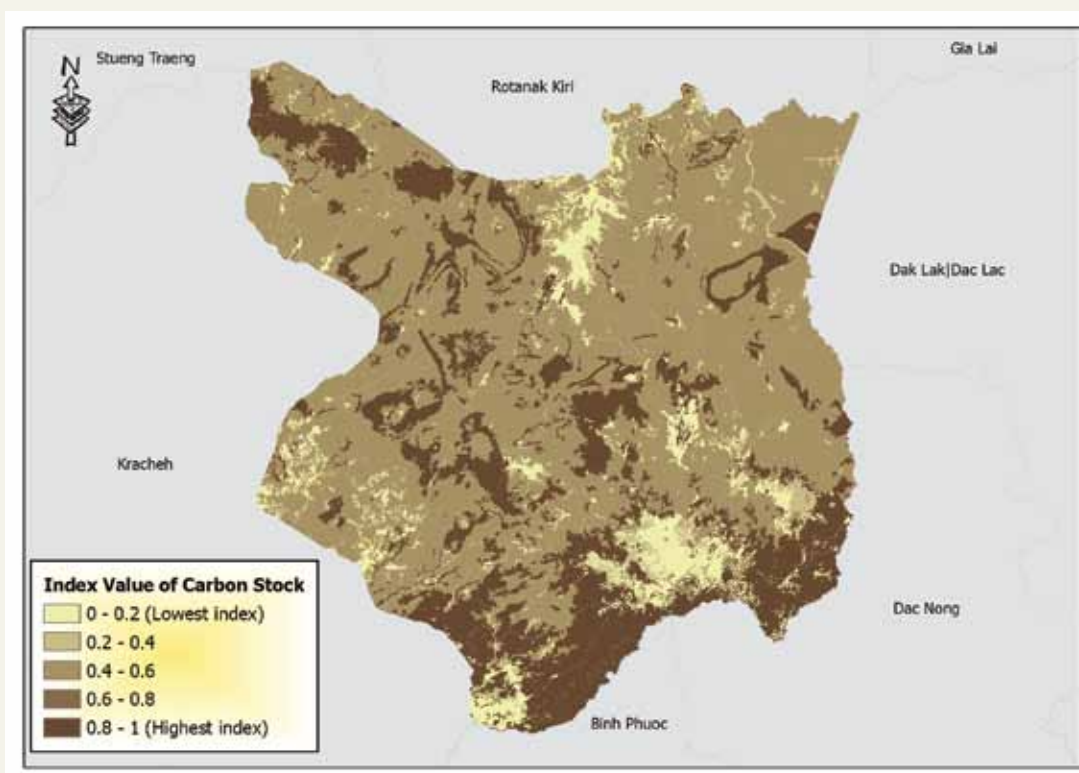
The baseline maps produced to quantify and identify the location of hotspots of ecosystem services used 2010 data on forest cover published by the Forestry Administration, Department of the Ministry of Agriculture, Forestry and Fisheries (MAFF 2011) in order to use the most recent official, Land Use Land Cover maps as a data source. In addition to the mapping and valuing of ecosystem services to produce the baseline maps, ecosystem services were mapped under different future scenarios which showed the changes in Mondulkiri's ecosystem services (in biophysical and economic terms) in 2030 under a: Conservation (or low deforestation) scenario, Green Economy (or moderate deforestation) scenario and Business as Usual (high deforestation) scenario.

Carbon Storage

Trees' ability to store (or sequester) carbon is an important ecosystem service provided by functioning forest ecosystems. The value of carbon storage is diminished if a forest is converted, e.g. through logging or burning (Aerts and Honnay 2011). As can be seen in the map below, the study assessed the carbon stock (or amount of carbon stored in the forest ecosystem).

Figure i shows the areas with the highest carbon stock in Mondulkiri (in dark brown) and the ones with the lowest carbon stock in Mondulkiri (in pale yellow), the legend shows a relative scale of carbon stock for Mondulkiri province. Even areas that have not been legally zoned can be seen to have a higher stock. The provinces with high carbon stock are serving an important function: regulating the climate, regulating water cycles and providing individuals nationally and globally with the goods and services needed for day to day activities. It is therefore recommended that decision-makers consider sustainable financing mechanisms such as carbon offsets, REDD+ and other options to sustain the functioning of these forest ecosystems.

Figure i: Baseline map of carbon stock (in pixels)

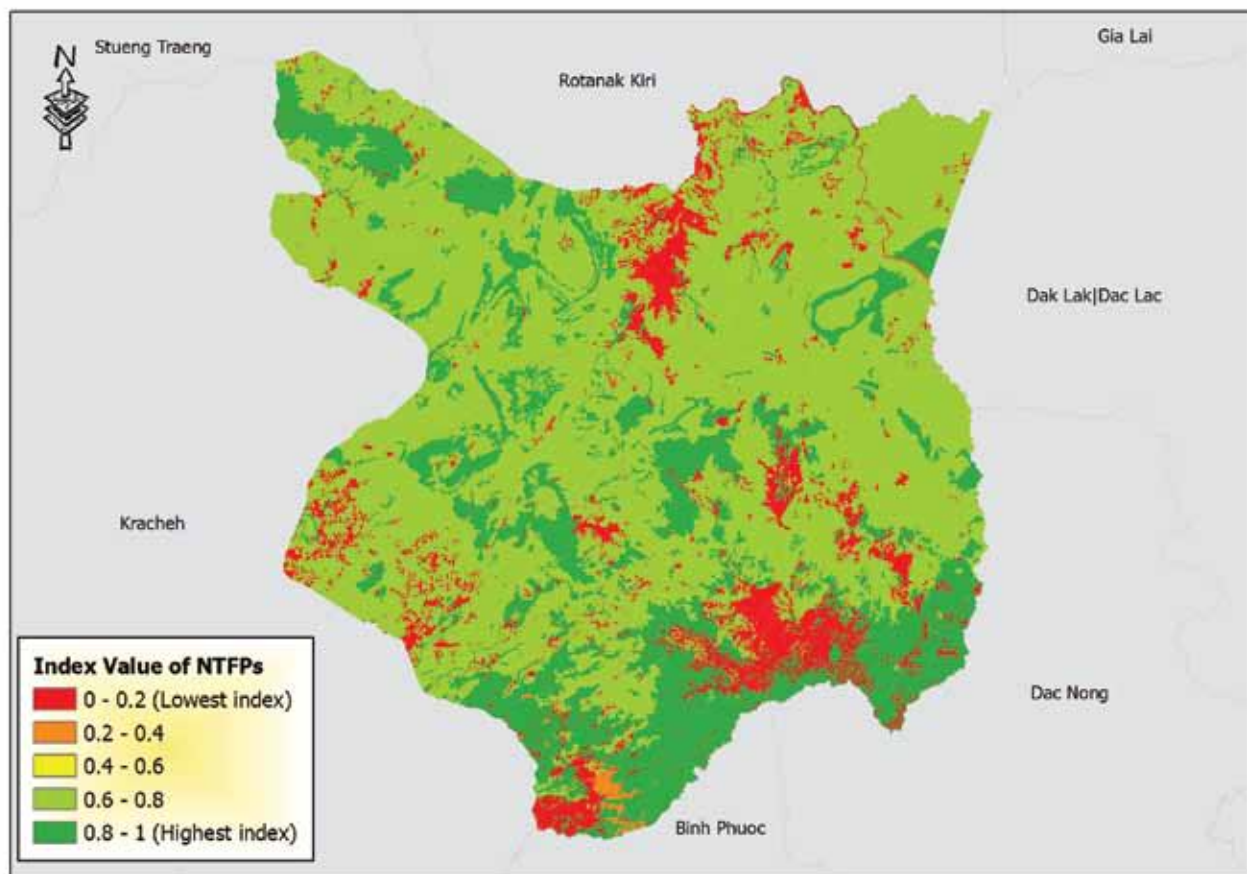


Non Timber Forest Products (NTFPs)

NTFPs provide: basic subsistence in the form of food; medicines; materials for constructing homes and furniture; cultural benefits; and a source of income (e.g. from selling honey or rattan products). NTFPs are important in the livelihoods of local people. The NTFPs that were taken into consideration in this mapping and valuation study include: liquid resin, solid resin, bamboo and wild honey. The communes with the highest quantities of NTFPs are: Bu Chri, Roya, Chong Phlah, Krong Teh and Dak Dam. By looking after the forests in these communes to ensure the well-functioning of the forest ecosystem, the commercial and livelihood opportunities of NTFPs would be enhanced. Local communities would consequently benefit from these sustained sources of income, on which households greatly depend.

The conservation and protection of the areas that produce the highest quantities of NTFPs (the darker green areas in Figure ii), can occur through planning economic development activities outside of these areas and strengthening law enforcement operations in these forests which would significantly reduce deforestation in these areas. The forest would then be able to continue to provide this vital ecosystem service, so highly valued by local communities. Supporting the birth and growth of NTFP enterprises e.g. promoting systems of sustainable bamboo harvest and production, is a way of supporting the local economy. This could also help reduce incentives for more unsustainable practices such as illegal logging.

Figure ii: Baseline map of NTFPs (in pixels)



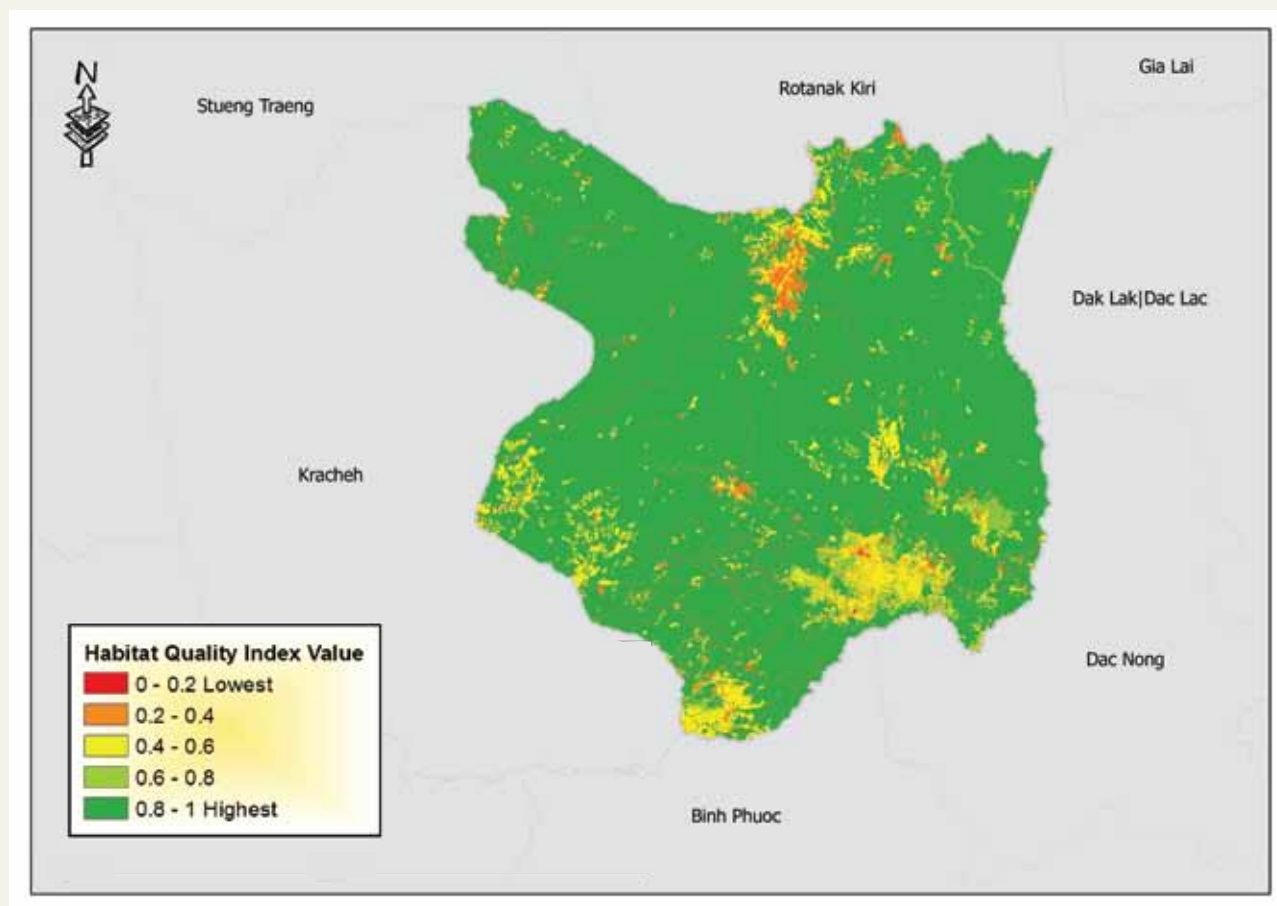
Habitat Quality

Habitat quality¹ is defined in this study as habitats that are suitable for the following wildlife species: Asian elephants, white rumped vultures and tigers, the latter of which are considered functionally extinct in Cambodia but which the country is trying to bring back into the wild by creating more enabling conditions such as enhancing the quality of potential habitats. These wildlife species attract tourism and provide recreational benefits as well as serve to contribute to the food chain on which we all depend. The areas of land that would be considered as suitable habitats for these three wildlife species are located in Phnom Prich Wildlife Sanctuary (PPWS),

¹ These 3 species were selected amongst 8 endangered and critically endangered species (IUCN list) to ensure that different types of habitats were represented. Mondulokiri has been recognized as one of the most suitable areas for recovery of tiger population density.

Mondulkiri Protected Forest (MPF) and some parts of Seima Protected Forest (SPF). Habitat quality is therefore highest in areas with dense forest. Ecotourism could be an additional way of making substantial economic returns from investing in wildlife conservation. WWF-Cambodia believes that ecotourism can help to create additional opportunities to sustain community livelihoods in the landscape, to raise awareness among community members about the value of forests and wildlife, and to co-finance the management of Protected Areas.

Figure iii: Baseline map of Habitat Quality (in pixels)



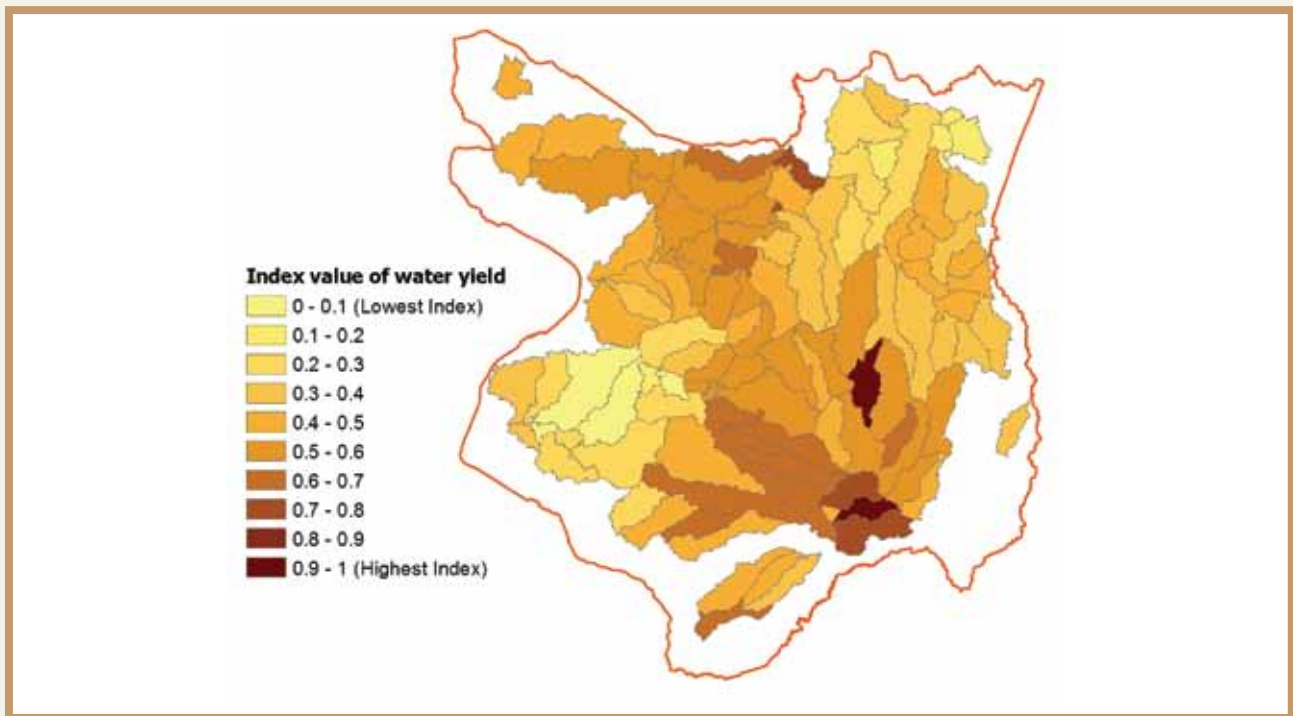
Annual Water Yield

The annual average water yield on a landscape is defined here as the annual average quantity of water produced by a watershed. Natural forests regulate the water cycle by absorbing and storing water in tree roots during the rainy season and releasing them back into the streams in the dry season. Without trees there are more extremes in water availability: in the short term there is likely to be more water entering the streams as a result of fewer trees, which could increase the likelihood of flash floods and of pollutants entering the water supply. In the longer term, things could change due to other factors, e.g. rainfall patterns change due to extensive deforestation, or loss of tree roots results in the soil losing water retention capacity, which could lead to flash flooding in rainy seasons followed by water shortages in dry season as the water is no longer held in the soil over time and released gradually over the year, but all released shortly after it falls as rain. This flow pattern cannot be captured by the model, however, as it currently only takes into consideration annual averages for water. However the InVEST seasonal water model, which does take the seasonal variability of water yield into account, is currently being developed and trialed.

As shown in Figure iv, the areas with the highest water yield (depicted in dark brown on the map) are the areas with the most precipitation and least amount of natural forest available to absorb this excess surface water. High water yield arises when annual estimations of evapotranspiration are low. Water yield is low where estimated evapotranspiration on a yearly basis is high. Evapotranspiration² is higher in a dense forest than on grassland.

² Evapotranspiration is a term for all processes through which water, in liquid or solid form, becomes atmospheric water vapor. It includes evaporation from soil, lakes and rivers and vegetative surfaces. It also includes transpiration, which represents evaporation from within the leaves of plants. Evapotranspiration is the primary link in the hydrological cycle between the land and the atmosphere therefore it plays a vital role in stabilising water availability (FAO no date; Allen et al. 1998).

Figure iv: Baseline map of Annual Water Yield by sub-watershed



Payments for Watershed Services (PWS) can help manage and maintain water. PWS are defined as contractual and voluntary transactions where a ‘buyer’ agrees to provide some kind of compensation or payment to a ‘seller’ conditional on delivery of a hydrological ecosystem service, or implementation of a land use or management practice likely to secure that service (Wunder 2005). PWS is a way of regulating the water supply, water quality, and erosion control, to the benefit of all.

Nutrient Retention

Nutrients are required for plants to grow. Nitrogen, phosphorus and potassium in particular are the most important contributors to the growth of plants including crops for food. Soil is a major source of nutrients however farmers also add nutrients to the soil when applying fertilizers (which tend to be made up of mostly nitrogen and phosphorus) to enhance agricultural productivity (Lines-Kelly 2004). Forests maintain the levels of nutrients in the soil by retaining nutrients in networks of tree roots thus limiting the runoff of fertilizers into nearby rivers and streams. Deforestation, and the consequent loss of these root networks, can result in a reduction in nutrient retention (the function trees perform to retain nutrients in the soil) and an increase in the flow of nutrients into water systems (Lines-Kelly 2004; An et al. 2008). This can lead to water contamination, affecting human health. Flooding, which can also increase if there are fewer tree root networks to absorb excess surface water, is likely to increase fertilizer runoff and affect water quality in rivers (Bhagabati et al. 2012).

This study estimated the relative importance of nutrient retention, per sub-watershed, as an annual average, using a ‘water purification: nutrient retention’ model to simulate nitrogen and phosphorus loading into streams and water bodies. The model used can map the amount of nitrogen and phosphorus nutrients (the most common nutrients in fertilizers) that go unabsorbed by the trees.

Figures v and vi map the sub-watersheds with the highest phosphorus and nitrogen exports (the areas in dark brown have the largest quantities of nutrients). Areas with large quantities of nutrients (or nitrogen and phosphorus export) tend to be in agricultural areas where fertilizers, herbicides or pesticides are likely to be used. Areas low in nutrients tend to be areas of dense forest.

Figure v: Baseline map of the sum (or total amount) of phosphorus export by sub-watershed.

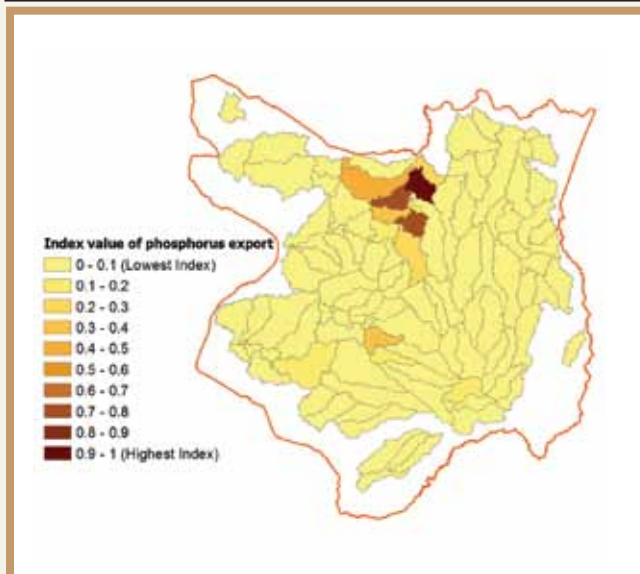
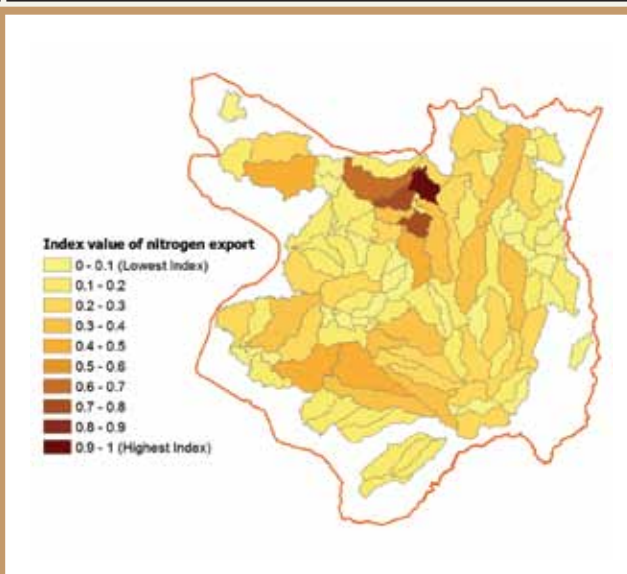


Figure vi: Baseline map of the sum of nitrogen export by sub-watershed



Sediment retention

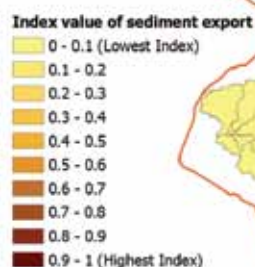
Soil erosion is a significant problem in environments with high rainfall intensity. Forest soils are normally protected by the canopy and stabilized by tree roots and leaf litter. A good root system reinforces the soil and holds it in place reducing the erosive effects of wind, rain, gravity and flowing water (Walker et al. 1996). Land disturbing activities such as logging, tree burning, poor agricultural practices, cause the surface of the soil to form a compacted crust, preventing infiltration (or water on the ground entering the soil) and increasing surface runoff and soil erosion (Van Paddenburg et al. 2012).

River sedimentation occurs when erosion upstream leads to higher sediment loads (or sediment export) in rivers and deposition of sediment downstream. The process occurs naturally and river deltas are formed by sediment deposition, but changes in land use activities upstream may lead to significant increases in the amount of sediment entering a river system (Van Paddenburg et al. 2012). Excessive amounts of sediment can lead to: the deterioration of water quality, as a result of pollutants and harmful bacteria that may be attached to soil particles; algal blooms which block out light that other plants need to grow and reduce the amount of oxygen in the water available for fish; change and often destroy fish habitats and spawning beds; and clog fish gills, impairing their functioning (Walker et al 1996). A build-up of sediment can also lead to a shallower body of water resulting in increased risk of flooding and a reduction in the navigability of water channels, making it more difficult for fishing boats to travel (Fondriest Environmental, Inc. 2014).

Because of the importance of the role of natural forests in retaining sediment, otherwise known as sediment retention or erosion control, this ecosystem service has been assessed in this study by measuring and mapping quantities of sediment export to show the current spread of sediment export and how the amount and spread of sediment is likely to change in 2030 under each future scenario.

In a province with local populations so dependent on fish for food and livelihoods and water for irrigation, cleaning and drinking, sedimentation is likely to have highly detrimental impacts on the wellbeing of local families and household incomes. As Figure vii shows, these impacts are likely to be most keenly felt in the southeastern parts of the province where volumes of sediment export (depicted in dark brown in Figure vii) are highest. Therefore putting in place measures to prevent or limit sedimentation is a more favorable and less costly approach than addressing the problems once the damage has been done. Examples of these measures include: confining deforestation to areas of flat land or small inclines outside of Protected Areas / Protected Forests to limit runoff; promoting sustainable agricultural practices among private sector stakeholders and local smallholders; and implementing watershed management and/or PWS.

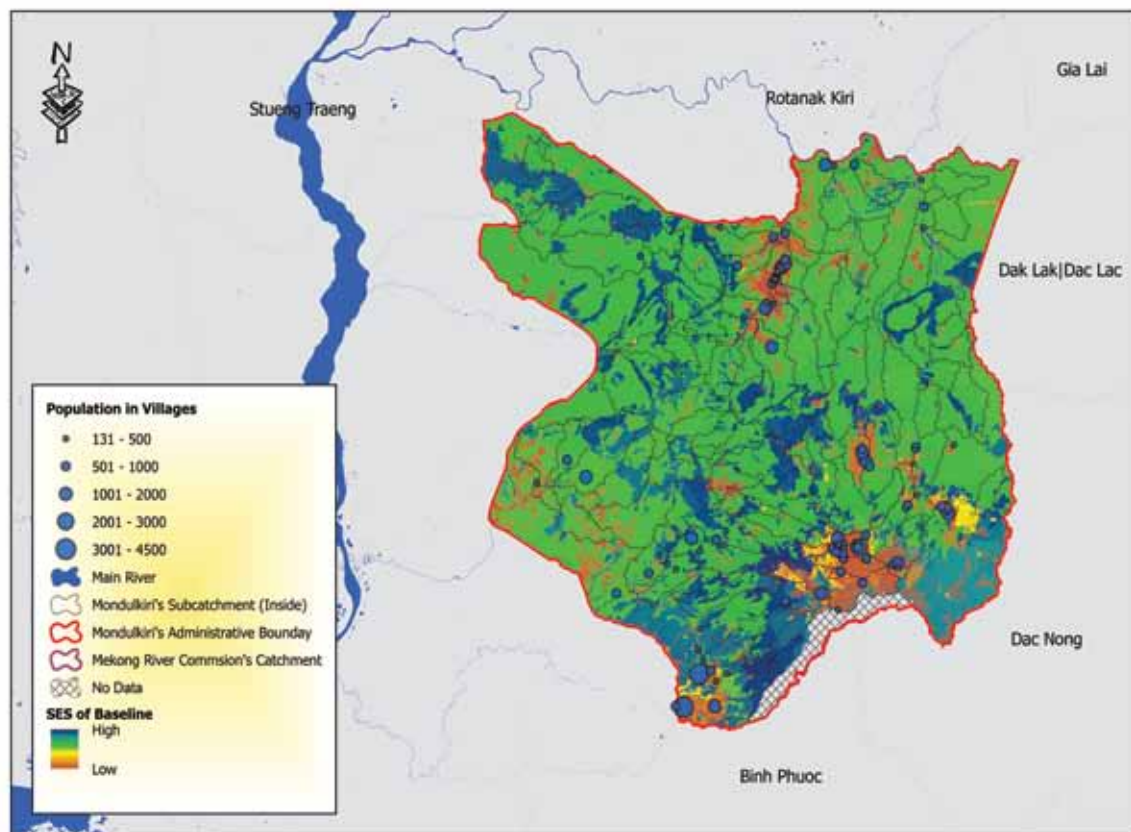
Figure vii: Baseline map of sediment export by sub-watershed



Combined Ecosystem Services

The total amount of all six ecosystem services that this study assessed were aggregated and given the label combined ecosystem services, enabling us to observe the geographical spread of the key ecosystem services that were the focus of this assessment. The map in Figure viii shows the areas with the most amount of combined ecosystem services and the areas with the least. Researchers found that the larger the forest cover in a commune, the higher the amount of combined ecosystem services. As highlighted in Figure viii, the areas in blue and green have a high volume of combined ecosystem services, notably in the Protected Areas, while the areas in yellow and red have fewer forest patches and some have a high population density. The areas depicted in blue and green in the map on Figure viii are important sources of ecosystem services on which local populations depend.

Figure viii: Baseline map showing combined ecosystem services in Mondul Kiri, from official data source (MAFF 2011)



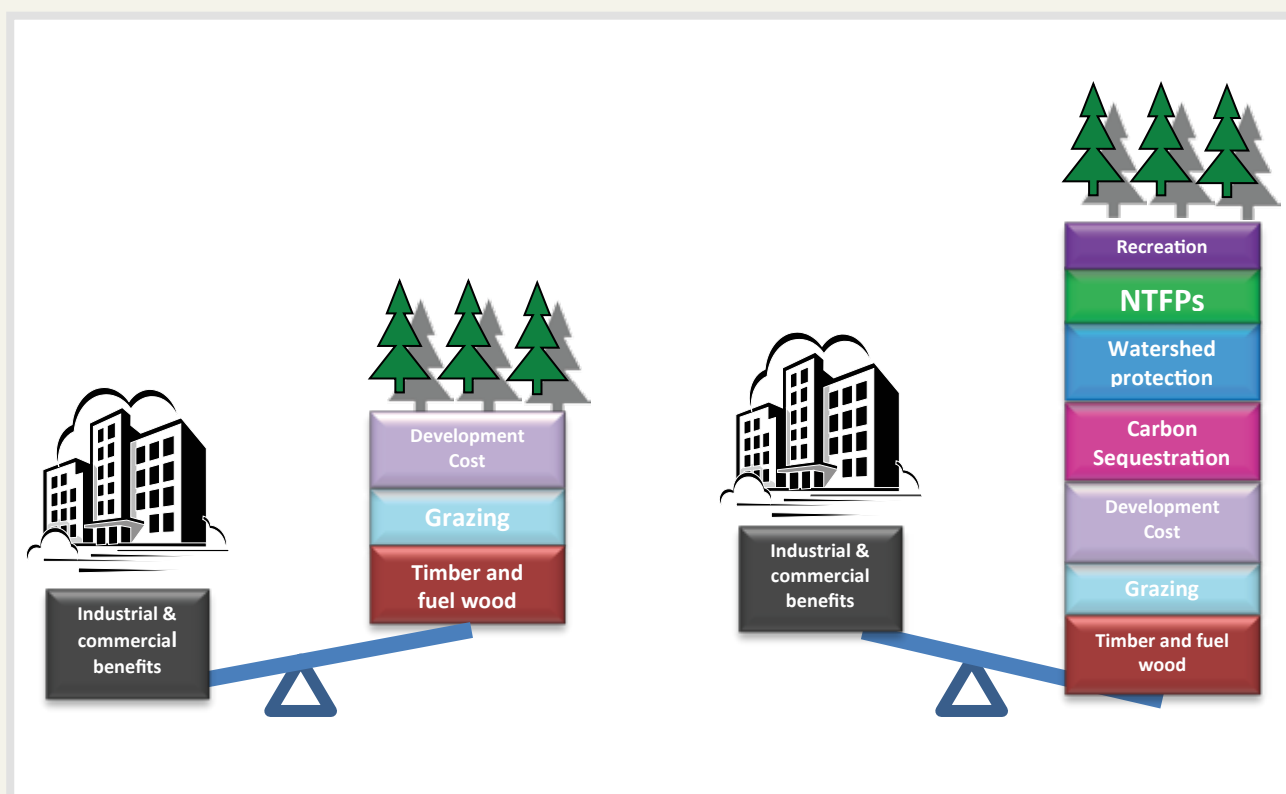
What is the Economic Value of Ecosystem Services in Mondulkiri Province?

Ecosystem services produce valuable benefits to society and to the local economy for example, the provision of clean water is useful for maintaining the health of fish populations which are important for nourishing humans and enabling local livelihoods. Ecosystems in the Eastern Plains Landscape provide these valuable services for free but these benefits are under threat due to unsustainable land practices that could jeopardize the functioning of these ecosystems thereby reducing the services provided. Economic valuations are a way of assigning a value to these free public services that are under threat to make the economic case for investing in or supporting nature conservation to maintain these vital ecosystem services (Emerton and Aung 2013). Economic valuations can also be useful for justifying and setting priorities for programs, policies or actions that protect or restore ecosystems and their services (Goulder and Kennedy 2011). By neglecting to include ecosystem services in policy or land use planning decisions, the costs and benefits they provide are not adequately represented which results in an undervaluation of ecosystem services. Figure ix provides a visual depiction of the benefits ecosystem services provide that are currently being omitted from these types of decisions.

As part of the assessment of ecosystem services in Mondulkiri province, an economic value was assigned to three ecosystem system services (NTFP availability, annual water yield and carbon storage). Three future economic development scenarios were developed and mapped, in collaboration with local stakeholders, each of which envisioned different land use changes between now and 2030, to help inform decisions by understanding how different economic development trajectories will lead to different outcomes. The economic valuation in this study was carried out by assigning a monetary value on the welfare changes that result from the impacts of each scenario on these three ecosystem services in 2030.

Unfortunately not all six ecosystem services could be assigned an economic value. Sediment and nutrient retention as well as habitat quality could not be assigned a value because of data limitations. Although this was not carried out as part of this study, these ecosystem services can be assigned an economic value as part of future research.

Figure ix: Illustration to demonstrate how ecosystem service valuation provides a more complete account of costs and benefits (The Natural Capital Project 2015)



How would Ecosystem Services be Affected by Different Future Development Scenarios?

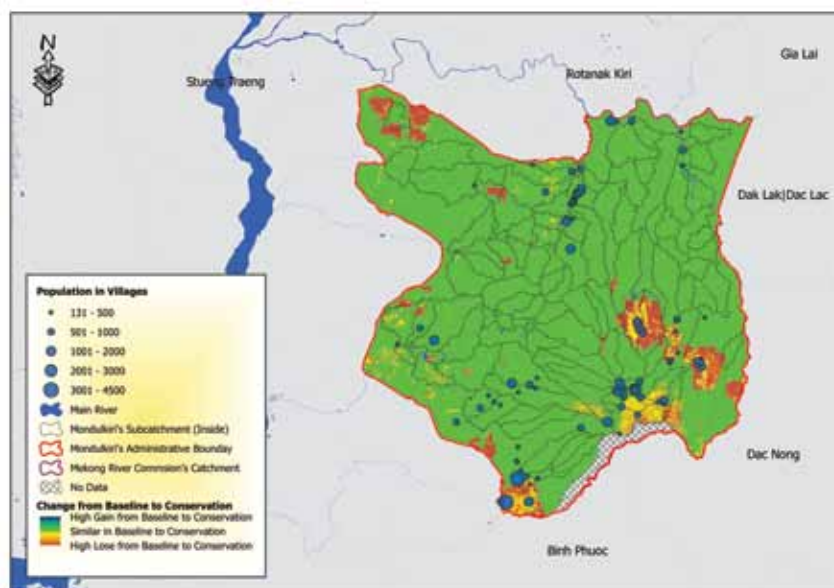


Figure x: Map showing changes in ecosystem services in Mondulakiri in 2030 under a Conservation Scenario from the from the baseline map (Figure xiii)

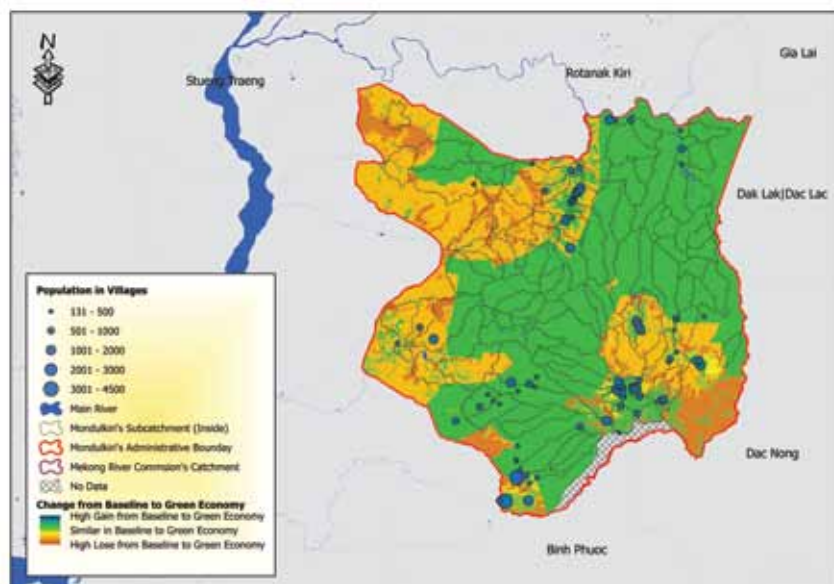


Figure xi: Map showing changes in ecosystem services in Mondulakiri in 2030 under a Green Economy scenario from the baseline map

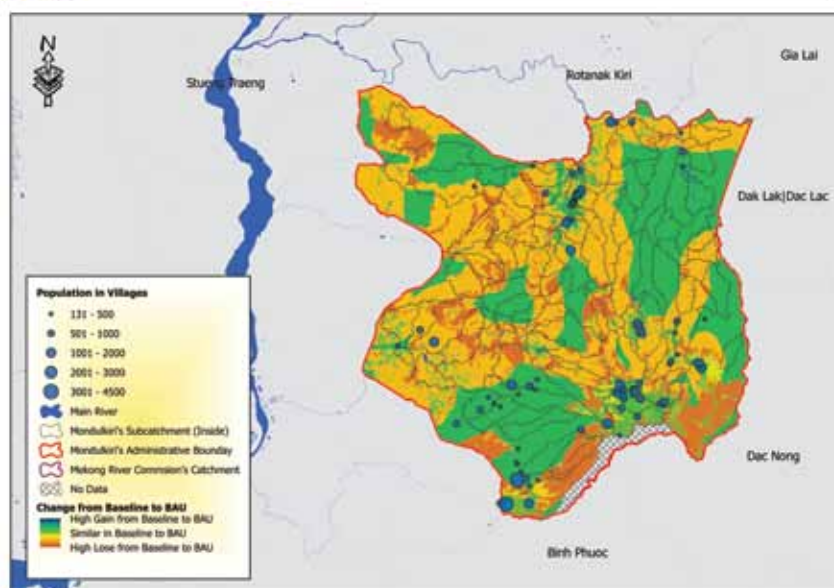


Figure xii: Map showing changes in ecosystem services in Mondulakiri in 2030 under a Business as Usual scenario from the baseline map

The project team developed maps showing changes in ecosystem services under three different development scenarios for 2030: Business As Usual (BAU), Conservation (CN) and Green Economy (GE). These spatial maps were produced on the basis of 'storylines' (or descriptions on which each different future scenario was imagined, visualised and produced into a map). These were developed by stakeholders, including provincial level government officials from Monduliri and civil society representatives, in conjunction with WWF and RUPP. Baseline maps (Figure viii is an example of one) were produced to show the 'current' situation in Monduliri. WWF Cambodia and RUPP used official government data sources to produce the Baseline maps therefore 2010 data was used as this is the most recent official government forest cover data for Cambodia.

The Business as Usual scenario envisages continued high deforestation rates between 2010 and 2030. The Conservation scenario prioritises the conservation of natural resources over unsustainable economic development activities and envisages a future with limited deforestation between 2010 and 2030. The Green Economy scenario visualizes a middle path, a moderate deforestation rate in which there is more of a balance between economic development and conservation. These future scenario spatial maps (examples of which are Figures x, xi and xii) were produced collaboratively with policymakers with the aim of helping them visualize how Monduliri will look in 2030 if the current trajectory continues and what Monduliri would look like in 2030 if alternative paths are taken. It shows the impacts of different economic development paths on ecosystem services and these maps can be used to support spatial planning in Monduliri.

Conservation scenario

As produced and agreed by local stakeholders, the Conservation scenario envisages a future development path of relatively low levels of deforestation, which would mean that in 2030, 85% of Monduliri's total land area would remain as forest cover. The Conservation scenario maps show fewer losses of ecosystem services (as shown in the bar chart on Figure xiii and by the relatively few areas in red and orange, which show little forest cover and few ecosystem services on the maps in Figure xiv) with some gains in carbon storage, as a result of the increase in tree cover from rubber plantations grown outside of Protected Forests and Protected Areas. Although some gains in terms of carbon storage can be made, in general monocrop plantations can degrade biodiversity especially if plantations take the place of natural forest as has happened in the Mekong region in the past (He and Martin 2015). In this scenario, the areas with the most ecosystem services (Protected Areas and Protected Forests) see no forest loss between 2010 and 2030.

Green Economy scenario

The Green Economy trajectory envisioned: increased protection of areas with high biodiversity; adherence to spatial plans; and implementation of sustainable finance mechanisms. This is very much aligned to the NSDP 2014-2018 (RGC 2013a); National Policy and Strategic Plan (RGC 2013b); and the National Green Growth Roadmap (2013c), which promote sustainable land use and natural resources management, and green investment to ensure green development in Cambodia. The GE scenario is also based on the following assumptions, that by 2030:

- Non-forest areas in the province, besides non-forest areas in ELCs, are kept as community use zones, multiple use zones, or sustainable development zones at community scale.
- Existing rice fields in Koh Nhek (in the North of the province) have expanded 10km in the buffer for rice production zones increasing rice production in response to a growing demand for rice.
- The remaining areas in Monduliri besides the areas mentioned previously are assumed to be buffer economic zones for rubber plantation (although these are assumed to be sustainable rubber plantations).
- Road projects planned (before 2020) do not go ahead due to the significantly greater contribution this will make to deforestation in the province.

The GE scenario witnesses a reduction in forest cover from 2010 to 2030 such that by 2030, 53% of Monduliri's total land area is forest cover.

However losses in carbon storage, habitat quality for wildlife and NTFPs are less significant than the losses in the BAU scenario (as shown on the maps in Figure xiv). Risks of sedimentation are also reduced, as forest cover on high slopes are maintained, but the increase in agricultural productivity for rice production may increase nutrient runoff into water channels. These results however do not take into account sustainable agricultural practices, such as terraced rice farming, which can reduce harmful fertilizers entering water channels and affecting water quality. These sustainable agricultural practices are promoted in the National Policy and Strategic Plan on Green Growth (2013b).

Improved governance and management of Protected Areas, as outlined in Cambodia's NSDP 2014-18 (RGC 2013a), are likely to reduce losses in vital ecosystem services. The adoption of the Green Economy scenario, allows for a pragmatic balance between development and conservation.

Business as Usual (BAU) Scenario

The BAU scenario takes into consideration the impact of development activities on ecosystem services that the RGC is currently planning on implementing in Mondulkiri, for example, ELCs in which rubber plantations are planned; land clearing for other types of monocrop cultivation; road construction; and the development of settlements (or villages). The two main drivers of deforestation between 2010 and 2030 in this scenario are ELCs and the construction of roads, as per the current development plans and as agreed by stakeholders in workshops. Therefore these planned ELCs and roads can be seen in the BAU maps in Figure xiv.

In this scenario, forest cover represents only 34% of the province's total land area in 2030. The high rate of deforestation in this scenario is likely to have detrimental impacts on forest biodiversity, habitat quality of wildlife, soil quality and the amount of carbon stored in the trees, all of which are likely to reduce. Figure xiv shows the losses of all six combined ecosystem services in red, orange and (to a lesser extent) yellow on the BAU maps. The effects are as follows:

- Annual water yield increases as a result of fewer trees to regulate the water, which results in increases in the risk of hazards such as flash floods.
- A 62% loss in the availability of NTFPs (as Figure xiii highlights) results in a reduction of sustainable sources of income for local communities. This can increase their vulnerability and exacerbate poverty in the province, especially if the loss of NTFPs which support households cannot be made up with other sources of income.
- A 33% loss in carbon stored in Mondulkiri's forests diminishes the ability of Cambodia's forests to regulate the carbon cycle therefore undermining efforts to mitigate climate change impacts and treaties that have been agreed to. Cambodia's target laid out in the country's Intended Nationally Determined Contribution (RGC 2014), to increase forest cover to 60% of Cambodia's land area, is unlikely to be achieved under this future development scenario, given the large forest losses by 2030 in one of the country's most densely forested provinces.
- The most significant losses in sediment and nutrient retention take place in this scenario as a result of the considerable forest loss. Significantly fewer trees upstream absorbing nutrients can increase the amount of nitrogen and phosphorus in water channels downstream. This increase in nutrients entering water supplies and higher rates of sedimentation can lead to diminished water quality. Increased sediment also increases the risk of flooding and can affect the fertility of the top soil on which farmers depend for agriculture. Therefore the security of local livelihoods is at increased risk due to the high forest loss.

Figure xiii: The changes of combined ecosystem services from baseline to each future

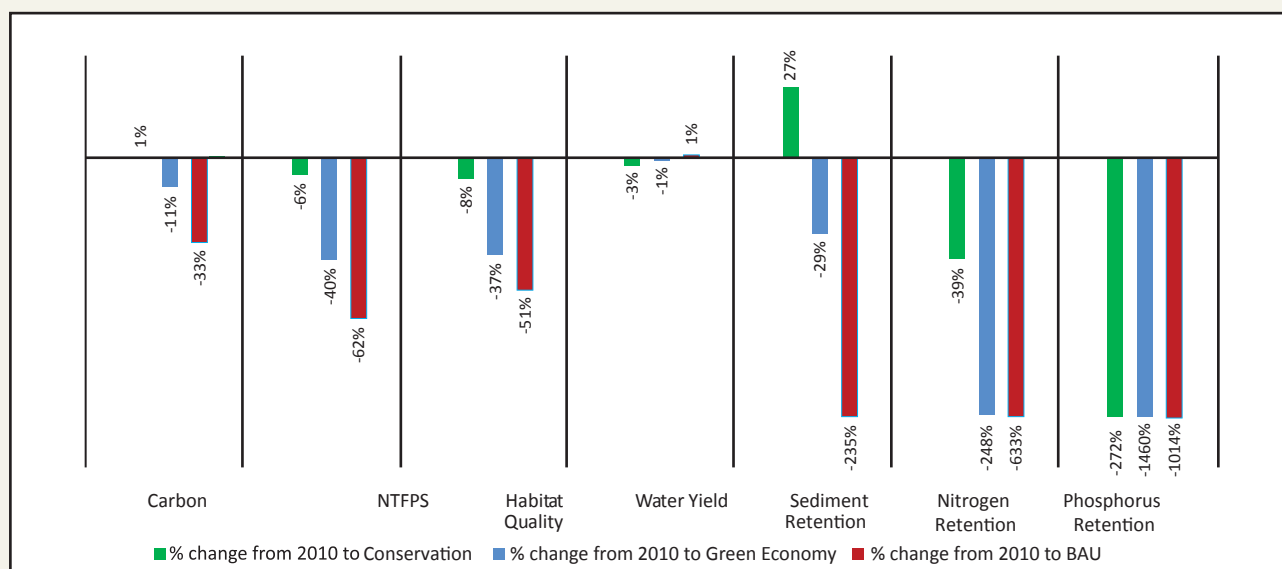
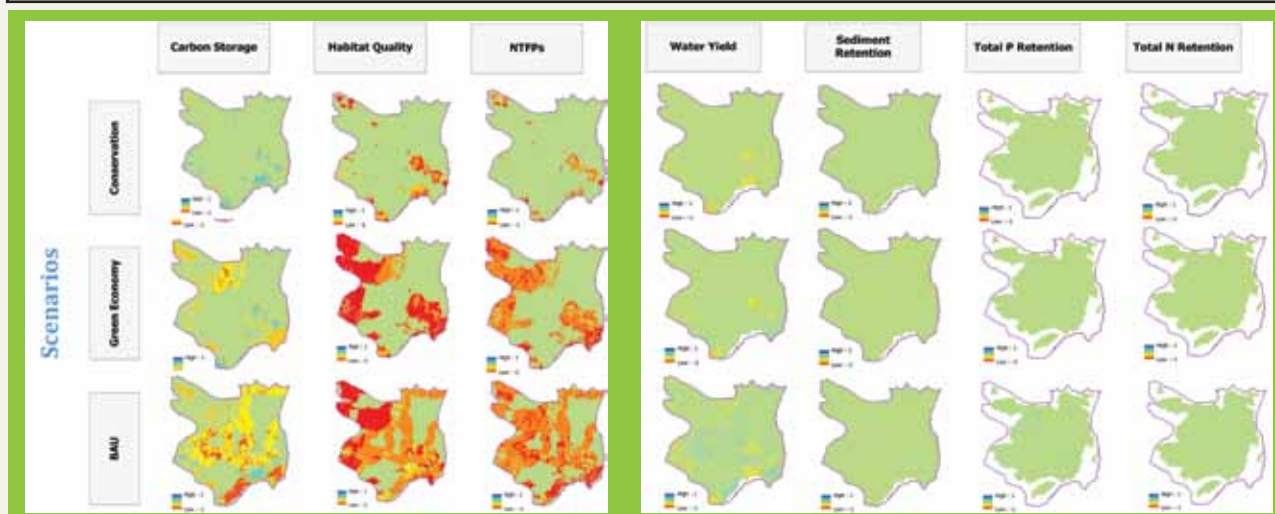


Figure xiv: Maps of relative changes (gains/losses) in carbon storage, habitat quality, NTFPs, water yield and sediment export for each future scenario



Economic valuation results

An economic valuation of carbon storage, NTFPs and water yield was carried out, both for each ecosystem services and as a combination of all three. Table i reports the difference in the annual value of forest ecosystem services in 2030 relative to their annual value in 2010.

Once the three ecosystem services were aggregated and assigned an economic value, the results show that their economic value changes between 2010 and 2030 under each different development scenario. By 2030, under the Conservation scenario, there is an increase in the value of the three combined ecosystem services of approximately US \$14.5 million. By 2030, under a Green Economy scenario, the reduction of ecosystem services (as a result of some forest loss) amounts to a loss of US \$370 million to the economy. The most severe loss in ecosystem services comes under the BAU scenario which sees a loss in ecosystem services worth US \$1.1 billion. Losses under a BAU scenario are approximately three times greater than under a GE scenario.

The increase in the value of ecosystem services in 2030 under a Conservation scenario is as a result of an increase in planned rubber plantations which increase the carbon storage in the province by 2030 relative to 2010; but the provision of NTFPs and water have decreased in 2030. GE sees economic losses in all three ecosystem services in 2030 as a result of land use change. The BAU scenario, which has considerably more agriculture and high rates of deforestation than the other scenarios results in the highest economic losses, which is likely to affect the local populations the most. The aggregated annual values of the three categories of ecosystem services are represented in Table i.

Table i. Changes in economic values of ecosystem services in 2030 relative to 2010 (USD, in 000s)

	Conservation scenario	Green Economy scenario	Business As Usual scenario
NTFPs	-3,551	-10,685	-21,479
Water yield	-1,303	-6,001	-6,827
Carbon (Social Cost of Carbon) ³	+19,350	360,250	-1,067,250
Total	+14,496	-376,936	-1,095,556

Table ii Potential value of marketed carbon credits from avoided carbon emissions, in 2030 relative to 2010 (in million tonnes of CO₂)

Value of carbon stored	Conservation scenario	Green Economy scenario	Business As Usual scenario
Saleable volume of carbon credits ⁴	74	48	0

³ The social cost of climate change reflects the damage caused by climate change due to additional carbon dioxide emissions. It is an estimate of the global damage/cost of climate change

⁴ Using the assumption that 20% of 'additional' carbon storage can be sold. Additional carbon is assessed relative to the BAU scenario.

Both the Conservation and GE scenarios result in large quantities of additional stored carbon, as Table ii shows. Using a conservative assumption that only 20% of additional stored carbon could be credited and sold in carbon markets, it is estimated that 74 million tonnes of CO₂ could be sold under the Conservation scenario; 48 million tonnes of CO₂ under a Green Economy scenario; but no carbon credits can be sold in 2030 under a BAU scenario, as summarized in Table ii. Therefore, for the period 2010-2030, the corresponding net revenues from crediting and selling stored carbon are \$536 million, under a Conservation scenario, and \$348 million, under a GE scenario. The Conservation scenario results in an increase in stored carbon in 2030 relative to the baseline in 2010. This removal of from the atmosphere has a value of US\$387 million. When the social cost of carbon is taken into consideration, which estimates the global cost of climate change, there are large losses of stored carbon under the GE and BAU scenarios. The damages associated with these large losses are estimated to be US\$7 and US\$21 billion respectively.

The sum of the annual value of NTFPs under the baseline scenario, or the total amount that NTFPs contributed to the Cambodian economy in 2010, is almost US\$26 million and this is predicted to fall to US\$10.6 million in 2030 under the BAU scenario. Under the baseline scenario, NTFPs represent an annual household income of 58% of mean household income. Under the BAU scenario, by 2030, the value of NTFPs reduces to only 24%. If households have no alternative livelihoods to make up that loss, then the reduction in incomes will increase poverty levels and worsen the vulnerability levels of already vulnerable communities.

Forests play a pivotal role in the regulation of water yield. Therefore, the estimated value function for water yield regulation by tropical forests was calculated under each future scenario. For water yield, A meta-analytic value transfer method was used to determine the values. The findings showed that the mean and median value of water yield per hectare of forest is higher under the GE and BAU scenarios, than the Conservation scenario. This is driven by the effect of scarcity on the value of water yield. As the forests decrease, the marginal value (per ha) of remaining forest increases. The loss in total annual value of water yield relative to the baseline is nevertheless much higher under the BAU and GE scenarios, as Table ii shows. Almost \$7 million per year is lost under BAU scenario.

Table iii: Annual value of water yield in 2030

	CN	GE	BAU
Mean (US\$/ha)	+88	+115	+123
Median (US\$/ha)	+72	+95	+103
Change in total annual value ⁵ (US\$; 000s)	-1,303	-6,001	-6,827

Losses in NTFP availability and water yield have a direct impact on local households as they currently represent a large proportion of household income. Under the BAU scenario, the reduction in the availability of NTFPs and water yield are equivalent to losing approximately 50% of household income. The loss of these ecosystem services will result in large reductions in household welfare in Mondulkiri.

Policy Recommendations for Decision Makers



The overarching policy recommendation resulting from the Mondulkiri ecosystem service assessment and policy analysis is for the RGC to adopt the Green Economy trajectory. Moving towards a Green Economy, which takes into account tradeoffs between conservation and development, involves the protection of geographical areas that are 'hotspots' for ecosystem services and involves enabling economic development activities to take place outside of these 'hotspots'. It will enable the country to be more resilient and sustain the continued benefits ecosystem services provide to local populations, citizens of Cambodia and people around the world. A GE pathway can enhance Cambodia's climate change preparedness, reduce social inequalities and income disparities, and ensure the country maintains its regional competitiveness.

⁵ Change in total annual value is computed relative to the baseline level of service provision

A Green Economy approach to development provides a more sustainable growth pattern and is aligned with government policies, notably Cambodia's NSDP 2014-18 (RGC 2013a); National Policy and Strategic Plan on Green Growth (2013b); and the National Green Growth Roadmap (2013c).

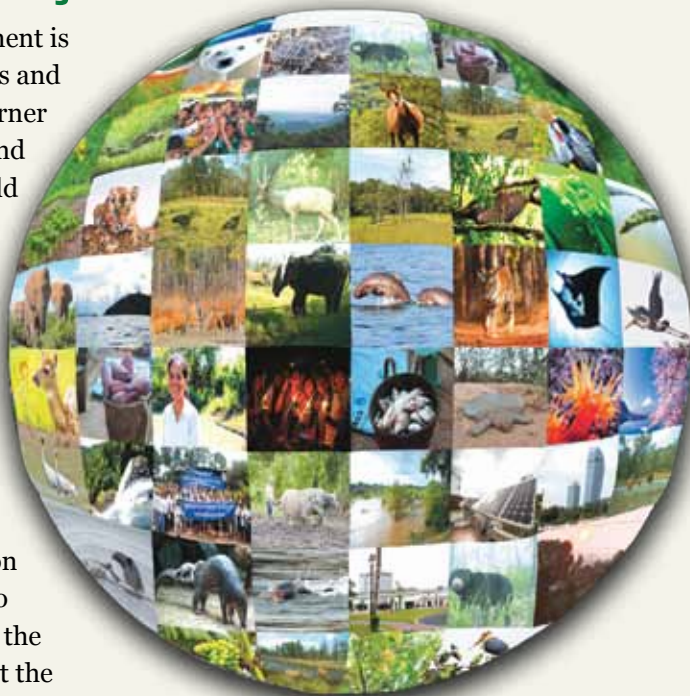
A GE approach requires:

- 1) ecosystem-based land use planning and management;
- 2) improved governance; and
- 3) sustainable sources of finance.

Ecosystem-based land use planning and management

Ecosystem-based land use planning and management is designed to protect and conserve natural resources and facilitate environmental restoration (Cohn and Lerner 2003). The process encourages decision makers and stakeholders to agree on which areas of land should be set aside for conservation and which set aside for economic development activities. This in turn helps to achieve a balance between keeping protected areas intact for conservation and areas designated for development.

This approach can provide an important platform to facilitate a balanced and green development pathway for Mondulkiri. Viewing the province through an ecosystem lens allows decision makers to make informed decisions on how best to sustain ecosystem services, sources of livelihoods, the continued regulation of climate and soil cycles that the country's natural forests provide. It can improve decisions around land use planning and result in a better balance between environmental protection and development in Cambodia. It also provides PA managers with a strong mandate to protect and maintain the valuable ecosystem services within a region and shows how these services are critically linked to the economic performance of small holders and private sector outside the PAs.



RECOMMENDATION: GOVERNMENT ADOPTS ECOSYSTEM-BASED MANAGEMENT AND PLANNING AT THE PROVINCIAL LEVEL. THIS WILL BE UNDERPINNED BY ECOSYSTEM SERVICE MAPPING; CAPACITY BUILDING; INCORPORATE FINDINGS OF THE MAPPING INTO SPATIAL PLANNING; AND PRACTICE MONITORING AND LAW ENFORCEMENT.

Ecosystem services assessments and valuations are ideal for incorporating into spatial and land use planning processes at commune, district and provincial levels. These can support decision-makers to better balance economic growth and human wellbeing.

Most businesses greatly depend on natural capital, for example, the supply of freshwater is vital for manufacturing, or the flooding control forests provide is important in the protection of facilities from flooding or erosion. The private sector should be encouraged to assess their impacts and dependencies on natural capital and incorporate these considerations into internal decision-making, and as stakeholders in spatial planning. Legal obligations for businesses to undertake these types of assessments would support the strengthening of ecosystems so fundamental for economic prosperity.

The Natural Capital Protocol, is a standardized framework for natural capital assessments that aims to support business managers to inform their decisions by discussing how we interact with nature or more specifically natural capital. It allows businesses to measure, value and integrate natural capital into their existing business processes.⁶

Strengthened Governance

Transparency, accountability and equity in natural resources governance strengthen the rule of law and empower marginalized communities. Efforts are required to strengthen governance at national and local levels to ensure that laws are effectively implemented which will maintain the natural forests in PAs that provide the benefits humans need to survive. Greater emphasis on law enforcement in Protected Areas is needed to reduce illegal logging and hunting activities in forests. Officials should work across Ministries and across levels of governance to also address the different drivers of deforestation. Strong and effective law enforcement would help in creating an improved governance environment that would promote responsible and sustainable private investments, respecting the interests of the local communities and forests. Effective governance requires collaboration from all stakeholders from national to commune level, as well as support from local communities. Raising the awareness of local communities on the consequences of deforestation and promoting sustainable livelihoods reduces the incentive at the local level to undertake illegal logging. Therefore more accountable and participatory governance will improve land use and sustainable natural resources management.

The cornerstone of successful ecosystem-based planning and management processes is participation from key stakeholders to ensure shared ownership and consensus among diverse interest groups. By having a collaborative approach to land use planning, this can: help raise awareness of the environmental challenges and laws among all stakeholders; lead to the mediation or resolution of disputed land claims; provide a forum to develop and strengthen PA management plans to ensure they take into consideration the needs of local populations residing in the landscape; lead to greater buy-in and increased respect for the plans decided upon; and lead to more effective implementation of plans as all stakeholders have taken part in the planning process.

Economic development activities should be confined to areas outside of PAs. In addition, Environmental Impact Assessments also need to take ecosystem services into consideration in order to improve land use planning and balance economic development and conservation. A key step in the EIA process is to mitigate project impacts on the benefits provided by ecosystems to at least achieve no loss in these benefits by affected stakeholders, and to manage dependencies of the project on priority ecosystem services. There is a need to develop mitigation measures to mitigate loss and enhance gain in ecosystem services benefits. However if these measures are considered insufficient, the following 4-step mitigation hierarchy should be applied to ecosystem services: 1. Avoid an impact altogether by not taking a certain action or parts of an action; 2. Minimize impacts by limiting the degree or magnitude of the action and its implementation; 3. Reduce preservation and maintenance operations on-site during the life of the action; 4. Impacts that can't be addressed by any previous steps, can be addressed by replacing or providing substitute resources or environments that offset the impact on ecosystem services (WRI 2013; Tallis, Wolny and Lozano 2011; McKenzie, no date).

Sustainable Financing Mechanisms

To support the Royal Government of Cambodia in improving the management of natural forests and sustain the benefits provided by ecosystem services, the government is encouraged to identify and promote sustainable financing mechanisms for the effective management and protection of Protected Areas. Some examples of these include: ecotourism, community-based enterprises dependent on NTFPs, REDD+, voluntary carbon markets, etc. Such opportunities could provide national, subnational and local stakeholders more incentives to protect these important 'hotspots' of ecosystem services sustaining the benefits provided by them.

⁶ Interested stakeholders can visit the following website for more information
<http://www.naturalcapitalcoalition.org/natural-capital-protocol.html>

The first carbon credits from a climate change mitigation project in Keo Seima Wildlife Sanctuary, Mondulkiri (WCS 2016), could be the first of many such initiatives that tap into existing voluntary carbon markets in efforts to protect Mondulkiri's forests.

It is recommended that the private sector be held to account if their activities impact negatively on the surrounding area. To ensure that the due compensation is provided to mitigate the impacts of any environmentally harmful activities, companies should be incentivized to participate in sustainable financing mechanisms, such as payment for ecosystem services, trust funds, conservation offsets, etc., through command and control regulation or the creation of market-driven motives.

Why Green Economy?

WWF Cambodia recommends the integration of the Green Economy scenario in Mondulkiri's land use and spatial planning process as this scenario strikes a balance between conservation – protecting the areas in which there is the largest amount of ecosystem services – and economic development.

Mondulkiri in 2030 under a BAU scenario sees a province with considerably fewer natural forests and consequently fewer ecosystem services that contribute to the wellbeing and livelihoods of local households. Therefore the landscape is drastically changed and, if nothing is done to replace the lost ecosystem services, the landscape will be less resilient in coping with the increased risk of floods and longer droughts; and local people will be using water that is likely to be contaminated and harmful to fish, other aquatic life and human health. To mitigate the negative impacts is likely to be costly and less effective than the beneficial services natural forests provide for free. The Conservation scenario would result in more tree cover, natural resources, ecosystem services and more suitable areas for wildlife species compared with the other two scenarios (provided these forests are well managed and law enforcement is strengthened). The GE scenario allows for the maintenance of trees in PAs (with strengthened governance, sustainable finance mechanisms etc.) while also enabling economic development outside of PAs to meet economic demands such as an increased demand for rice due to a rising population. Therefore the GE scenario allows for a more strategic and balanced economic development trajectory. Through integrated, evidence-based planning processes, more sustainable approaches to development are possible.

The Green Economy scenario seeks to minimize losses to ecosystems services by conserving protected areas and enabling economic development and food security in the productive parts of the landscape. In addition, the Green Economy scenario ensures structural connectivity of forest habitat, vital for wildlife corridors, without compromising the province's ability to develop and generate jobs. Evidently the PAs form the backbone of ecosystem services across the province. It is imperative therefore to ensure they are supported with best practice management, species protection, law enforcement, and that local and national populations continue to receive the environmental services provided by them. The value of the PAs for their provision of clean water, climate regulation, biodiversity, recreational values, non-timber forest products and services vital for agriculture and development has been made clear in this scientific assessment. Under a GE scenario, natural capital remains a critical enabler of growth, and development takes place but not at the expense of important sources of ecosystem services. This evidence-based scientific assessment and recommendations can inform land use planning and economic development decisions and support the transition to a greener and more sustainable economy, helping Cambodia in achieving its INDC and Sustainable Development Goals.

2. ABBREVIATIONS

ARIES	ARtificial Intelligence for Ecosystem Services
BAU	Business as Usual
BL	Baseline (scenario)
BMZ	Bundesministerium Für Wirtschaftliche Zusammenarbeit (German Federal Ministry for Economic Development Cooperation)
CBNRM	Community Based Natural Resource Management
CBOs	Community Based Organizations
CF	Community Forestry
CFis	Community Fisheries
CN	Conservation Scenario
CPAs	Community Protected Areas
D&D	Decentralization and Deconcentration
ELCs	Economic Land Concessions
EPL	Eastern Plains Landscape
EU	European Union
FCs	Forest Concessions
GE	Green Economy
GIS	Geographic Information System
GIZ	German Development Corporation
INDC	Intended Nationally Determined Contribution
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
LULC	Land Use and Land Cover
MAFF	Ministry of Agriculture, Forestry and Fisheries
MCs	Mining Concessions
MDK	Mondulkiri
MoE	Ministry of Environment
MPF	Mondulkiri Protected Forest
NGOs	Non-Governmental Organizations
NRM	Natural Resources Management
NSDP	National Strategic Development Plan 2014-2018
NTFPs	Non-Timber Forest Products
PAs	Protected Areas
PPWS	Phnom Prich Wildlife Sanctuary
PWS	Payment for Watershed Services
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RGC	Royal Government of Cambodia
RUPP	Royal University of Phnom Penh
SLCs	Social Land Concessions
SPF	Seima Protected Forest
USAID	US Agency for International Development
WWF	Worldwide Fund for Nature

3. INTRODUCTION



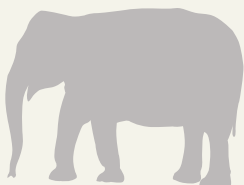
Cambodia is a country rich in natural resources that sustain the wellbeing of the nation's population and contribute to the country's economy. It has the largest areas of contiguous and intact forests in mainland Southeast Asia. Millions of people in Cambodia, many rural and poor, depend directly on the natural environment for their daily basic food, water, energy needs and income generation. All Cambodians depend on the country's forests to: regulate the water and soil cycles; provide protection against floods; storm protection; recreational benefits and tourism revenues. All of these benefits are known as ecosystem services which are the goods and services nature provides us for free and are essential for life support processes (Millennium Ecosystem Assessment 2005). These services however are threatened by continued deforestation driven by large-scale infrastructure projects, timber production, illegal logging, mining projects, and other development activities.



Economic growth is essential for the country to develop. However economic growth at the expense of natural resources and ecosystem services is unsustainable, weakening the functioning of the country's ecosystems and increasing vulnerability among the poorest communities. WWF Cambodia therefore recommends an ecosystem approach to land use planning to ensure that development projects take place outside of areas of critical ecological importance thus preventing economic activities from undermining the functioning of ecosystems. With the generous support of the European Union and USAID and in collaboration with the Royal University of Phnom Penh, WWF Cambodia has conducted a study in the densely forested province of Mondulkiri to highlight the location and value of the province's key ecosystem services with a view to integrate ecosystem services into land use and spatial planning decisions.



The RGC's National Spatial Planning Policy aims to address land use challenges and ensure that land and natural resources are used and managed in a sustainable, effective and equitable manner to support socio-economic development, food security, national defense and natural balance (RGC 2011). Without effective land management planning and integrated land use plans, it is likely that: encroachment into Protected Areas (PAs); unsustainable exploitation of forests and fisheries; and poor water management, will become exacerbated. The poorest are likely to be most severely affected (Diepart 2008) however Cambodia's economy too is also likely to be impacted as the country depends on natural resources for economic development and tourism.



As recognized in the NSDP 2014-18, there is a need to better manage PAs and a need for more information on biodiversity and natural resources. The RGC has demonstrated its willingness and commitment to work towards sustainable development, as evidenced in the National Policy and Strategic Plan on Green Growth (2013b) and the National Green Growth Roadmap (2013c) and the current efforts to develop an Environmental Code (in development, 2016). Ecosystem-based management and planning can contribute to achieving sustainable development, defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987; Cohn and Lerner 2003).



A set of tools called InVEST (which stands for Integrated Valuation of Ecosystem Services and Tradeoffs) was used to spatially map and economically value different ecosystem services in the Mondulkiri province as part of a natural capital assessment undertaken from June 2014 to September 2016. The overall objective of the project was to support policymaking and provide information useful for land use and spatial planning decisions. The specific objectives were to:

1. Produce baseline maps demonstrating the areas with the most priority ecosystem services (or 'hotspots' of priority ecosystem services) and areas with the least.
2. Assign an economic value to priority ecosystem services by carrying out an economic valuation of these ecosystem services; and
3. Provide insights on how priority ecosystem services could be affected by different interventions (policies / actions) in the future, by producing maps of these ecosystem services in 2030 according to different future scenarios.

The team produced maps, in pixels and by sub-watershed, of the following ecosystem services: carbon storage; non-timber forest products (NTFPs); habitat quality of wildlife; annual water yield; avoided nutrient pollution (or nutrient retention); and avoided sediment pollution (or sediment retention). Each priority ecosystem service studied was mapped and assigned an economic value under different future scenarios, which mapped how Mondulkiri would look in 2030 under a Conservation (or low deforestation) scenario, Green Economy (or moderate deforestation) scenario, and a Business as Usual (high deforestation) scenario.

The InVEST tool used for this report is part of a larger project - The Natural Capital Project - which is a joint venture of university institutions and NGOs. The Natural Capital Project develops science-based tools and approaches to map and quantify the value of ecosystem services and integrate this information into decisions. These tools can be used to inform decision making, land use planning processes and policymaking, with improved outcomes for people and ecosystems.

Quantifying, mapping and valuing ecosystem services provides an important scientific basis for developing land-use plans, policies, regulatory instruments and programmes for protection. Identifying the areas that provide the most (and least) ecosystem services could prove useful to policymakers in supporting the identification of zones as a basis of land use planning, as well as identifying environmental management zones, as promoted in the National Policy and Strategic Plan on Green Growth (RGC 2013b). This information can also be incorporated in provincial spatial plans. This approach of quantifying, mapping and valuing ecosystem services is already popular around the world and has been applied in countries such as China (Wang et al., 2015), Indonesia (Bhagabati et al., 2014), and Australia (Kragt and Robertson, 2014), and others.

Case Study: Assessing Natural Capital in China

In 2013, the CPC Central Committee announced a priority objective of making China an "Eco-civilisation" with greater measures for implementing and financing environmental protection and has since been exploring methods of incorporating environmental indicators and capital values into accounting frameworks (IUCN 2013).

In 2010, in China it was estimated by the Chinese Academy of Environmental Planning that environmental degradation was costing the economy around \$230 billion per year. Therefore a call for improved accounting for natural capital came from the top of China's administration. This has resulted in the designation of approximately 35% percent of China's land area as Ecological Function Conservation Areas (EFCAs), restricting or prohibiting the development of this land (Guerry et al. 2015). This area increased to 45% of China's land area in 2015. This is being implemented by China's National Development and Reform Commission and the Ministry of Environmental Protection. By investing in the local economy and providing alternative less destructive livelihoods (such as NTFP harvesting, conservation training and ecotourism pilot project creation), it is argued that the sunk costs of necessary biodiversity compensation payments will be reduced in the long term as the need for management and compensation will diminish with lower levels of damaging activity (Daily et al., 2013).

The pilot project in Mondulkiri aimed to integrate natural capital approaches in Cambodia. Participation from all the key stakeholders, including national and provincial level government officials, was at the heart of the highly collaborative work produced by WWF and RUPP for this report. The benefits of carrying out such ecosystem service assessments are that they provide a useful basis for identifying win-win solutions that meet development and conservation goals and they also underpin spatial planning for sustainable development within the region.

This report comes at a crucial time for Cambodia, as the natural resources found within the country are currently under threat and in decline. According to a report by the World Resources Institute (2015) using satellite images, forest loss in Cambodia accelerated at a faster rate than any other country in the world. The Royal Government of Cambodia has committed to increase forest cover to 60% of national land area by 2030, according to Cambodia's Intended Nationally Determined Contribution (INDC). It is therefore imperative to consider how forests underpin ecosystem service provision in Cambodia.

The report outlines the findings of the work carried out since June 2014, beginning with a geographical, socioeconomic and political contextual analysis, which provides an understanding as to why ecosystem services assessments and valuations are needed in Cambodia, particularly Mondulkiri province. The report presents the assessment, mapping and economic valuation made for six key ecosystem services – carbon storage and sequestration, non-timber forest products (NTFPs), annual water yield, sediment retention, nutrient retention and wildlife habitat quality (which used biodiversity as a proxy). In addition, it provides an overview on how these ecosystem services could be affected under three different development scenarios for 2030. The report concludes with policy recommendations and conclusions.



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4. GEOGRAPHICAL, SOCIOECONOMIC AND POLICY CONTEXT

4.1 Cambodia

Cambodia enjoys a rich per capita endowment of natural resources. Over 20% of the countryside is available for arable land; subsistence freshwater and coastal fishing is commonplace, with 4,520 km² of inland water and 443 km of coastline. Forests also span nearly 57% of Cambodia's landscape, approximately 100,613 km² – one of the highest endowments of forest cover in East Asia (CIA World Fact Book 2015). To achieve the sustainable development goals, the government has taken steps to ensure that all people, including local communities, have the right to development, especially through democratic governance of the country's natural resources.

Cambodia's Rectangular Strategy places good governance at its heart; Phase 3 of which involves multi-stakeholder collaboration, as well as integrated planning for strengthening long-term sustainable development. This strategy is aimed at stimulating green economic growth, job creation, and equitable and inclusive benefit sharing of development outputs; all of this, without compromising opportunities to ensure effective public institutions and sustainable management and conservation of natural resources.

Governance of land and natural resources include both centralized and decentralized governance models. The centralized state-based governance model involves allocating specific plots of environmentally significant areas for exclusive conservation (i.e. protected area system). Cambodia's protected area system includes seven national parks (742,250 ha), ten wildlife sanctuaries (2,030,000 ha), three protected landscapes (9,700 ha), six protection forests (1,350,000 ha) and eight fish sanctuaries (23,544 ha). As well as this, Cambodia has 3 sites designated as 'Wetlands of International Importance', with a total surface area of 54,600 ha. The Royal Government of Cambodia (RGC) has introduced a wide range of policy and regulatory frameworks supporting land and natural resource management (NRM), a sample of laws and policies on which can be found in Box 1 below.



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Box 1: Key Policies and Laws related to natural resource management

National Policy and Strategic Plan on Green Growth 2013-2030 (2013) formulated with key directions on green investment and green job creation, green economy development in balance with environment, green environment and natural resource management, and good governance on green growth.

Forestry Law (2002, amended in 2006 and then again in 2010) aims to improve the framework for management, harvest, use, development, conservation and preservation of Cambodia's forests and NTFPs. Sustainable management of forests and their socio-economic and environmental benefits, including conservation of biodiversity and cultural heritage are placed as the core objectives of this law.

National Forest Program (NFP) 2010-2029 (2010) was issued in 2010 with an aim to secure forest cover at 60% of Cambodia's total land area.

Protected Area Law (2008) provides guidance for managing conservation of biodiversity and sustainable use of natural resources within protected areas in Cambodia, as well as defines categories for management zones in the protected areas.

National Biodiversity Strategy and Action Plan (2002) the three main objectives are: the conservation of biodiversity; the sustainable use of natural resources and; equitable sharing of benefits resulting from the use of genetic resources.

Law on Environmental Protection and Natural Resources (2001) outlines provisions and procedures for creating national and regional action plans based on identified environmental priorities and protection of natural resources through consultation with other relevant ministries.

In addition to state-based conservation regimes, the RGC encourages the transfer of some of the decision making powers of the government at national level to sub-national institutions at provincial, district, city, commune and village levels. To achieve effective decentralization of resource governance the full participation of the entire population is required, as well as active partnerships of various actors: national and local government; non-governmental government (NGOs), community-based organizations (CBOs); and private corporations.

Commercial exploitation of land and natural resources is typically granted through concessions by the state, rather than the outright transfer of ownership. Concessions are the rights to use land or natural resources granted by the government. The policies and laws stated in Box 1 above can affect the temporal and regional distribution of these land concessions within Cambodia. The concessions granted can include forest concessions (FCs) for timber, economic land concessions (ELCs) for agribusiness and mining concessions (MCs). The establishment of the land concession system as part of the country's land reform policy has strongly affected land use change and integrated spatial planning in recent decades. Current ELCs, FCs, and MCs in Mondulakiri are considered as a negative change agent that can also lead to economic threats for the entire province if performed poorly or differently from the RGC's development and operation plans.

In addition to this, there is no common approach for monitoring or managing ELCs. Different Ministries use different forest cover maps, which results in a lack of institutional coordination. More coordination and systematic processes are needed to improve environmental management. It is hoped that the Environmental Code (in development) will go some way to achieve this.

In Cambodia, there is currently no systematic framework in place to assess the cumulative environmental and social (economic and non-economic) impacts of hydropower and other infrastructure projects, (for example irrigation schemes, or mining operations), or to consider these objectively against the expected benefits. Environmental and social impact assessment procedures have tended not to consider the cumulative impacts on ecosystem services; such as the maintenance of fisheries' habitats and migration routes through riverine and floodplain connectivity. They also tend not to consider the social and economic implications for communities beyond the immediate project area. As a result of a lack of assessments of project impacts on the wider ecosystem and broader population, and a failure to engage these communities in reviewing and voicing their interests before investment decisions are finalized, there are serious gaps in stakeholder representation and science-based information.

There is also concern for the forests and forestlands in concession areas, which have often been cleared with no consideration for their natural value. Extensive exercises of forestland clearance and conversion into high-commercial agricultural lands have painfully negative environmental consequences on soil erosion and fertility as well as the quantity and quality of surface water and groundwater, biodiversity resources, and other ecosystem services that benefit the people of Mondulakiri and of Cambodia as a whole.

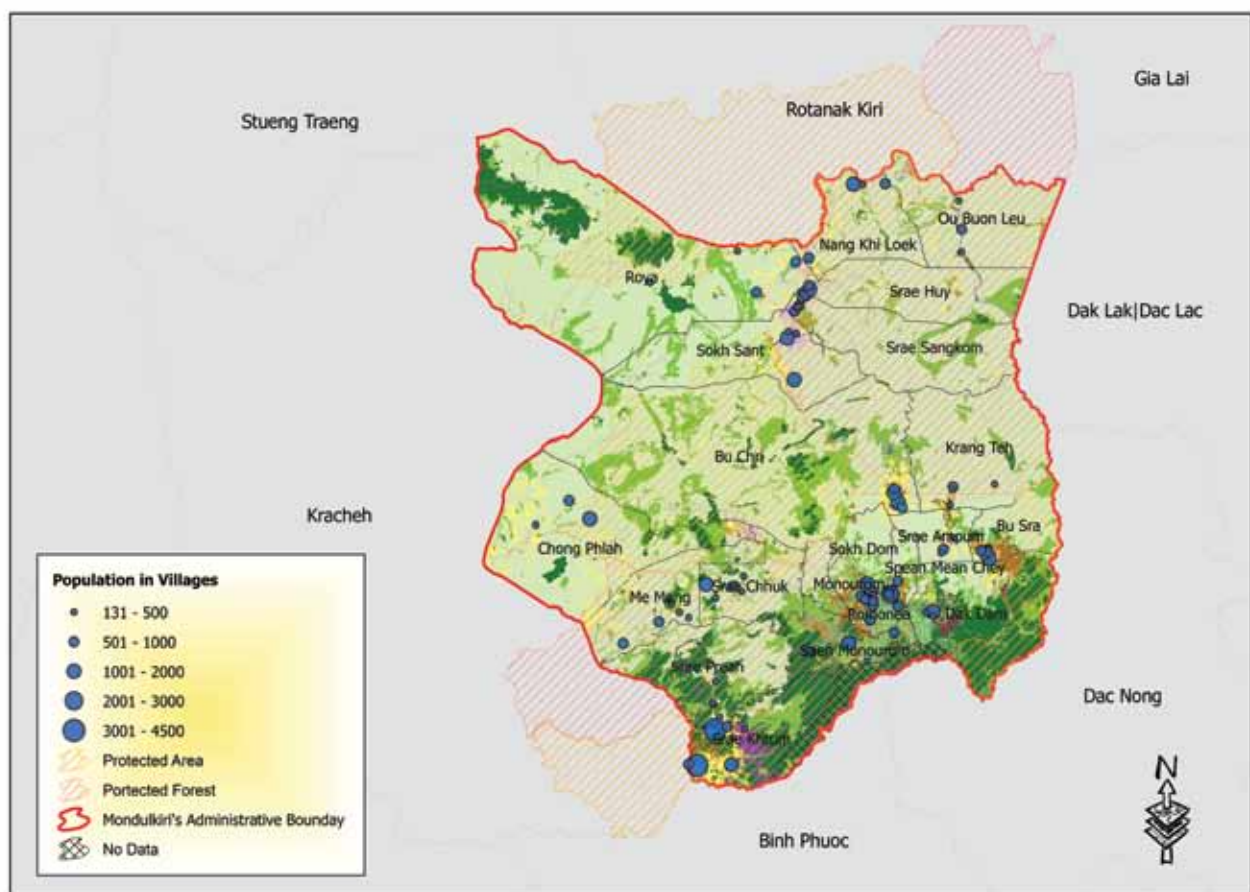
The increase in forest clearance has also resulted in clashes with communities of indigenous people who reside in these landscapes and who rely on these valuable ecosystem services for food, water and livelihoods. The result of this forest clearance has at times been land conflict and involuntary or forced resettlement / eviction of such communities as well as denied access to tenure rights over land and natural resources. Recognizing these social and environmental challenges, the Cambodian government put in place more decentralized land and resource governance systems that support the direct conservation of common-pool resources and community-based management (e.g. PAs, Community Forestry (CF) and Community Fisheries (CFi) etc.) including communal land titles for indigenous communities. But according to a report published by WorldFish in 2010, the process to apply to establish a community forest is lengthy (it involves 12 steps, each step can take a year) and it costs around \$55,000 to establish a CF (according to data from the Forestry Administration Department, MAFF). The process needs to be reevaluated and simplified in order to open it up as a viable option for the communities that require it the most.

Continued overexploitation at the current scope and scale of rapid macroeconomic development will undermine future socio-economic development, increase greenhouse gas emissions, and could lead to the rapid decline of the country's natural capital stocks; it may also induce social unrest and instability. To reduce overexploitation of natural resources, the Land Law needs to be more effectively implemented. It already includes protections for indigenous people's rights to the territories they have traditionally used and inhabited, though these are routinely disregarded in practice. The effectiveness of enforcement in the forestry sector depends significantly on the performance of forestry officials or their collaboration with community members. There are currently too few forest rangers to patrol all of the remote areas, so forestry officials need to communicate and negotiate with police and other local authorities for law enforcement to be effective. Forest rangers also require skills in facilitation and capacity building to support the CF, which is largely lacking. Community institutions require similar capacities, along with the ability to catalyze collective action in support of local management plans. Therefore poor law enforcement and challenges with community based natural resource management is contributing to environmental degradation and the loss of ecosystem services in Cambodia.

4.2 Mondulkiri

The Eastern Plains Landscape (EPL) is part of the Lower Mekong Dry Forest - the largest intact block of dry forest in Southeast Asia. There is a significant amount of deciduous forest (as indicated by the pale green that dominates the majority of the map in Figure 1) and evergreen forest (depicted in dark green on Figure 1). EPL harbors a large diversity of habitats, ranging from evergreen hills to open dry forest, and is also home to populations of many endangered species. The region is sparsely populated, with 67,305 people; five persons/km². Therefore the area offers the unique opportunity to secure its forest biodiversity at the landscape scale.

Figure 1: Overview map of 2010 Land Use Land Cover data (MAFF 2011) overlaid with: PAs; provincial boundaries; and commune names and boundaries



Natural resources in the EPL are decreasing at an alarming rate. The forests and their rich biodiversity are under tremendous pressure from commercial land clearance, agricultural expansion and illegal trade in luxury wood and wildlife. The emphasis on economic development over environmental protection is taking its toll and if it continues on the current path, very little forest cover will remain in this area.

As a result of the state's emphasis on economic growth in recent decades and the strengthened nexus of the government-business sector, local communities in Mondulkiri

have been increasingly losing control over what they see as their local common pool resources. The majority of land and natural resources in Mondulkiri have been transformed from government-controlled, to private sector controlled in the form of long-term land leases, ELCs, MCs, and FCs. In recent years, most of the land and forest ecosystems that used to be managed by local communities have become the property of the state and state-allocated private sector companies, which has resulted in the marginalization and alienation of local communities.

In areas still managed by local communities through Community Protected Areas (CPA), CFs and CFIs, the discrepancies between indigenous local systems and government-imposed land and resource use have been the source of tensions and conflicts; this is mainly due to resource access and consumption (Neth, Knerr, and Rith, 2008). Current land disputes usually occur between large companies such as owners of rubber plantations and local indigenous people. It is a common occurrence that logging, mining, large-scale agribusiness plantations and other industrial companies have found it relatively easy to obtain large-scale concessions or even ownership over huge tracts of land. On the other hand, it is very difficult and time-consuming for local communities to try to regain rights over land and resources inside or in close proximity to their localities. It has been publicly accepted that current and future agricultural leases / land concessions and the mines in Mondulkiri may trigger an influx of outsiders. The low-skilled and unskilled local communities who have limited capacity will consequently be competing in new labor markets on what they consider to be their own land. Leaving out the voices of indigenous populations from decision making could result in unsustainable use of natural resources by local communities.

The Eastern Plains Landscape, in Mondulkiri province, is one of WWF's priority landscapes because it is rich in natural and wildlife resources, but also has a large number of land concessions. It is therefore a priority area to reduce the loss of natural habitats and ecosystem services. WWF adopts a landscape approach, i.e. a framework for making landscape level conservation decisions using top down planning and bottom up participatory approaches. This approach helps to reach decisions about the advisability of particular interventions and facilitates the planning, negotiation and implementation of activities across a whole landscape. WWF strongly supports efforts to increase equitable economic benefits from ecosystem-based management of forests through improving land use management and income generation opportunities from sustainable use and management of forest resources. Therefore WWF initiated two projects that will jointly support decision-makers to have access to fact-based information that would support them in their land use planning, as well as capacitate them to utilize and implement the information and plans effectively.

Two major projects in the EPL are supporting WWF Cambodia's green economy agenda: the USAID-funded project "Supporting Forests and Biodiversity" and the EU-funded project "Sustaining biodiversity, environmental and social benefits in the Protected Areas of the Eastern Plains Landscape". At the core of these two projects, WWF and RUPP have undertaken an ecosystem services assessment and valuation to map, quantify and value the ecosystem services in the region in order to empower decision makers to mainstream natural capital in their policies and specifically into land use planning in Mondulkiri.



5. WHAT IS ECOSYSTEM SERVICE MAPPING AND VALUATION?

5.1 Context and Explanation of Ecosystem Service Mapping and Valuation



Mapping and valuing ecosystem services provides an important scientific basis for developing land-use plans, policies, regulatory instruments and programmes for protection. Identifying the areas that provide the most (and least) ecosystem services could prove useful to policymakers in supporting the identification of zones as a basis of land use planning, as well as identifying environmental management zones, as promoted in the National Policy and Strategic Plan on Green Growth (RGC 2013b). This information can also be incorporated in provincial spatial plans.

Ecosystem services produce valuable benefits to society and to the local economy for example, the provision of clean water is useful for maintaining the health of fish populations which are important for nourishing humans and enabling supporting local livelihoods. Ecosystems in the Eastern Plains Landscape provide these valuable services for free but these benefits are under threat due to unsustainable land practices that could jeopardize the functioning of these ecosystems thereby reducing the services provided. Economic valuations are a way of assigning a value to these free public services that are under threat to make the economic case for investing in or supporting nature conservation to maintain these vital ecosystem services (Emerton and Aung 2013). Economic valuations can also be useful for justifying and setting priorities for programs, policies or actions that protect or restore ecosystems and their services (Goulder and Kennedy 2011). By neglecting to include ecosystem services in policy or land use planning decisions, the costs and benefits they provide are not adequately represented which results in an undervaluation of ecosystem services.

There are many different tools and methods available to identify, assess and value ecosystem services in any given region. Some examples of these tools include: ARIES (ARTificial Intelligence for Ecosystem Services), Ecosystem Services Review, Ecological Asset Inventory and Management, EcoMetrix and InVEST. These tools and science-based approaches can be used to inform decision making, land use planning and policymaking, with improved outcomes for people and ecosystems.

5.2 Context and Explanation of the InVEST Tool

The Natural Capital Project, a joint venture of university institutions and NGOs, developed InVEST, a science-based tool and approach, to map and quantify the value of ecosystem services in various parts of the world, with the objective of integrating this information into decisions.

InVEST stands for Integrated Valuation of Ecosystem Services and Trade-offs and is a suite of ecosystem service models that provide information on ecosystem services and how different plans and policies can affect the ecosystem services of a given area under current and future land use scenarios. These scenarios are developed in collaboration with key stakeholders to ensure an inclusive, participatory approach. Decision makers, at national and subnational levels, can assess the tradeoffs between alternative land use scenarios and identify where investments in ecosystem services can enhance both human development and conservation. InVEST helps decision-makers incorporate ecosystem services into a range of policy and planning contexts, including spatial planning, strategic environmental assessments and environmental impact assessments.

Governments, companies, non-profits, and multilateral development institutions that manage natural resources employ InVEST to evaluate the impact of their decisions on the environment and on human well-being, and to inform planning efforts. It can help support the development of ecosystem based spatial plans.

The Natural Capital Project, which developed InVEST, is a joint venture of Stanford University's Woods Institute for the Environment, University of Minnesota's Institute on the Environment, The Nature Conservancy, and WWF. It has been peer-reviewed and has an active community of more than 30,000 users. More information can be found on the Natural Capital Project website: <http://www.naturalcapitalproject.org/>

5.3 Introducing InVEST In Mondulkiri

InVEST was introduced in Cambodia in June 2014 as part of an initiative jointly funded by USAID and the EU. InVEST, the set of tools used to carry out this ecosystem services assessment and valuation, enabled the mapping and valuing of ecosystem services in Mondulkiri and capacity building of provincial level stakeholders to: understand, interpret and apply the results of this ecosystem services assessment and valuation; and, where possible, mainstream these outcomes into decision making concerning natural resource management, socio-economic development and land use planning.



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Currently, political trends toward promoting participatory governance and democratic development initiatives can be demonstrated by the implementation of the Decentralization and Deconcentration (D&D) policy (2008) and the collaborative process involved in the development of the Environmental Code (in process, 2016). It is observed that sub-national level stakeholders need the most engagement since they are both direct beneficiaries of the ecosystem services assessment and valuation outcomes and the decision-makers concerning project implementation in Mondulkiri and the EPL. Although, D&D reforms in Cambodia have not yet been fully implemented, especially true in the Protected Areas, WWF focused on engaging the provincial level government in order to build their understanding of the potential benefits of taking ecosystem services into account in decision-making and to obtain their support for ecosystem services assessments and valuations. Therefore WWF organized workshops to involve stakeholders, at national and provincial levels, in the scenario modeling process to create ownership through participation and mainstream results in national policies and legislation.

5.4 How Ecosystem Services Assessments and Valuations can Improve Management of Natural Resources in Mondulkiri

Unsustainable levels of resource use is diminishing the supply of natural resources, on which the economy and human wellbeing depend. More integrated and coordinated approaches to planning and natural resources governance is needed to overcome this challenge. Ecosystem services assessments and valuations can provide useful, evidence-based information in the form of spatial maps that can support and improve the management of natural resources at national and/or subnational levels.

Ecosystem services assessments and valuations enable users to quantify, visualize and compare the delivery of ecosystem services under different scenarios of land, water, and marine uses. Model outputs can describe natural resources in terms of their biophysical supply, the services they provide humans, or their projected value. It empowers users to account for ecosystem services in their decisions and preserve the benefits they provide to human wellbeing. Decision-making can be enhanced through the identification of different management options or interventions e.g. decision makers can develop future scenarios to illustrate alternative or additional areas where forest Protected Areas should be established. They can also develop scenarios where existing PAs or PFs might be converted to commercial plantation or residential areas, or even where climate change is expected to affect precipitation and temperature patterns. In short, InVEST can be used to support land use and economic development decision / policy-making that could help to:

1. Identify what ecosystem services are providing benefits to local populations in the Eastern Plains Landscape and Mondulkiri;
2. Estimate the value of these services to local populations and economies;
3. Provide insights on how priority ecosystem services may be affected by different policy interventions, e.g. land use planning, improved management regimes in forest areas; and
4. Inform efforts to develop livelihoods and benefit-sharing mechanisms that will be supported by conservation activities in the Eastern Plains Landscape.

At present in Cambodia, the barriers to effective environmental governance and economic development include: limited stakeholder participation and representation in policy implementation; institutional capacity limitations; and limited integrated mechanisms to value both economic and non-economic values of natural resources and the holistic ecosystem prior to decision making regarding conservation or development decisions. InVEST can help solve the last of these challenges and - if used in an iterative process of engagement with stakeholders, researchers and decision-makers – can also be part of addressing the other barriers.

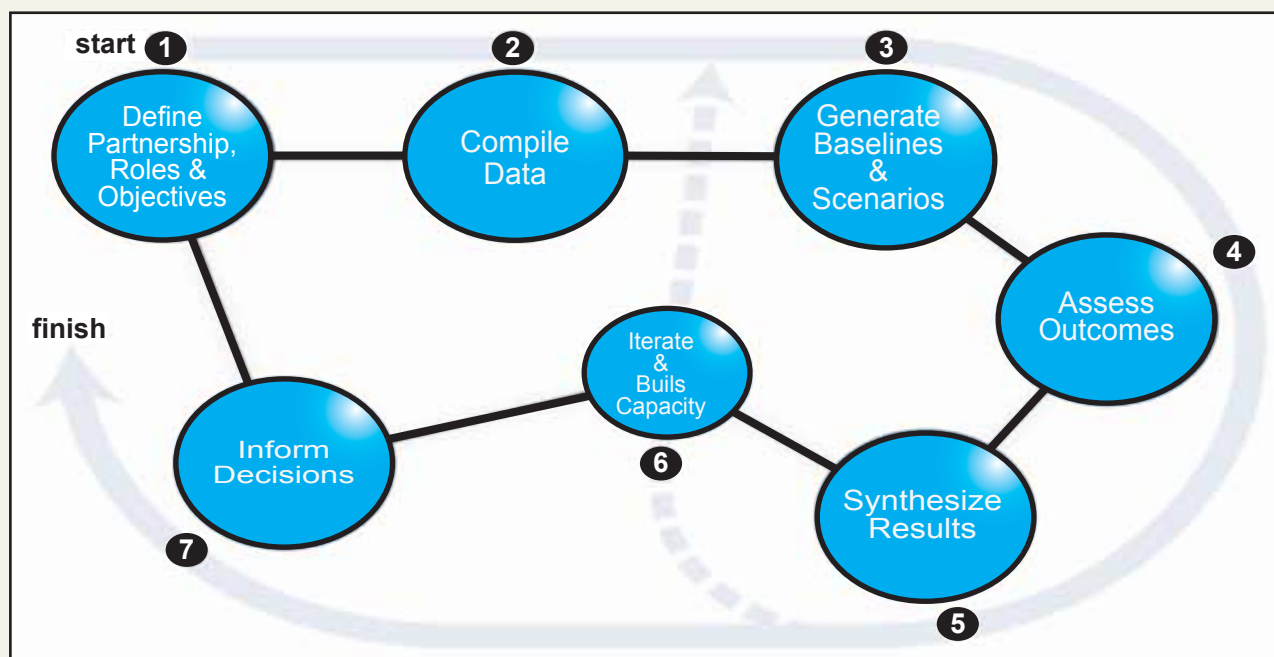
Firstly, **the process is collaborative** (see Figure 2). Implementation of InVEST requires a platform for initially developing a holistic structured decision framework and ensuring multi-stakeholder approaches. This collaborative platform starts with the data identification stage, and the formation of a working group. This working group is formed by bringing relevant stakeholders together to work hand-in-hand across a range of expertise and authority, until the very last stage of the process. Results can easily be shared with stakeholders and policymakers to inform upcoming decisions. The core working group could voice their concerns and provide feedback on the projected scenarios. InVEST is used most effectively as an iterative process; users may choose to create new scenarios based on model results and improve data sources until suitable solutions are identified.

When InVEST was brought to Mondulkiri province, a capacity building workshop was initially conducted by experts from the Natural Capital Project. The stakeholders involved in this workshop felt empowered and engaged to absorb the natural capital assessment process and understand how it would work in the province. This engagement motivated many to consider the current status of development in Mondulkiri and contemplate solutions, chosen by decision-makers and policymakers, which could mitigate impacts and produce a more sustainable path to development.



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Figure 2: The Ecosystem Services Assessment and Valuation Process using InVEST



Secondly, ***InVEST provides up-to-date scientific information on qualitative, quantitative and, in some cases, monetary values for ecosystem services.*** Cross-governance issues in the province remain unresolved. This leads to a lack of collective objectives due to a disparity of interests among relevant institutions. This lack of coordination and the fragmentation of stakeholders' interests will remain unless clear scientific information on ecosystem services are valued and integrated into future decisions for the province as a whole. Effective and wide-ranging valuations of ecosystem services increase the likelihood of more rigorous and well-informed decisions regarding conservation and development. Quantifying ecosystem services and integrating them into decisions is likely to reduce the transactional cost of policies, reduce the amount of unintended risks, consequences and surprises and promote greater equity.

Thirdly, ***the use of specific scientific data produced by InVEST in provincial spatial land use planning, could contribute significantly to determining the ideal locations for conservation and development activities.*** It could help, for instance, choose more suitable areas where the local indigenous populations can benefit from NTFPs and traditional customs the most, and where large-scale economic development projects would be most profitable. These projects often occur in areas with a high concentration of ecosystem services, areas that indigenous peoples rely on to continue to practice their traditional way of life. Degradation of forest resources and land clearance results in soil fertility run-off and biodiversity loss, which is the foundation of local communities' livelihoods and culture. In response to such conflict for resources, ecosystem services assessments and valuations could help decision-makers choose the most suitable location for large scale economic development projects so that the project avoids negatively impacting the ecosystem services, which the local communities and the general population, depend on.

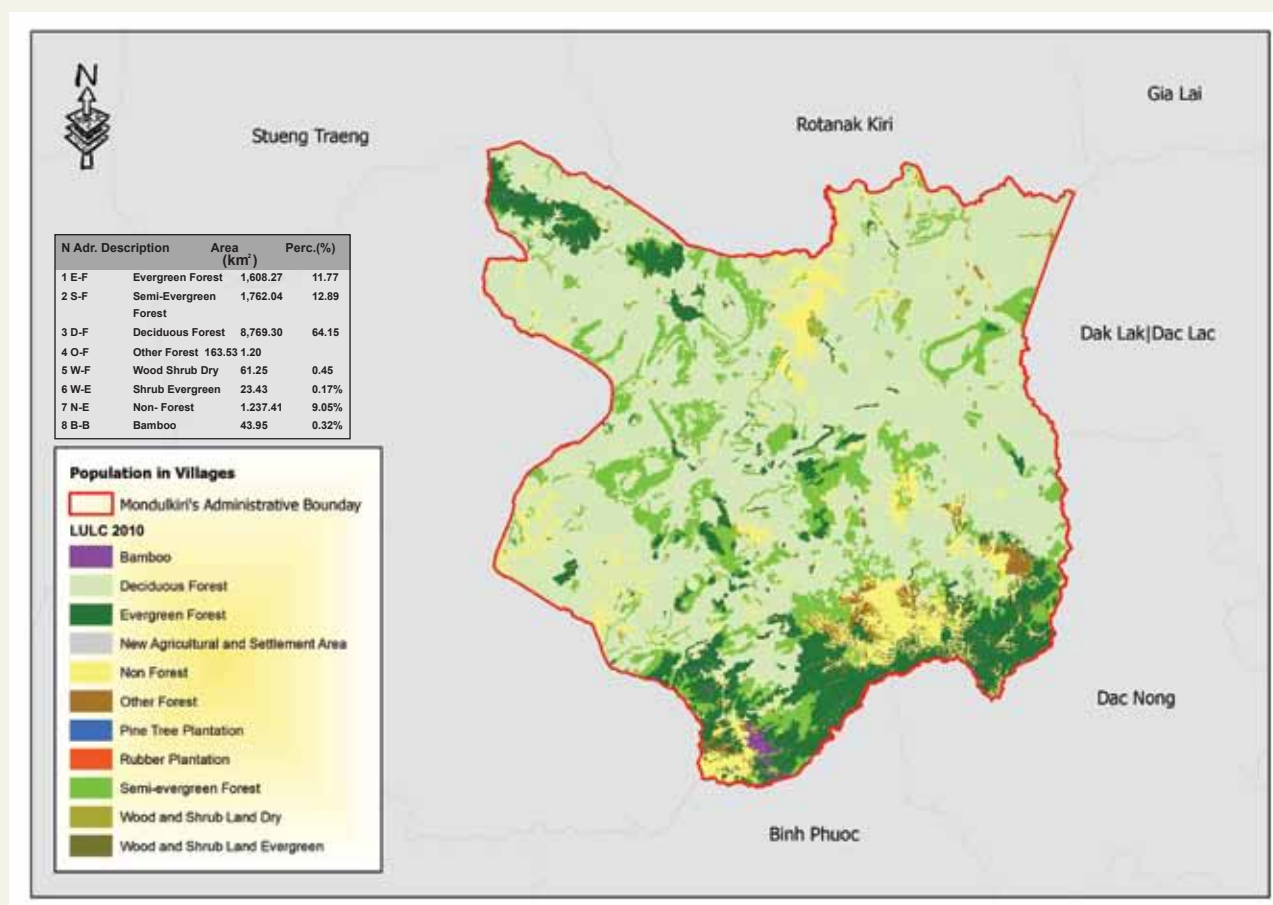
Finally, ***the future development scenarios generated by InVEST can contribute to greater harmony between different stakeholders.*** Better targeted locations identified for development and conservation of natural resources will improve social relations between the different sections of society. Although, overlapping land and management rights would still need to be resolved. Fundamentally, the impacts generated from different scenarios would enable locations specified for economic activities to have less of a detrimental impact on natural resources.

6. SCENARIO DEVELOPMENT

As part of the initiative, key stakeholders were invited to discuss and develop different future land use scenarios. Scenarios were developed on the basis of ‘storylines’ (or descriptions in which each different future scenario was imagined, visualized and produced into a map) and were developed by stakeholders, including provincial level government officials from Mondulakiri and civil society representatives, in workshops facilitated by WWF and RUPP. Three different scenario maps have been developed as options for comparison of land use change and its underlying impacts on future development, economic growth, conservation, and community livelihoods in Mondulakiri province.

Before developing each future scenario, Baseline maps of Mondulakiri were produced to show the ‘current’ situation in Mondulakiri. WWF Cambodia and RUPP used official government data sources to produce the Baseline maps therefore 2010 data, published by the Forestry Administration Department of the MAFF (MAFF 2011) was used as this is the most recent official government forest cover data for Cambodia. The Baseline map for this can be seen in Figure 3.

Figure 3: Baseline map of Mondulakiri forest cover and land use (using 2010 data)



The Baseline map in Figure 3 shows a high prevalence of deciduous forest. This type of forest constitutes almost 9,000km² of Mondulakiri's total land area. There is also a large amount of evergreen and semi-evergreen trees in which reside high levels of biodiversity, wildlife and plant species as well as a number of vital ecosystem services. The areas in yellow in Figure 3 constitute non-forest areas and are predominantly in places with many populations centers: towns or villages.

There is a considerable amount of evergreen and semi-evergreen trees which provide a home to a range of wildlife as well as plant species and contribute significantly in the regulation of the hydrological and nutrient cycles. The areas in yellow on Figure 3 constitute non-forest areas and are predominantly located in areas with a number of population centers.

Subsequent to creating the baseline map, future scenario maps were developed that build on the map in Figure 3. They are based on the following descriptions of different land use change paths (2010-2030).

- A low deforestation or Conservation Scenario (CN). This scenario places a high value on the conservation of significant natural resources, while development activities are allowed mostly in areas outside of these designated plots. In addition, sizeable financial incentives are assumed to be earmarked for conservation of significant resources located within or adjacent to development areas.
- A moderate deforestation or green economy (GE) scenario. This scenario recognizes the value of natural capital, reflected in local actions. There is increased protection of areas with high biodiversity, carbon stocks, and watersheds. This scenario assumes that there is improved governance, adherence to spatial plans and implementation of sustainable finance mechanisms.
- A high deforestation or business as usual (BAU) scenario. This places importance on economic development activities. It also refers to the continuation of the current plans, e.g. road development plans, rubber plantations etc. in spite of existing conflicts and challenges, discussed in section 4.2. This scenario assumes development follows its current trajectory, with weak governance and limited financial incentives for sustainable development.

The method for developing and designing scenario maps involved inputting data from different sources, including:

- Technical discussions and consultations with key stakeholders at all InVEST-related workshops especially the National Workshop on InVEST held on 19th-21st June 2014 and the Consultative Workshop on InVEST Scenario Development for Sustainable Land Use Planning in Monduliri Province held on 16th February 2015; Existing data from relevant line ministries, provincial departments and sub-national administrations of MDK province;
- Technical meetings and discussion among RUPP-InVEST team and WWF technical team on current and future environmental and land use performance and the likelihood of land use change based upon planned policy and development frameworks of the Royal Government of Cambodia; and
- Technical consultations with the InVEST Technical Working Group of Monduliri province.

The scenario maps developed show the impacts of different environmental and land use change options for the years 2010 to 2030



Scenario mapping inputs were provided by all concerned experts of line ministries, sub national authorities and Monduliri line departments, academics and scientists, and community-based organizations that have been working in different disciplines or fields in relation to land use planning, land and forest governance, natural resource management, and community development in Monduliri province. In workshops, all of these parties worked collaboratively to envisage different future paths which Monduliri could take.

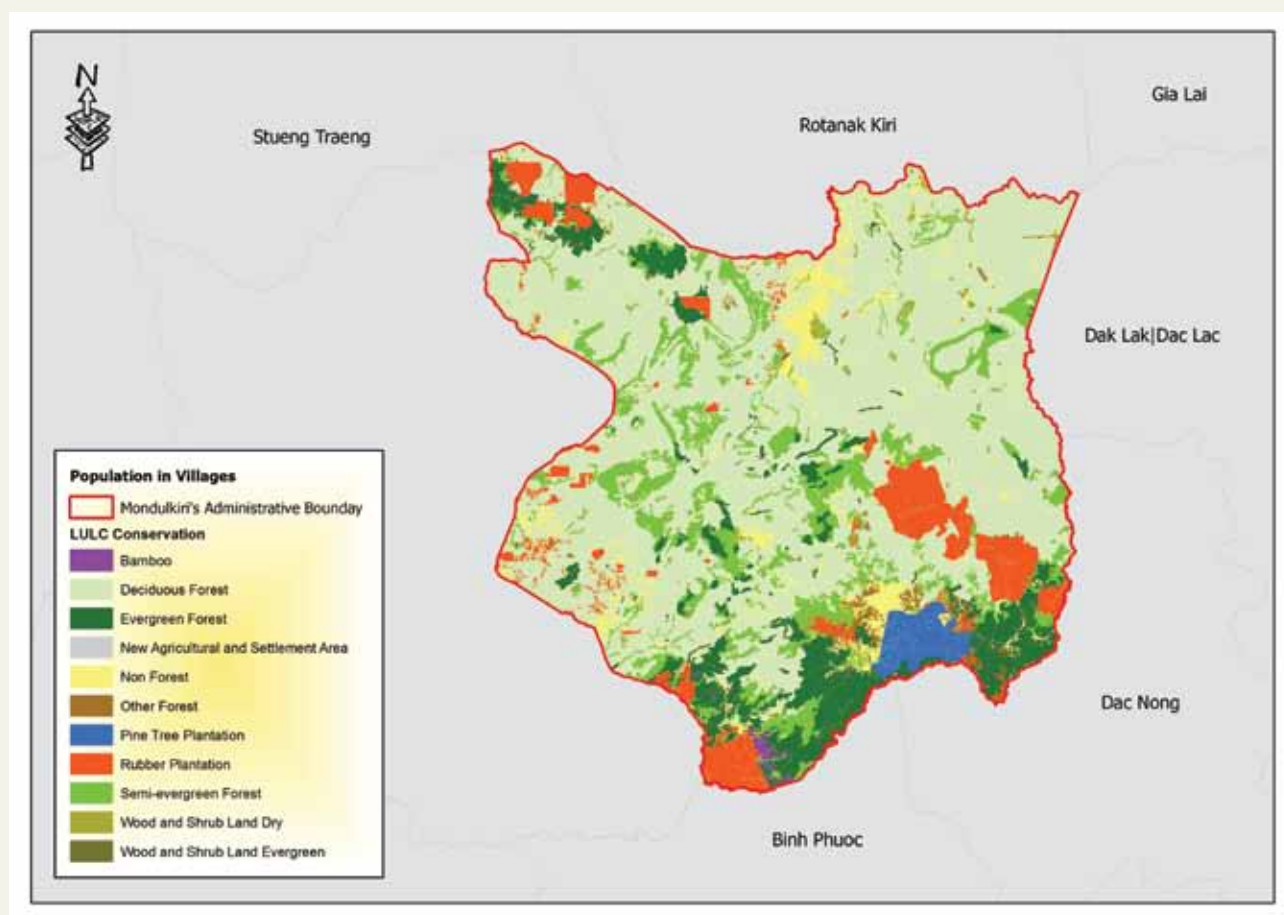
The storylines of each scenario map are described in detail below.

6.1 Conservation Scenario

The Conservation Scenario map is shown Figure 4 below. Compared with the baseline map, it would have 85% remaining forest cover in Mondulkiri and EPL region. Under this scenario, from 2010 until 2030, non-forest areas inside and outside ELCs in Mondulakiri Province (based on 2010 data (MAFF 2011)) are assumed to be agricultural development areas. There is no further forest loss in Mondulakiri Province any more, including in Protected Areas and Protected Forests. All other areas remain unchanged.

When the forest cover map was presented to all stakeholders who attended the workshop, the 'Conservation' team wanted all the remaining forest conserved. This assumption matches the polygon inputs from different relevant stakeholders working on the development of the Conservation scenario map during the first InVEST Scenario Workshop.

Figure 4: Conservation Scenario, Land Use and Land Cover Map of Mondulakiri in 2030



6.2 Green Economy Scenario

The Green Economy Scenario is based on the storyline developed during the scenario workshops by the 'Green Economy' team and technical group discussions between WWF and RUPP. It assumes that from 2010 until 2030, there is no further forest loss in protected areas and protected forests. This means that existing non-forest areas inside ELCs and FCs are regarded as agricultural development land areas / rubber plantations, depicted in orange and grey on the map in Figure 5.

Existing rice fields in Koh Nhek are assumed to have expanded - more than 10km over the buffer for rice production zones. This would support the increase of rice productivity to address increasing demand of rice consumption for Mondulakiri and other provinces in the Northeastern region. Non-forest areas in the province besides non-forest areas in ELCs, are kept as community use zones, multiple use zones, or sustainable development zones at the community scale. As shown in Figure 5, the areas outside of the Protected Areas and Protected Forests are mostly rubber plantations.

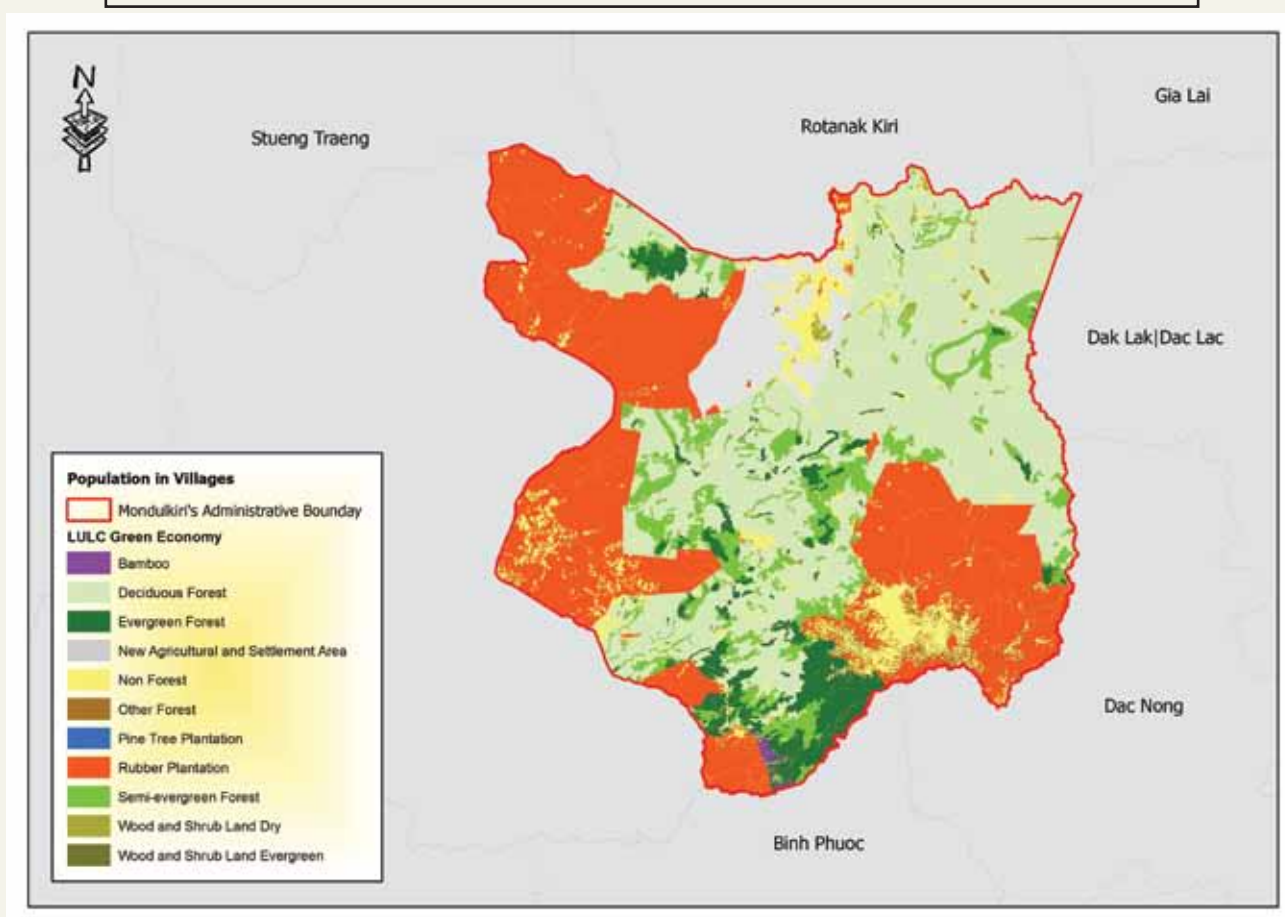
Based on the above-mentioned assumptions, the Green Economy Scenario map would look like Figure 5 with a remaining forest cover of 53% of the total land area in Mondulkiri.

WWF Cambodia recommend the integration of the Green Economy scenario in Mondulakiri's land use and spatial planning process as this scenario strikes a balance between conservation – protecting the areas in which there is the largest amount of ecosystem services – and economic development.

Mondulakiri in 2030 under a BAU scenario sees a province with considerably fewer natural forests and consequently fewer ecosystem services that contribute to the wellbeing and livelihoods of local households. Therefore the landscape is drastically changed and, if nothing is done to replace the lost ecosystem services, the landscape will be less resilient in coping with the increased risk of floods and longer droughts; and local people will be using water that is likely to be contaminated and harmful to fish, other aquatic life and human health. Trying to mitigate the negative impacts is likely to be costly and less effective than the beneficial services natural forests provide for free. The Conservation scenario would result in more tree cover, natural resources, ecosystem services and more suitable areas for wildlife species compared with the other two scenarios (provided these forests are well managed and law enforcement is strengthened). The GE scenario allows for the maintenance of trees in PAs (with strengthened governance, sustainable finance mechanisms etc.) while also enabling economic development outside of PAs to meet economic demands such as an increased demand for rice due to a rising population. Therefore the GE scenario allows for a more strategic and balanced economic development trajectory. Through integrated, evidence-based planning processes, more sustainable approaches to development are possible.

The Green Economy scenario seeks to minimize losses to ecosystems services by conserving protected areas and enabling economic development and food security in the productive parts of the landscape. In addition, the Green Economy scenario ensures structural connectivity of forest habitat, vital for wildlife corridors, without compromising the province's ability to develop and generate jobs. Evidently the PAs form the backbone of ecosystem services across the province.

Figure 5: Green Economy Land Use and Land Cover map of Mondulakiri in 2030



It is imperative therefore to ensure they are supported with best practice management, species protection, law enforcement, and that local and national populations continue to receive the environmental services provided by them. The value of the PAs for their provision of clean water, climate regulation, biodiversity, recreational values, non-timber forest products and services vital for agriculture and development has been made clear in this scientific assessment. Under a GE scenario, natural capital remains a critical enabler of growth, and development takes place but not at the expense of important sources of ecosystem services. This evidence-based scientific assessment and recommendations can inform land use planning and economic development decisions and support the transition to a greener and more sustainable economy, helping Cambodia in achieving its INDC and Sustainable Development Goals.

6.3 Business as Usual Scenario

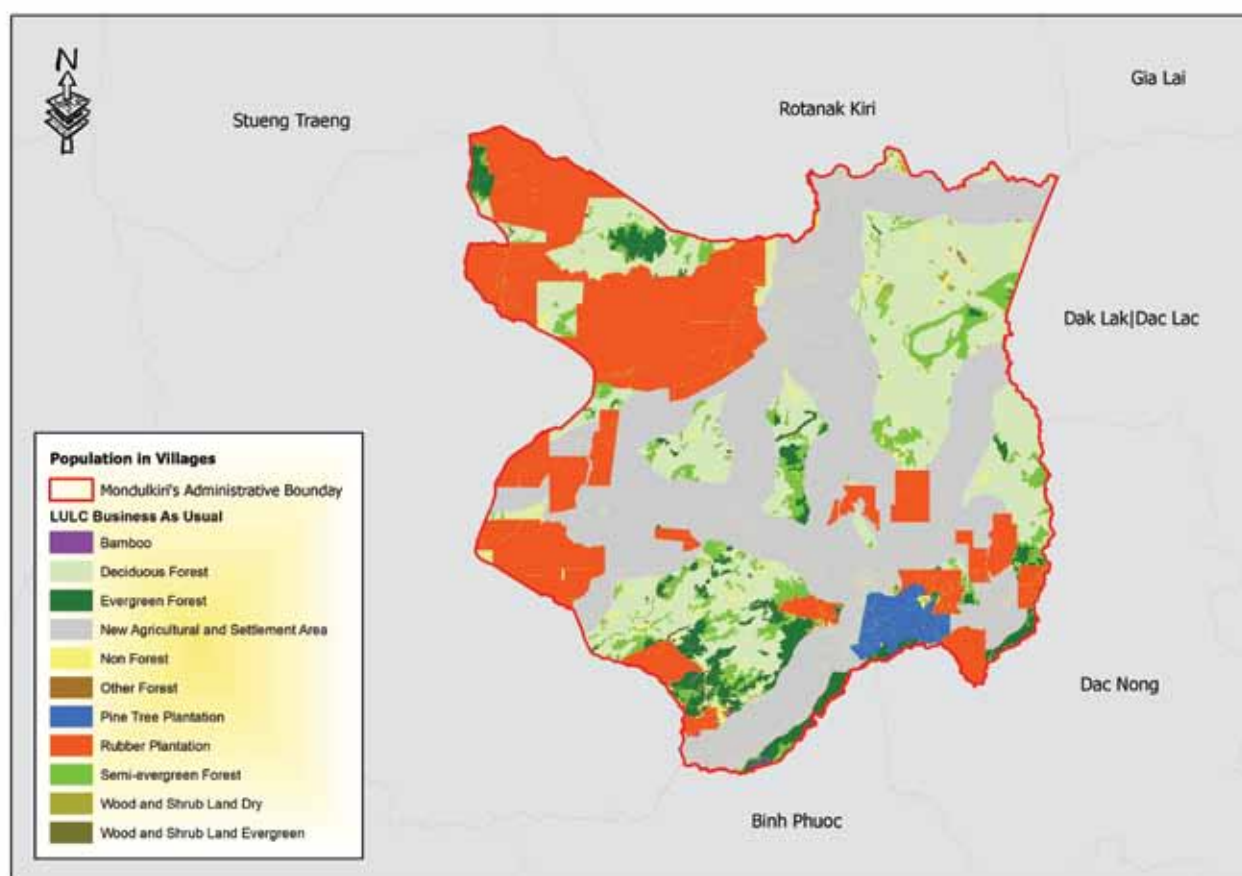
The BAU scenario was developed by stakeholders in the Business As Usual team during scenario workshops and technical group discussions between WWF and RUPP. It assumes that from 2010 until 2030, existing ELCs, covering 26% of the total area of Mondulakiri in 2010, would be further kept as agricultural development areas.

Protected Areas and Protected Forests would no longer be protected for environmental purposes but development activities would be allowed in all parts of the province resulting in considerably fewer trees, fewer natural forests to regulate the climate, hydrological cycles and provide other ecosystem services.

The buffer areas of 5km from existing and planned road development zones (depicted in grey on the map in Figure 6), are assumed to be new agricultural and settlement areas. These areas equate to 38% of Mondulakiri's total land area. Other forestlands would remain the same.

Based on the above-mentioned assumptions, the business as usual scenario map would look like Figure 6 with a remaining forest cover of 34% of the total land area in Mondulakiri.

Figure 6: Business as Usual Land Use and Land Cover map of Mondulakiri in 2030



7. CARBON STORAGE

7.1 Introduction

Terrestrial ecosystems, which store more carbon than the atmosphere, are vital to influencing carbon dioxide-driven climate change. Primarily through tropical forest loss and degradation, land-use change is estimated to contribute to between 6-17% of all global anthropogenic greenhouse gas emissions (Van der Wert et al, 2009 cited in Kapos, 2010). The RGC has made considerable efforts to address the issue of deforestation in the recent years.

Carbon storage or carbon sequestration is one of the most important ecosystem services provided by functioning forest ecosystems. Trees remove carbon dioxide from the atmosphere through the natural process of photosynthesis and store the carbon in their leaves, branches, stems, bark and roots. Although forests do release some CO₂ from natural processes, a healthy forest typically stores carbon at a greater rate than it releases it (Johnson and Coburn 2010; New York State no date). Carbon storage value is lost if a forest is converted through logging or burning.

A study by Kapos (2010) suggested that co-benefits derived from carbon sequestration, biodiversity conservation and maintenance of ecosystem services, can also directly improve local livelihoods and the rights and well-being of local communities. In this sense, the RGC's National Forest Program aims to develop and manage forests to ensure improved livelihoods, environmental services and overall economic development.

Being able to value carbon stored in forests in Cambodia could also help in the implementation of REDD+ (Reducing Emissions from Deforestation and forest Degradation). This carbon trading system received a boost on the global stage recently with its inclusion in the Paris Agreement (UNFCCC 2015), in the adherence of Cambodia's Intended Nationally Determined Contribution (RGC, 2014). Being able to estimate the amount of carbon currently stored in a landscape will provide a baseline for developing REDD+ mechanisms.

For the purposes of this assessment, the carbon below ground, carbon in dead wood (for each forest type), carbon in the soil as well as the carbon in trees was analyzed and the carbon storage and sequestration of Mondulkiri's carbon was assessed, mapped and valued.



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7.2 Results of the Mapping of Carbon Storage

The areas with the highest amount of carbon stock are located in PAs, REDD+ project sites, Seima Protected Forest and PPWS. Even Protected Areas that have not been legally zoned prove to have a higher carbon stock and therefore worth continuing to protect and manage carefully. Stronger governance of PAs and law enforcement should be enhanced to ensure this. A baseline study showed that Mondulkiri has a higher carbon stock than the rest of Cambodia as a whole. Therefore, opportunities for financing mechanisms such as REDD+ and carbon offsets should be considered. The carbon model study also performed scenario analyses to show how carbon storage will be affected in each of the different development scenarios.



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Figure 7: Baseline map of carbon stock volumes (in pixels)

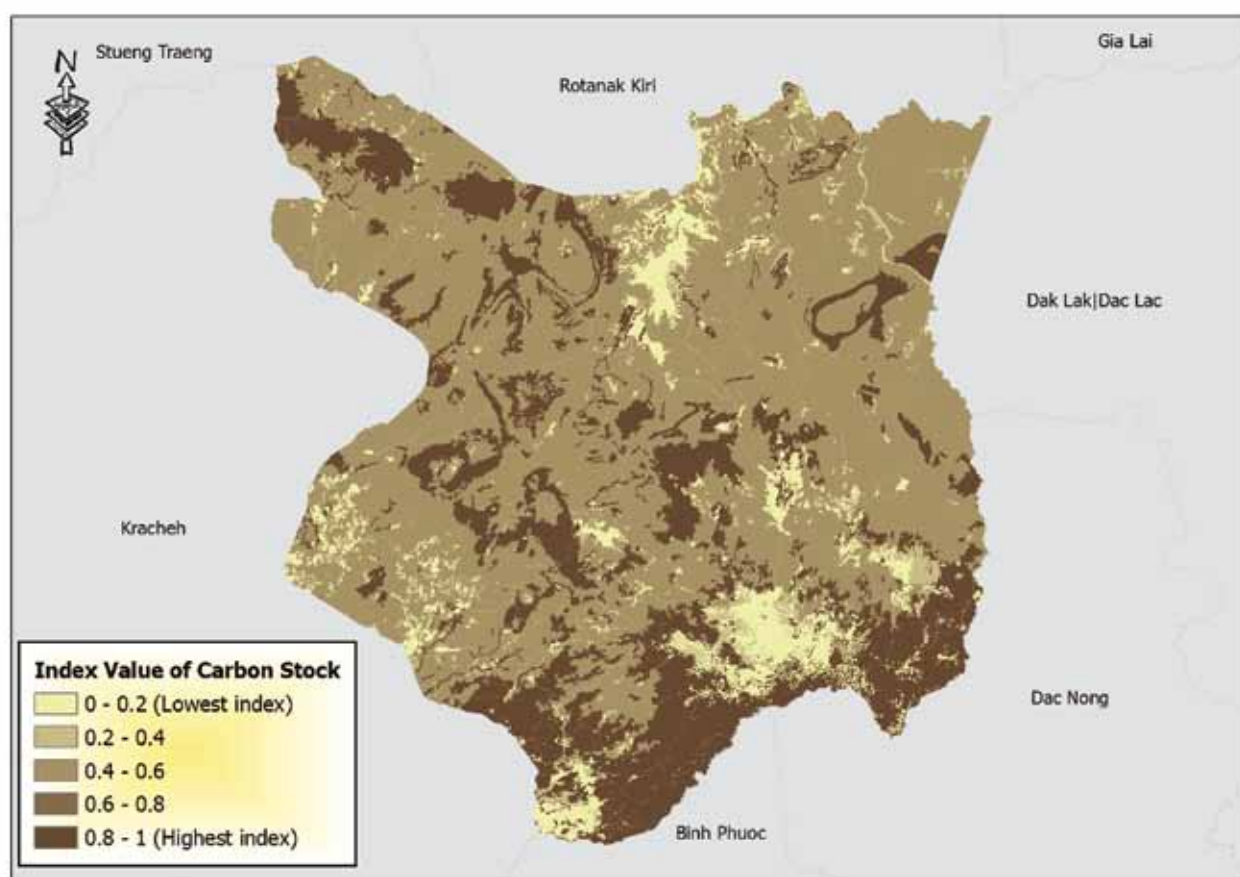


Figure 8: Changes in carbon storage under each future scenario in 2030 (in pixels)

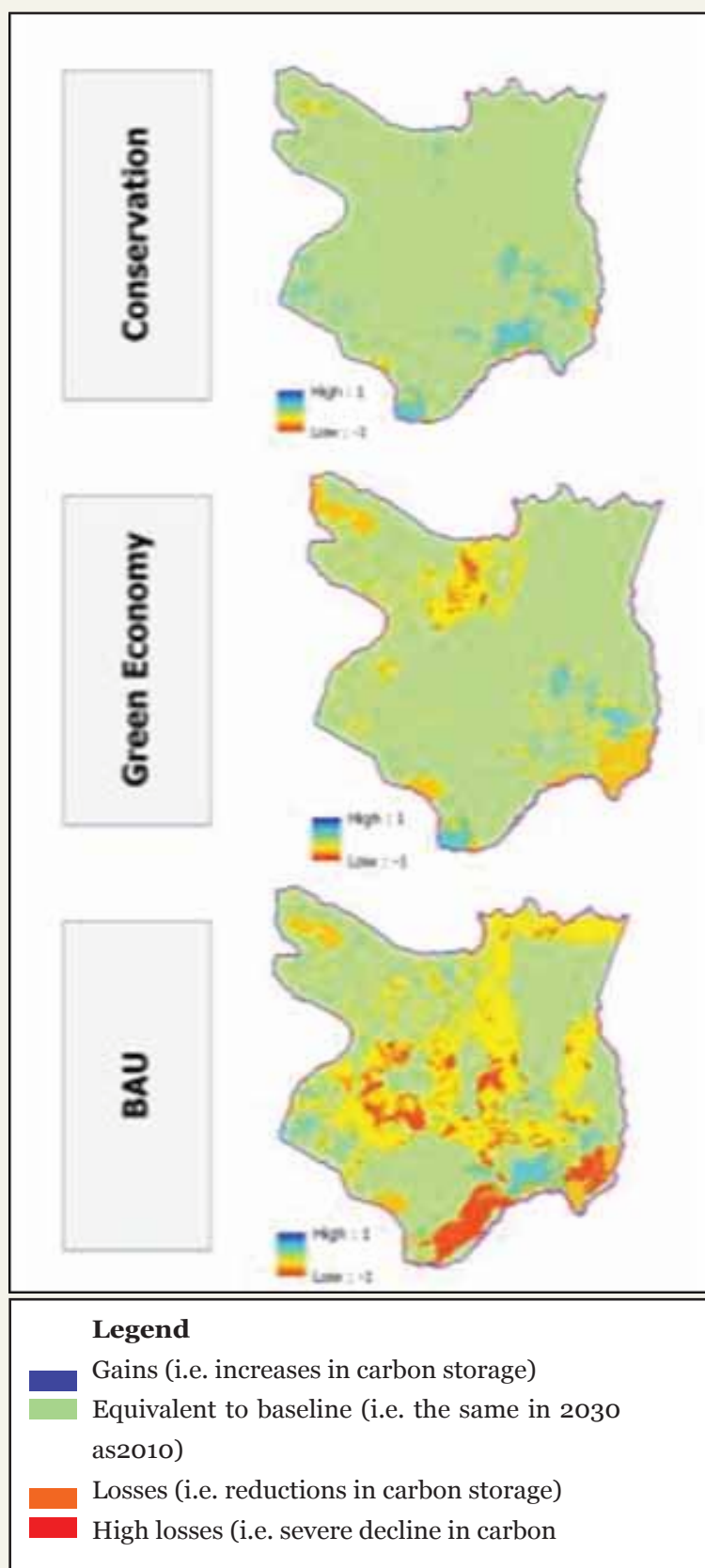


Figure 8 (left) and Figure 9 (overleaf) show the areas where carbon storage has increased and areas where it has declined by 2030 under each future scenario.

In the Conservation scenario in Figure 8, the majority of the map remains light green, as land area in 2030 is the same as it was in 2010 (baseline map). The blue areas show an increase in carbon in the areas that have already been allocated for plantations, where it was formerly barren land (in 2010). These provide some carbon storage, but not as much as areas such as Seima Protected Forest in the south of the province.

Figure 9 shows high carbon storage areas (in dark brown) and areas of low carbon storage in yellow. The Conservation scenario map on Figure 9 shows fewer non-forest areas (depicted in yellow) than the baseline map. This is because by 2030, it is assumed that a pine tree plantation is cultivated in Monorom (in the Southeast of the province) and a rubber plantation in Srae Khtum (the southernmost tip of the province) (see areas in blue in Figure 8 left). Monocrop plantations may provide carbon storage but the loss of biodiversity has severe impacts on populations of humans and wildlife.

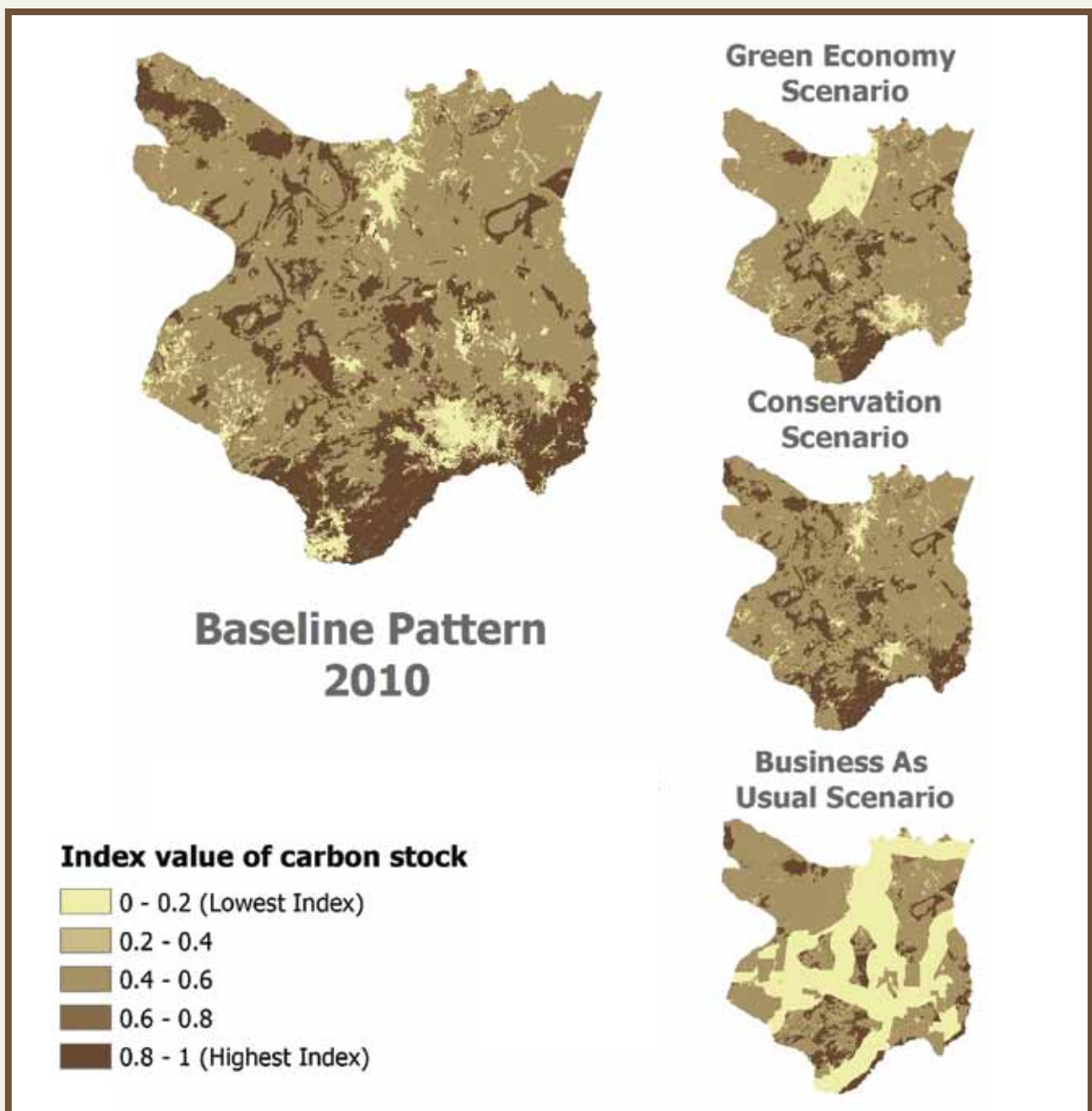
Under the Green Economy scenario, greater areas of orange and red show losses in carbon in Figure 8 in previously forested areas allocated for rice paddies and rubber plantations, to meet the increasing demand for rice from a rising population. The blue area in the south and southeast of the province represents the increase in carbon storage where rubber plantation ELCs have been allocated in degraded forest areas.

In the GE map in Figure 9, the area in pale yellow represents the agricultural areas that will result in a loss of carbon storage, circled. In addition to high losses in carbon storage in the northwest of the province, in Roya, additional losses can be seen throughout the province.

The Business as Usual scenario map in Figure 8 shows important losses as a result of road development and based on the assumption of a 5km buffer of new settlements and agricultural development areas. This results in fewer trees and therefore less carbon stored (as indicated in yellow on Figures 8 and 9). The red areas in the south, represent significant losses in carbon sequestered due to forests being transformed for other land uses.

The BAU map in Figure 9 also shows the extensive loss of carbon stock (which means the amount of carbon stored in these forests) in the areas that will represent new agricultural and settlement areas around roads. The considerable loss in carbon under this scenario is likely to have far-reaching repercussions, as more greenhouse gases are emitted because there are fewer trees available to retain and store carbon.

Figure 9: Carbon storage baseline map, Conservation scenario map, BAU scenario map and Green Economy scenario map (in pixels)



7.3 Results of Valuing Carbon Storage

Trees' ability to store (or sequester) carbon is an important ecosystem service provided by functioning forest ecosystems. The value of carbon storage is diminished if a forest is converted, e.g. through logging or burning (Aerts and Honnay 2011). The economic valuation of carbon storage examines two aspects of carbon value: 1) the potential value of marketed carbon credits from avoided emissions; and 2) the social cost of carbon which is the estimated damage caused by climate change resulting from additional units of carbon emitted to the atmosphere. This represents the global cost of climate change.

Both approaches used to assess the economic value of carbon stored in forests in Mondulkiri reveal the very high value of carbon stored in forests. The values of carbon storage are presented in Table 2, below:

Table 2: Value of changes in carbon storage 2010-2030 under different scenarios

	Scenarios		
	Conservation	Green Economy	Business as Usual
Change in carbon stock ⁷ (tCO ₂ ; millions)	7	-122	-362
Saleable volume ⁸ (tCO ₂ ; millions)	74	48	0
Carbon credit revenues (US\$; millions)	589	383	0
Carbon credit costs (US\$; millions)	54	35	0
Carbon credit net revenue (US\$; millions)	536	348	0
Social Cost of Carbon ⁹ (US\$; millions)	387	-7,205	-21,345

Using a conservative assumption that only 20% of additional stored carbon could be credited and sold in carbon markets, it is estimated that 74 million tonnes of CO₂ could be sold under the Conservation scenario; 48 million tonnes of CO₂ under a Green Economy scenario; but no carbon credits can be sold in 2030 under a BAU scenario, as summarized in Table 2.

Therefore, for the period 2010-2030, the corresponding net revenues from crediting and selling stored carbon are \$536 million in Conservation scenario and \$348 million, under a GE scenario.

The GE and BAU scenarios result in large losses of stored carbon and the damages associated with this are estimated to be US\$7 and US\$21 billion, respectively. The Conservation scenario results in an increase in stored carbon in 2030 relative to the baseline in 2010. This removal of CO₂ from the atmosphere has a value of US\$387 million.

⁷ Change in carbon stored relative to the baseline stock of carbon.

⁸ Using the assumption that 20% of 'additional' carbon storage can be sold, additional carbon is assessed relative to the BAU scenario.

⁹ The social cost of climate change reflects the damage caused by climate change due to additional carbon dioxide emissions. It is an estimate of the global damage/cost of climate change.

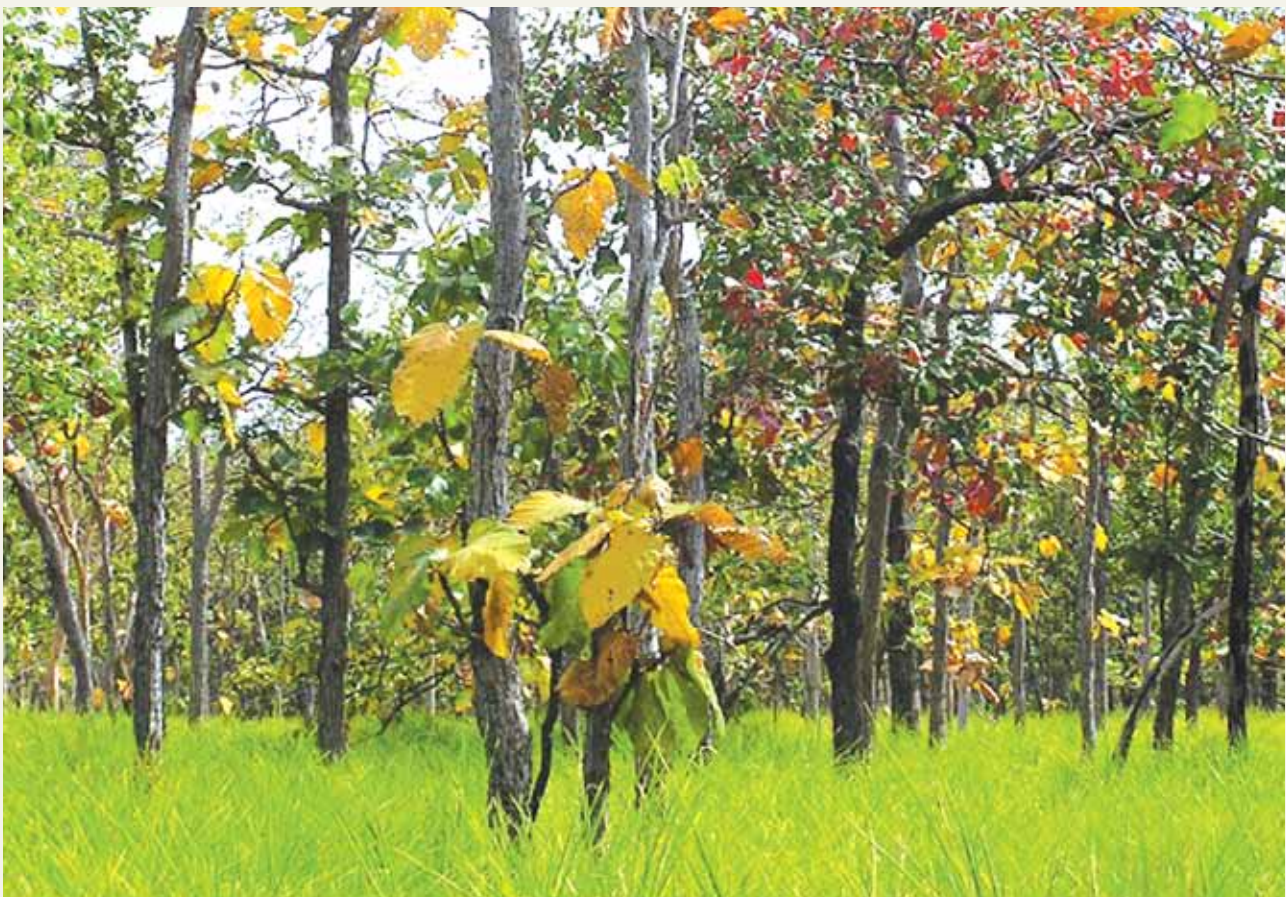
7.4 Conclusions

As the findings of the carbon storage maps demonstrate, the Conservation scenario is optimal in terms of maintaining and even increasing the amount of carbon stored in Mondulkiri. It proves the most remunerative when it comes to the value of carbon storage. However, even the Green Economy scenario successfully maintains a large part of the carbon stored, compared to the baseline.

The value of carbon storage is extremely high when compared with other forest ecosystem services. The benefits of carbon storage, whilst vital for regulating the climate locally and globally, do not necessarily accrue to the local land users or land owners of Mondulkiri.

This is because carbon storage is not a tangible ecosystem service that the local people can directly benefit from; it does not directly affect the agricultural growing conditions or water sources that people rely on for their livelihoods but it is important for ensuring a stable climate. Voluntary carbon markets could provide an incentive to maintain the stocks of forest carbon in Mondulkiri. The recent climate change agreement at the United Nations 21st Convention of Parties in Paris earlier this year, in which countries agreed to limit greenhouse gas emissions “to well below 2°C and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels” (Article 2 of the Paris Agreement, 12 December 2015), provided a boost to carbon markets. This could reinforce efforts to credit and trade carbon stock in Mondulkiri's forests, which is one option for incentivizing conservation over deforestation. The first carbon credits from a climate change mitigation project in Keo Seima Wildlife Sanctuary, Mondulkiri (WCS 2016), could be the first of many such initiatives that tap into existing voluntary carbon markets in efforts to protect Mondulkiri's forests.

More in depth research could prove valuable in light of these developments. The limitations to these results included the use of mostly secondary data and resulted in findings that underestimated carbon storage. This was due to a lack of information and leakage of belt boundary¹¹ in the sub-watershed estimation, especially for those sub-watersheds with catchment areas outside the province boundary. Therefore more research is needed to produce more comprehensive assessments of Mondulkiri's forest.



¹¹ Leakage belt boundary here refers to the uncertainty of estimating carbon in sub-watersheds as boundaries of sub-watersheds extend into other neighboring provinces, districts or communes. The leakage belt refers to the changes in estimated carbon, either underestimations or overestimations, due to changes in Land Use and Land Cover over time to projected years.

8. NON-TIMBER FOREST PRODUCTS (NTFPs)

8.1 Introduction

NTFPs, such as liquid resin, solid resin, bamboo, wild-honey bees and strychnine trees, have been widely promoted as a rural development mechanism (Arnold and Perez, 2001), but currently, there is little recognition of the significant household income they provide to local communities (Cunningham, 2011). People living in Cambodia's forest frontier are heavily dependent on NTFPs for domestic consumption and complementary cash income (Milne & Mahanty 2015).



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Around 37% of Mondulkiri's population live below the consumption poverty line (Sorn, 2010). The main livelihood activities of individuals are: shifting rice cultivation, fruit trees plantation, livestock production, and NTFP collection. Local people also raise cattle and livestock in the wild for both farming activities and eating. Some also receive benefits from eco-tourism and as laborers to rubber plantations.

Food production is reported to be kept for eating only rather than sold for additional incomes. In the rainy season, edible by-forest products or NTFPs, such as bamboo, mushroom, wild fruit, vegetable and animals are collected to support the nutritional regime and to contribute to additional household incomes. The household survey carried out for this study shows an annual household income of USD\$3,600 in Mondulkiri, of which 58% (or US\$ 2,095) is from the sale of NTFPs.

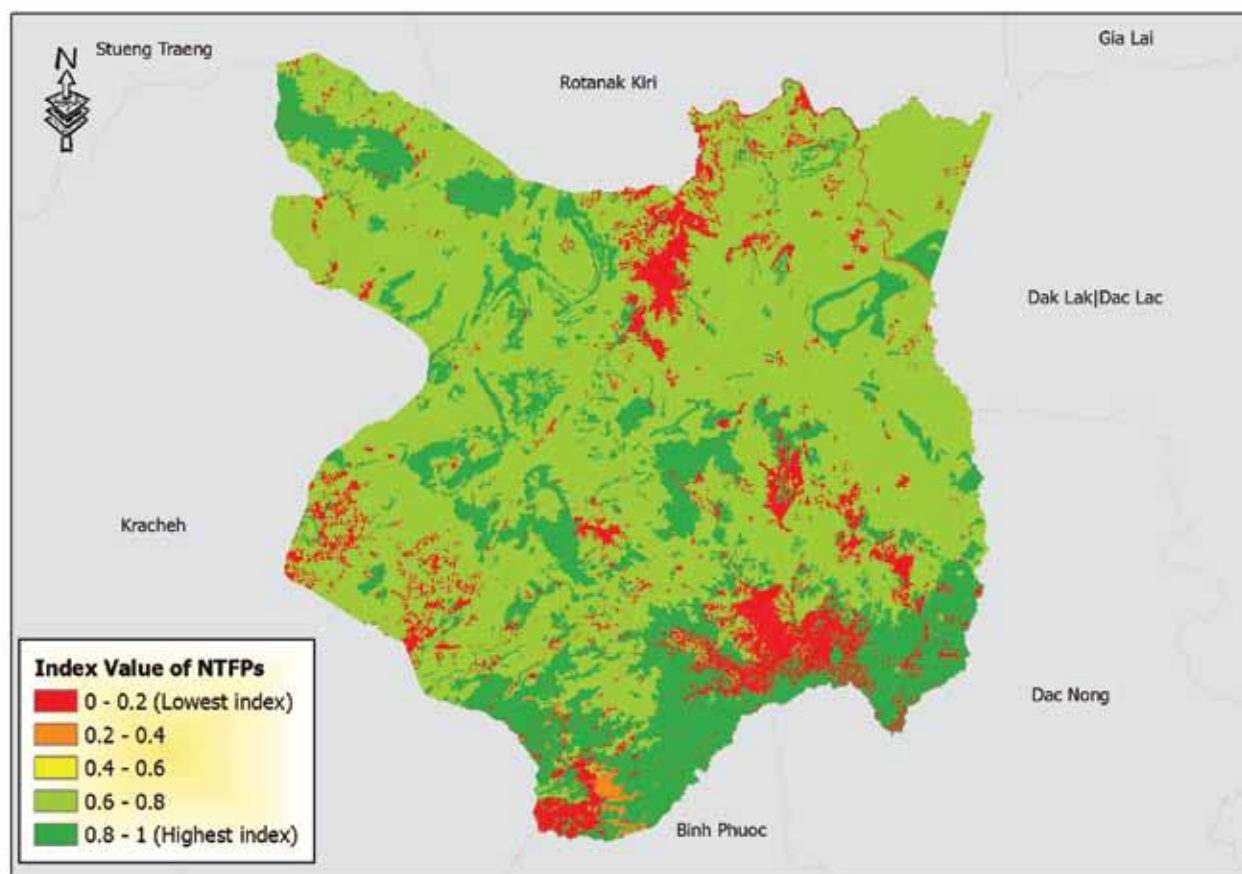
NTFP collection has been promoted as a pathway for poverty reduction and forest conservation in Mondulkiri (NTFP-EP, 2013; Total et al., 2003; FAO, 2002). NTFPs play a vital role for food, medicine, house materials, agricultural tools and supplementary incomes to household, especially when agricultural yields are low (Tola et al. 2003). The NTFPs that were taken into consideration in this mapping and valuation study include: liquid resin, solid resin, bamboo and wild honey.

8.2 Results of the Mapping of NTFPs

This study consisted of a biophysical modeling of NTFPs to assess their spatial distribution in Mondulkiri and assessed how this distribution might be affected in the different development scenarios for 2030. Arc-GIS is the geographic information system (GIS) that was used for data preparation, analysis and visualization in this study. Both secondary and primary data were used.

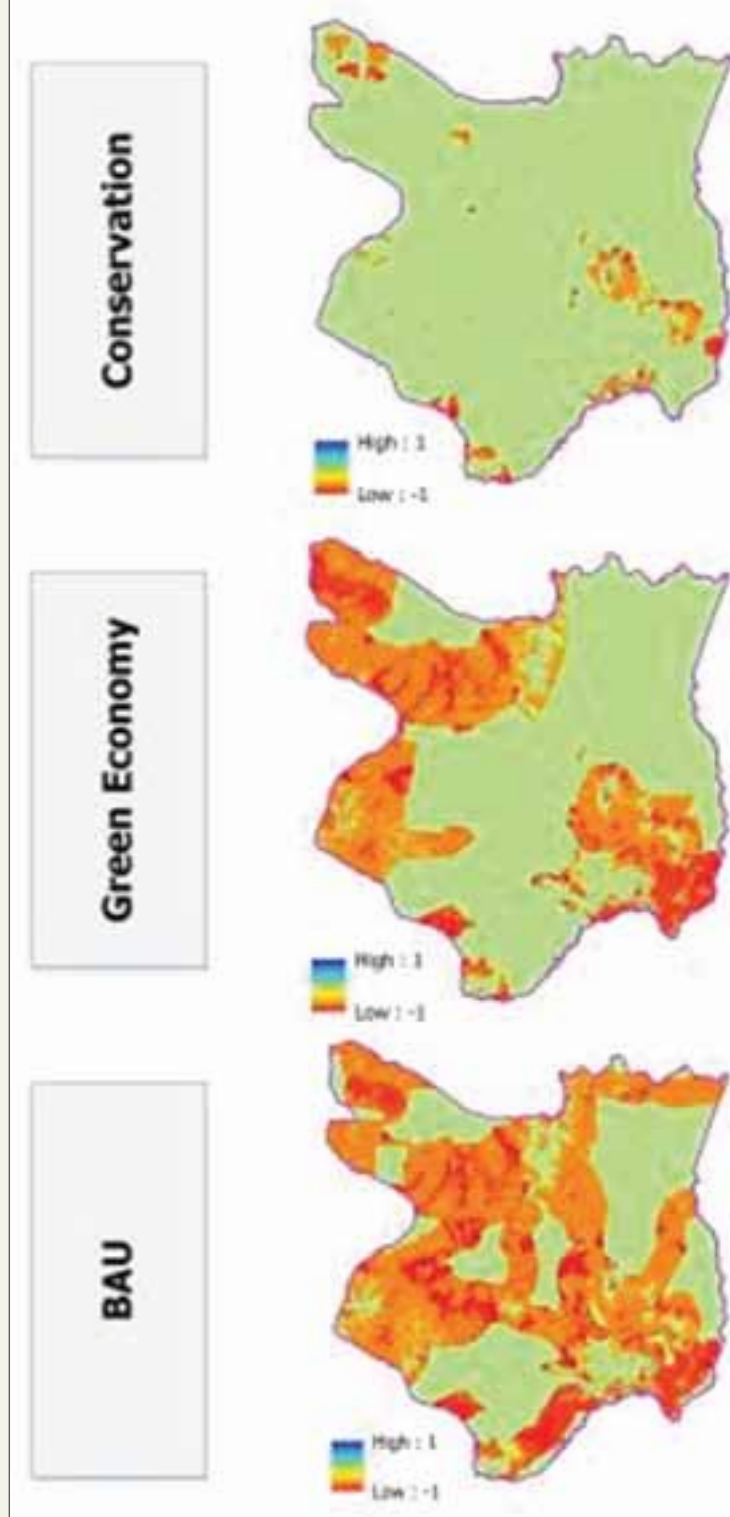
Figure 10 shows the baseline map of NTFPs in pixels demonstrating an index value of NTFP availability in which areas low in NTFPs are depicted in red and orange) and areas high in NTFPs are depicted in green. The areas with the most amount of NTFPs are mostly located in PPWS and Seima Protected Forest. These areas of natural forest provide important contributions to the livelihoods of local communities.

Figure 10: Baseline map of NTFPs availability (in pixels)



NTFPs WERE THEN MAPPED ACCORDING TO THE DIFFERENT SCENARIOS: BAU, GREEN ECONOMY AND CONSERVATION AS OUTLINED BELOW.

Figure 11: Maps showing gains and losses in the availability of NTFPs under each future scenario (in pixels)



Conservation Scenario

The Conservation scenario map is similar to the baseline map as there relatively little deforestation has occurred between 2010 and 2030 under this scenario. The areas in red and orange in the Conservation map of Figure 11 show losses in NTFPs from planned rubber plantations in ELCs outside PAs and PFs. Population growth would lead to a slight reduction in the availability of NTFPs (because increased demand reduces supply) and more land being used for agriculture as well as an increase in the natural resources used by the community. But as shown in Figure 12, most communes will have very small reductions in NTFPs availability as compared with the other scenarios; while some communes experience no loss in NTFPs. The loss of only 15% of forest cover by 2030 as compared with the baseline is key in the minimal losses in NTFPs.

Green Economy Scenario

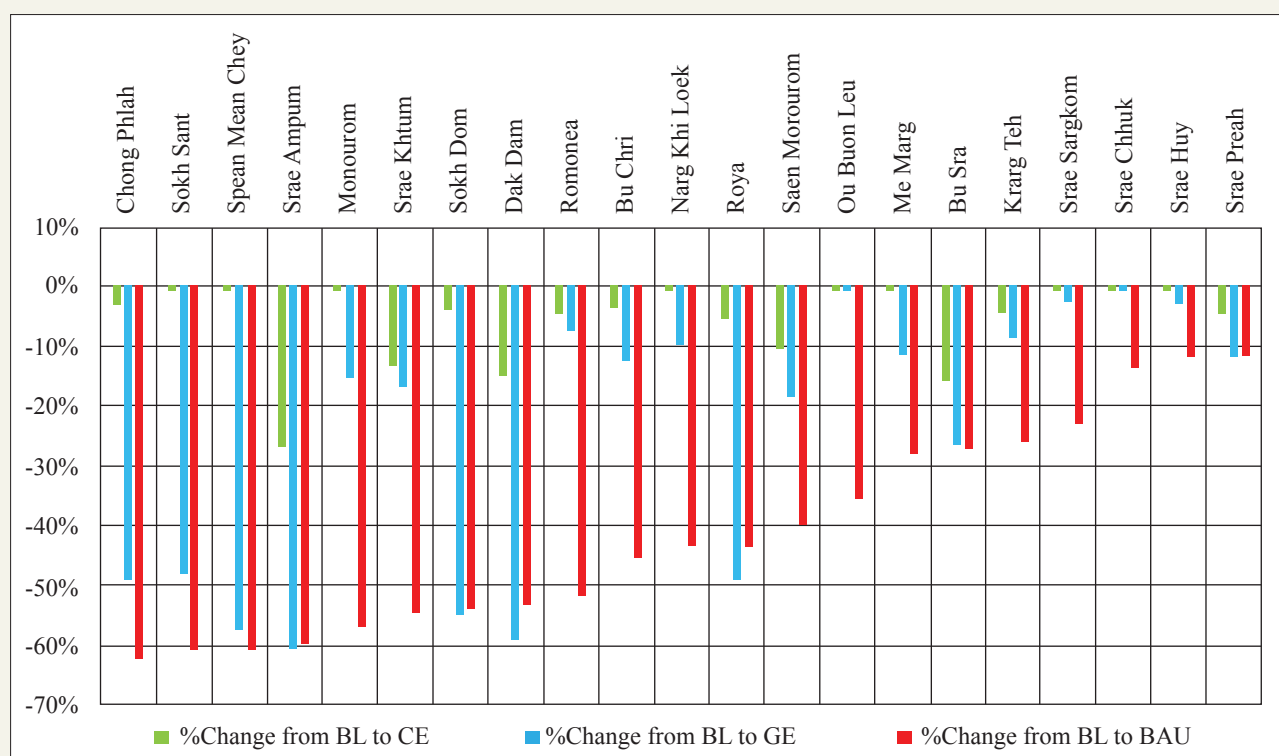
In the Green Economy scenario map in Figure 11, the sections in orange and red show losses in NTFPs, mostly as a result of rubber plantations, as rubber trees cannot provide the resin or honey that the old forests contain. NTFP losses occur most severely in Roya, Dak Dam and Srae Ampum, and losses occur in almost all other communes as well. It is clear from the map that the retention of natural forest in Protected Areas and Protected Forests also protect the availability of NTFPs.

Business as Usual Scenario

The 2030 BAU scenario shows more severe losses in NTFPs availability than under the other scenarios. The graph showing percentage changes by commune (Figure 12) shows that almost half of all communes in Mondulkiri, lose more than 50% of NTFPs resources by 2030.

In a BAU scenario, planned road development projects, timber exploitation and mass crop plantations are responsible for the losses in NTFPs (represented in orange and red color in Figure 11).

Figure 12: Percentage changes in NTFPs by commune for each future scenario compared with the baseline (BL)



8.3 Results of Valuing NTFPs

To calculate the results, the valuation of NTFPs involved data collection and the use of a production function method. A survey of 177 households in seven villages in Mondulkiri province was implemented to collect data on NTFP harvesting practices and yields. The data from the household survey was augmented with data generated through InVEST on the availability of each NTFP within the maximum harvesting distance specified by each household. The household survey carried out for this study showed an annual household income of USD\$3,600 in Mondulkiri. It also found that households living in areas with higher NTFP availability are also likely to make more harvesting trips per month which is found to have a positive effect on yield for liquid resin, solid resin and honey. The reverse is the case for bamboo poles and shoots however.

The current contribution of resin, bamboo and honey to Cambodia's economy is estimated to be almost US\$26 million per year, as the baseline results in Table 3 highlight. This amount is predicted to drop to US\$4.5 million in 2030 under the BAU scenario.

Table 3: Total annual values (net revenues) for NTFPs under alternative scenarios (USD; 000s)

NTFPs	Scenario			
	Baseline	Conservation	Green Economy	Business as Usual
Liquid Resin	1,237	737	361	45
Solid Resin	4,793	4,603	4,565	4,237
Bamboo Poles	1,304	981	678	439
Bamboo Shoots	303	145	-102	-263
Honey	18,300	15,920	9,750	6,171
Total	25,937	22,386	15,252	4,458

The financial value of NTFPs may not be as large as the value of carbon storage, but the benefits of NTFPs are felt directly by the local communities. Indeed, putting these values in per household terms, highlights how important NTFPs are as a component of total household income.

8.4 Conclusions

Under the baseline scenario, NTFPs represent an annual household income of US\$2,095 or 58% of household.

- The CN scenario sees a decline in the value of NTFPs by 13% compared with the baseline contribution to the economy, because of the relatively minimal loss of NTFPs.
- Under the GE scenario, the contribution of NTFPs to household incomes reduces more significantly therefore NTFPs only contribute 34% of household incomes (compared to the 58% NTFPs contributed in 2010, according to the baseline results).
- Under the BAU scenario, the decline in NTFPs leads to an even steeper fall in the contribution NTFPs make to household incomes resulting in NTFPs only representing 24% of household incomes (compared to 58% in the baseline).

If the reductions in the contribution of NTFPs to household incomes are not replaced, this can increase vulnerability and poverty among local communities, particularly if the loss is sizable (as it is under the BAU scenario. A BAU scenario leads to a loss of 34% of household income from NTFPs in 2030 which, assuming this loss will not be replaced, would have devastating impacts on the lives of rural families.



Greater protection of the forests in PAs and Protected Forests is a necessary measure to ensure that the forest continues to provide these products that are a key resource for local communities. Supporting the birth and growth of NTFP enterprises is a way of supporting local economy. This support can also help to reduce the incentives for illegal deforestation for livelihood purposes among local populations.

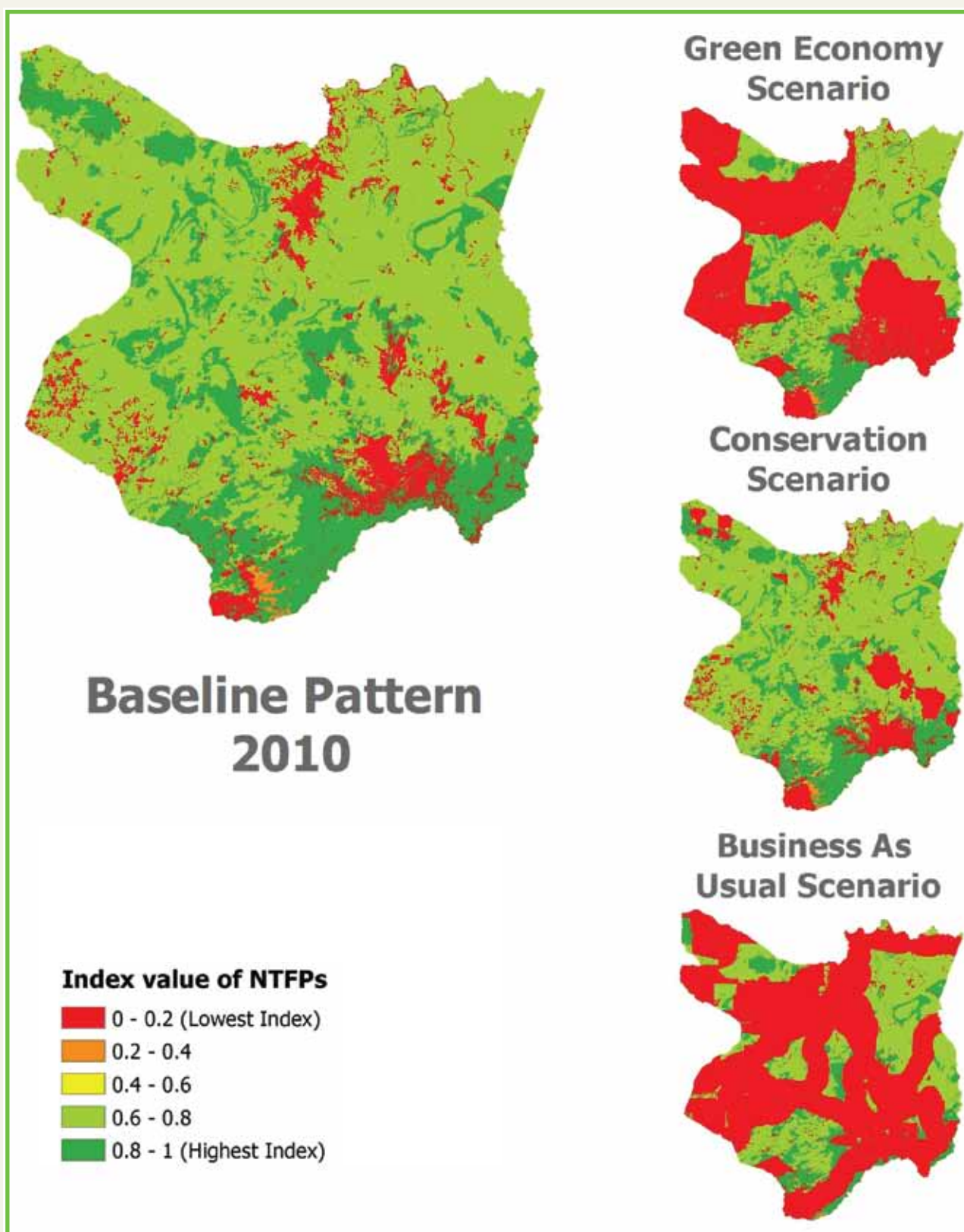
In the future, it would be beneficial to have a study assessing the direct benefits that local communities will receive from land use changes under each scenario. This would adequately provide a comparison as to what gains and losses will result. It is likely that short term benefits of land use change may be outweighed by long term environmental damage.

A more extensive field verification is also needed to more adequately assess NTFPs. Primary data from other communes would produce more representative data for the whole province. If researchers are able to travel with the collectors (local community members who extract NTFPs) to the forest zone where the collection takes place, it would be easier to obtain the measurements from the GIS more accurately and also gauge the distance travelled more accurately, rather than relying on collectors information (many collectors interviewed during this study were unable to express how far they travelled or where they went to collect NTFPs).



“NTFPS REPRESENT 58% OF MEAN HOUSEHOLD INCOME. IF LOCAL COMMUNITIES LOSE THE NTFPS THEY RELY ON, IT IS HIGHLY LIKELY THAT LEVELS OF VULNERABILITY AND POVERTY IN THE PROVINCE WILL INCREASE”

Figure 13: Baseline map of NTFPs availability and changes in NTFPs availability by 2030 under the three future scenarios (in pixels)



9. ANNUAL WATER YIELD

9.1 Introduction

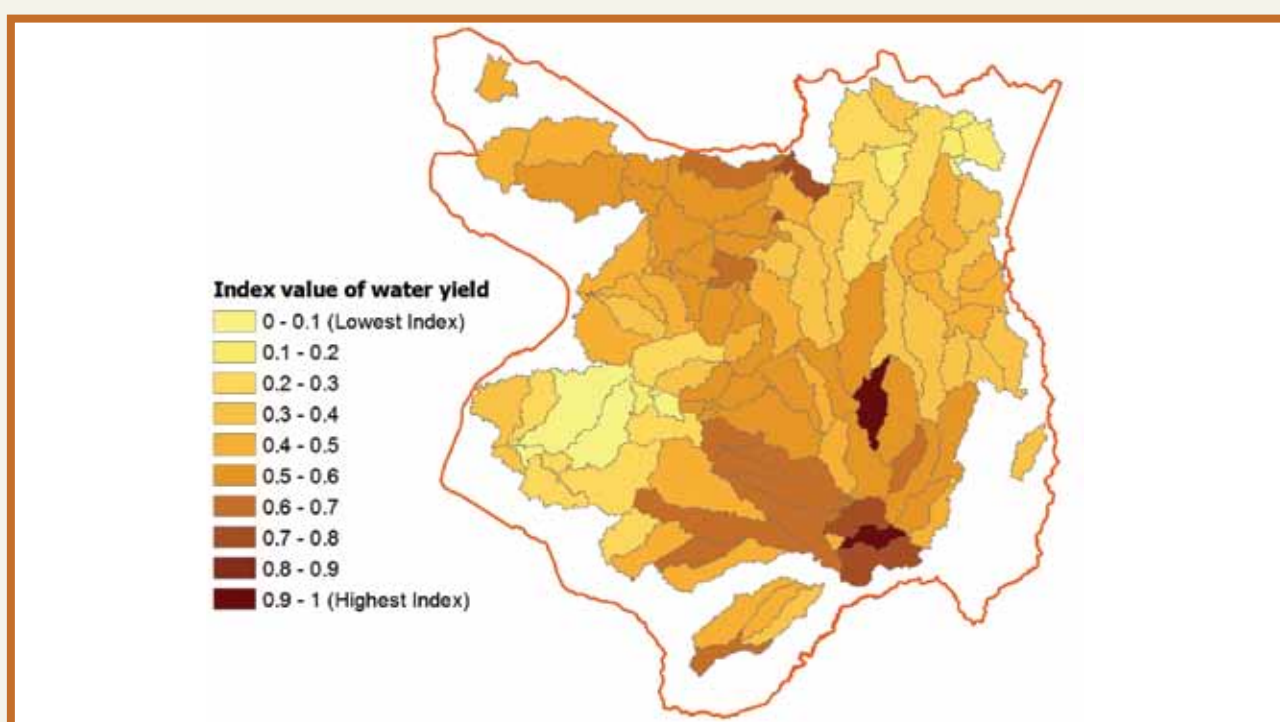
The annual average water yield on a landscape is defined here as the annual average quantity of water produced by a watershed that does not evapotranspire (defined as the process of transferring moisture from the earth to the atmosphere by evaporation of water and transpiration from plants), and is therefore left on the surface. Natural forests regulate the water cycle by absorbing and storing water in tree roots. Without trees the process is disrupted and water is less easily absorbed.

While all of the water yield is not available to downstream users, its relative distribution across the landscape can offer insights into the current availability of, and potential changes to, water supply for human uses. The InVEST Tier 1 water yield model is designed to evaluate how land use and land cover affect annual water yield across a landscape. This water balance model can accommodate areas with minimal access to data, and can be used with globally available data sources on annual precipitation and dryness indices (Zhang et al. 2001, Budyko and Zubenok 1961, Milly 1994). Changes in annual water yield can be both positive and negative: they may result in flood reduction, drought or seasonal instability in the water supply. This section outlines the findings of the mapping of water yield in Mondulkiri and the findings of the valuation of water yield, before concluding and making recommendations for future research.

9.2 Results of the Mapping of Annual Water Yield

The areas in dark brown on the baseline map of annual water yield in Figure 14 indicate the areas with the highest water yield (highest volume of accumulated water in millimeters). The future scenario maps in Figure 15 show the changes in annual water yield in 2030 relative to 2010 for each scenario. The increases in annual water yield are depicted in blue/turquoise (represented in the legend as 'High'). The reductions in this ecosystem service are depicted in red and, to lesser extents, yellow (represented in the legend as 'Low'). Where there has been no or minimal change in the provision of this ecosystem service, the color remains green. These are also areas with the least amount of natural forest available to retain water and regulate the water cycle.

Figure 14: Baseline map of annual water yield by sub-watershed (in pixels)



Conservation Scenario

There is a higher prevalence of red than blue on the Conservation scenario map in Figure 15, demonstrating the reductions in water yield, especially degraded forest areas newly allocated to rubber plantations. There is a 1% reduction in water yield under this scenario as compared with the baseline therefore the impact is relatively little.

The area in white in the South of the province on all the maps indicates where no “Plant Available Fraction” data was available. The area that lacked data represents 1.5% of the province area (21,239 hectares).

Green Economy Scenario

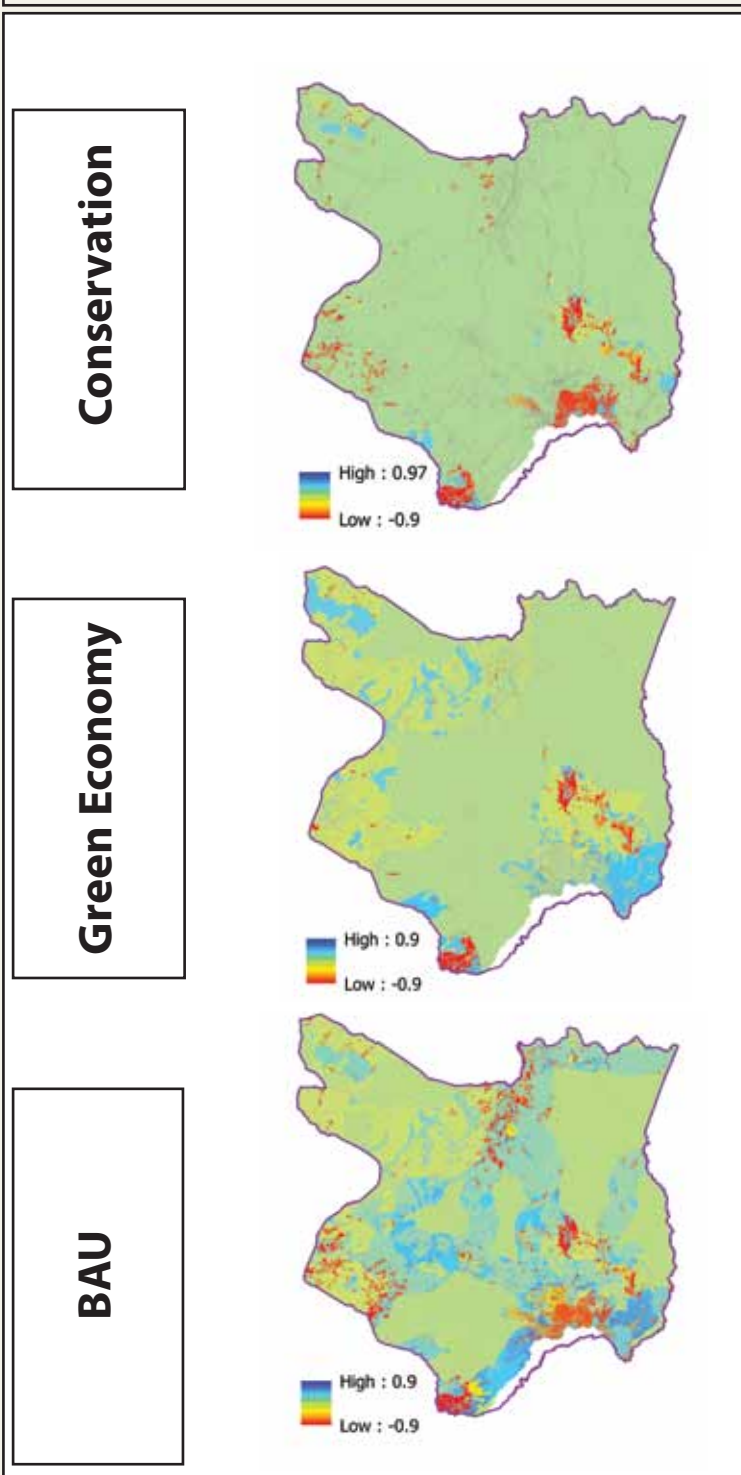
In 2030, there are areas of increased water yield as depicted in pale blue and turquoise in Figure 15. These are mostly in areas where there will be deforestation for rice farming or for sustainable agricultural development practices. The areas in red show reductions in water yield (mostly in former degraded forest areas allocated to ELCs for rubber plantations), while the areas in yellow show no or minimal change as compared with the baseline map. Overall there is a 3% reduction in water yield under this scenario which is very little.

Business as Usual Scenario

Under the Business as Usual scenario (the BAU map in Figure 15), in 2030 there is less of this ecosystem service available as a result of the higher deforestation. The areas in red show reductions in water yield where trees in rubber plantations are able to absorb water. However there is a higher prevalence of areas in turquoise blue which shows increases in water yield.

The turquoise areas, in the middle of the province, show the concrete roads and surrounding 5km buffer for settlement and agricultural purposes. There would therefore be fewer trees in these areas that can absorb the water in the rainy season to be released in the dry season, a decline in evapotranspiration and an increase in surface water. However, the findings of this model show that increases in water yield under a BAU scenario are not significant: there is a 1% increase in water yield under a BAU scenario. This, however, does not take into account seasonal variation which is likely to become even more extreme under this scenario, with even wetter wet seasons and drier dry seasons (Mac Sweeney et al. 2008).

Figure 15: Gains and losses under future scenario in annual water yield (in pixels)



9.3 Results of the Valuation of Annual Water Yield

The approach used to estimate the value of forests in regulating water yield applies a meta-analytic value transfer method.¹² Since this ecosystem service can currently only be modelled in InVEST to estimate the relative scale of provision, it is not possible to estimate economic values directly. The estimated relative scales of provision was used as an explanatory variable in a meta-analytic value function, and used to predict the value of water yield per patch of forest in Mondulkiri.¹³

A Geographic Information System (GIS) was used to construct a database with information on each patch of forest in Mondulkiri. 986 forest patches with a total area of over 1.2 million are represented in the database. The data included information on the relative scale of the water yield service derived from InVEST output for each future scenario. The data on forests in Mondulkiri were inputted into the meta-analytic value function to estimate patch specific values for water yield.

Forests play a pivotal role in the regulation of water yield. Therefore the estimated value function for water yield regulation by tropical forests was calculated under each future scenario. For water yield, the mean and median value of water yield per hectare of forest is higher under the GE and BAU scenarios, than the Conservation scenario. This is driven by the effect of scarcity on the value of water yield. As the forests decrease, the marginal value (per ha) of remaining forest increases.

The loss in total annual value of water yield relative to the baseline is nevertheless much higher under the BAU and GE scenarios, as Table 4 shows. Almost \$7 million per year is lost under a BAU scenario.

Table 4: Annual value of water yield in 2030 (US\$)

	Conservation scenario	Green Economy scenario	BAU scenario
Mean (US\$/ha)	+88	+115	+123
Median (US\$/ha)	+72	+95	+103
Change in total annual value ¹⁴ (US\$, 000s)	-1,303	-6,001	-6,827

Losses in water yield have a direct impact on local households as they currently represent a large proportion of household income. Under the BAU scenario, the loss of NTFPs and water yield, would be equivalent to losing approximately 50% of local household income. The reduction in the provision of these two ecosystem services in Mondulkiri, would result in large reductions in household welfare in Mondulkiri, if these services were not replaced. It would be very difficult to substitute these services due to the irreplaceability of the role natural forests play in regulating the water and climate cycles and providing useful products (e.g. NTFPs).



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¹² Meta-analytic function transfer uses a value function estimated from the results of multiple primary studies representing multiple study sites. A value function is an equation that relates the value of an ecosystem service to the characteristics of the ecosystem and the beneficiaries of the ecosystem service. Since the value function is estimated from the results of multiple studies, it is able to represent and control for greater variation in the characteristics of ecosystems, beneficiaries and other contextual characteristics (Brander, 2013).

¹³ Forest patches are distinct parcels of forest. The 986 forest patches assessed in Mondulkiri cover a total area of 1,238,781 ha, with an average size of 1,256 ha and range in size from less than 1 ha to a maximum of 818,159 ha.

¹⁴ Change in total annual value is computed relative to the baseline level of service provision.

9.4 Conclusions

The InVEST water yield model shows that on an annual basis, more water is available in each land parcel when there are fewer trees. The change in water yield under any scenario is relatively modest relative to current water yield. This change could have either positive or negative social and environmental impacts that cannot be investigated using this simple model.

Increased water yield under the BAU scenario, for example, might result in more water being available to people downstream, at least in the short term after deforestation has occurred. However, it could also lead to more flooding. Long term effects of extensive deforestation could include changes in rainfall patterns, or losses in water retention capacity in the soil due to loss of roots and changes in soil structure, which could lead to increased variability in the hydrological cycle. This could manifest itself as flash flooding in rainy seasons, followed by water shortages in dry season as the water is no longer held in the soil over time and released gradually over the year, but all released shortly after it falls as rain. Likewise, the modest decreases in water yield under the Conservation and Green Economy scenarios could translate to reduced water availability downstream in the short term, but could also imply reduced flood risk or a more even seasonal distribution of water supply.

The water yield model used in this analysis does not address these possible long term implications. A recommendation for future research is assessing how the scenarios would influence seasonal water yield fluctuations, assessing how that might impact the well-being of people. A water yield seasonal variation InVEST model is currently being developed. Once ready, it should be applied to the Monduliri context. It would also be valuable to incorporate climate change projections and assess how these might affect water yield.

The economic valuation results show that a reduction in forest area results in reduced water provisioning (because there is less forest to provide this benefit), which perhaps better reflects the long term implications of deforestation. Whereas the InVEST model results indicate larger volumes of available water in the near term after deforestation (with ensuing positive or negative impacts on people and ecosystems), the valuation exercise hints at the long term implications of this forest loss, for example., after any initial water yield increases resulting from deforestation, eventually the reductions in forest area on the landscape will result in lost water yield and ensuing economic damages, assuming the relationship between forest area and water yield in the valuation model holds for the landscape.

A sustainable financing option to better manage water as a resource could be Payments for Watershed Services (PWS). PWS are defined as contractual and voluntary transactions where a 'buyer' agrees to provide some kind of compensation or payment to a 'seller' conditional on delivery of a hydrological ecosystem service, or implementation of a land use or management practice likely to secure that service (Wunder 2005). PWS is a way of regulating the water supply (water yield), water quality (nutrient reduction), and erosion control (sediment retention), where population centers are among the beneficiaries. To do so, an Environmental Impact Assessment to international standards should be conducted by an external party. In addition, any PWS and/or improved watershed should not negatively impact current livelihoods biodiversity or land use.

10. HABITAT QUALITY

Habitat quality¹⁵ is defined in this study as habitats that are suitable for the following wildlife species: Asian elephants, white rumped vultures and tigers, the latter of which are considered functionally extinct in Cambodia but which the country is trying to bring back into the wild by creating more enabling conditions such as enhancing the quality of potential habitats. These wildlife species attract tourism and provide recreational benefits as well as serve to contribute to the food chain on which we all depend.

Habitat quality depends on suitability for the wildlife to stay there for extended periods of time and the proximity and intensity of threats to those habitats. The main threats to habitat quality were assessed to be: rubber plantations, field crops, orchards, paddy fields, swidden agriculture, village garden crops, built-up areas, national roads, provincial roads, pave-way roads, and pathway roads. The proximity of threats was measured by assessing the distance between the three species' habitats to any of the above-mentioned threats and the intensity of threats was measured by how severe a threat is considered to be.

¹⁵ These three species were selected amongst eight endangered and critically endangered species (IUCN list) to ensure that different types of habitats were represented. Mondulkiri has been recognized as one of the most suitable areas for recovery of tiger population density.

*Figure 16:
White-rumped Vulture*



*Figure 17:
Asian Elephant*



*Figure 18: A tiger
in Mondulkiri in 2007*



10.1 Results of the Mapping of Habitat Quality

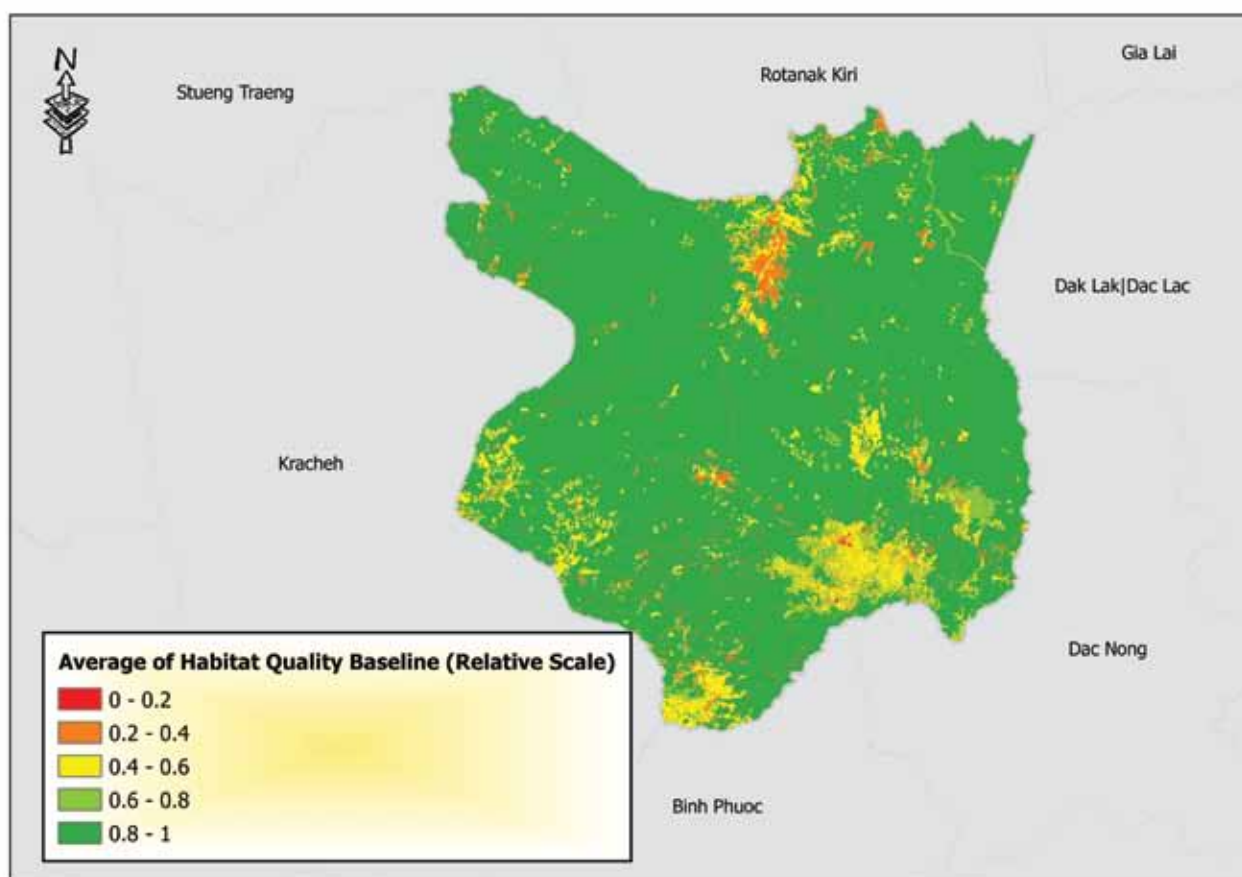
The areas of land that would be considered as suitable habitats for these three wildlife species are located in Phnom Prich Wildlife Sanctuary, Mondulkiri Protected Forest and some parts of Seima Protected Forest. Habitat quality is therefore highest in areas with dense forest. These areas offer the most suitable places for shelter as well as a variety of sources of food as a result of the rich biodiversity of the area and the rich concentration of evergreen trees.

Currently, according to 2010 data on land use cover, the majority of Mondulkiri provides suitable habitat quality for wildlife, as shown in Figure 19. Areas in green, on this map show areas that are conducive for wildlife habitats, while areas in yellow, orange and red, indicate areas less suitable or unsuitable for wildlife habitats. The areas in yellow are non-forest areas therefore fail to provide sources of food, drink and shelter that these species need. The establishment and effective governance of wildlife corridors is needed to avoid human-wildlife conflict.

Conservation Scenario

By 2030, it is assumed that there will be a rubber plantation in the southernmost tip of the province and potentially other rubber plantations and a pine tree plantation in the southeast of the province. These are represented in red on the Conservation map (Figure 20), as these are unsuitable locations for all the above-mentioned wildlife species due to a lack of biodiversity and/or a lack of diversity in trees etc. However there are the fewest patches of 'red' in this scenario as compared to the others therefore this scenario is considered the most ideal in terms of habitat quality.

Figure 19: Baseline map of Mondulkiri habitat quality (in pixels)



Green Economy Scenario

By 2030, it is assumed that there will be planned rubber plantations in the west and the south of the province (depicted in red in the Green Economy maps in Figure 20), as well as some rice fields / new agricultural areas in the north (depicted in orange). The areas in yellow in the south represent non-forest areas. The land uses that are least suitable for elephants, tigers and white-rumped vultures are mono-crop plantations as these do not provide the required biodiversity, clean water and other necessary conditions which natural forests do. There is a larger proportion of areas suitable for wildlife (depicted in green in the GE maps in Figure 20) under this scenario than under the BAU scenario. However the Conservation scenario is the optimal scenario in the provision of this ecosystem service.

Business as Usual Scenario

By 2030, the amount of land left available to these three species under a BAU scenario is very limited as a result of economic development activities and the considerable reduction in natural forest. The areas in orange in the BAU maps in Figure 20 indicate the areas that will be less suitable for wildlife species as a result of the assumed road development plans and subsequent 5km buffer zone which will become settlement and new agricultural areas. The areas in red in the west of the province are assumed to be rubber plantations while in the southeast of the province, the area in red is assumed to be a planned pine tree plantation. Neither a rubber plantation nor a pine tree plantation can provide the diversity of food sources, and shelter necessary for these species to live and thrive.

10.2 Conclusions

Habitat fragmentation and loss of large predators such as tigers can have widespread and sometimes surprising impacts on ecosystems such as changes in vegetation and water quality. The loss of these species, that are part of the web of life, can disrupt food chains and other negative impacts on humans (Estes et al. 2011). The ideal locations for wildlife, and in particular Asian elephants, tigers and white-rumped vultures are natural forests, particularly in the Protected Areas and Protected Forests. Mono-crop plantations are the least suitable habitat quality for wildlife species as these areas fail to provide the services and food sources that natural forests currently provide. The Conservation scenario is the most ideal however even the Green Economy scenario provides more spaces conducive for wildlife species than the BAU scenario while at the same time conserving the existing wildlife corridors.



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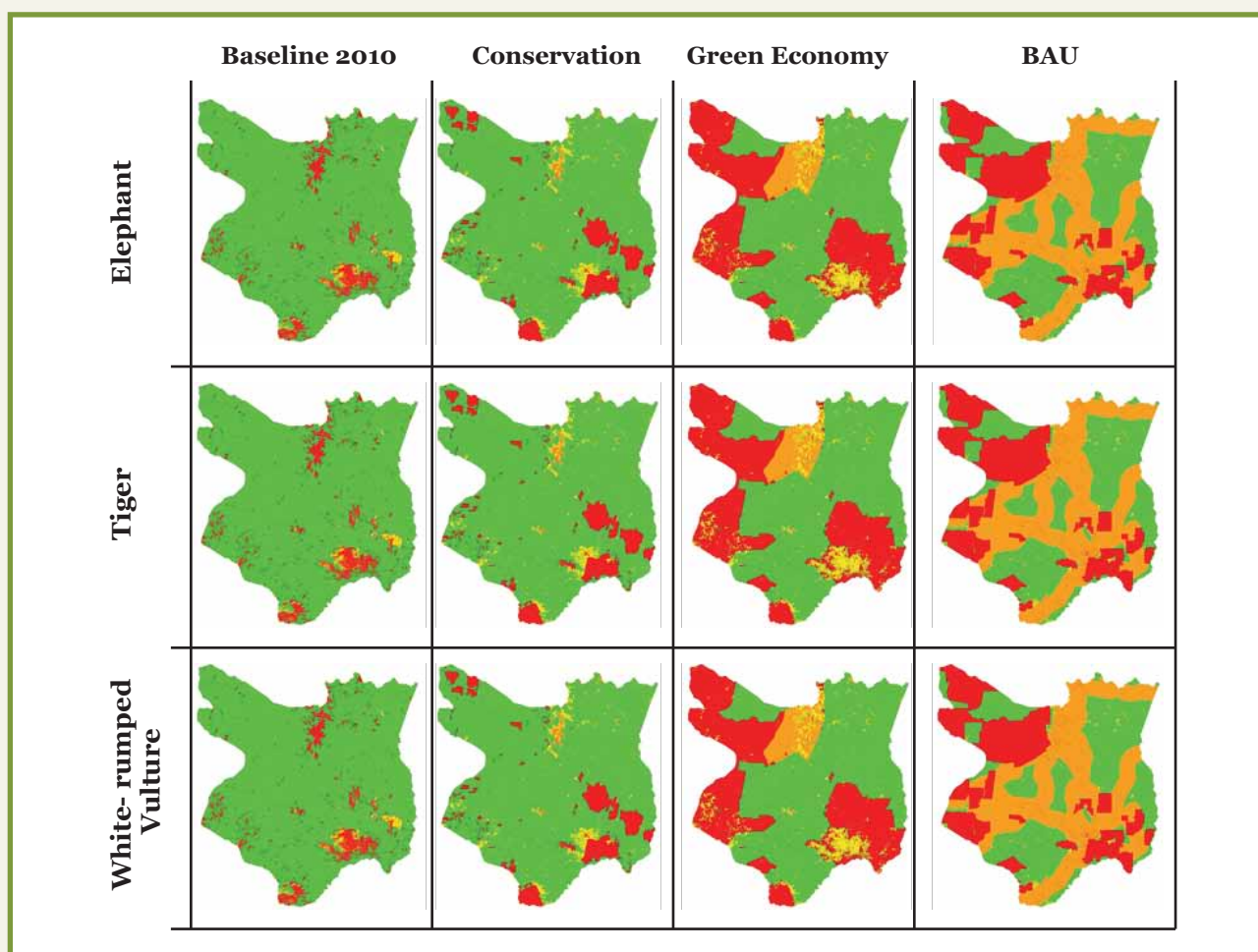


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Figure 20: Habitat quality for white-rumped vulture, tiger, and elephant under each future scenario (in pixels)



The model used to calculate habitat quality is a fairly simple model and other, more sophisticated modeling for biodiversity needs would be recommended to confirm the results. Additional field verification for habitat quality would be required. For more accurate results, more secondary data is required such as the most up to date Land Use and Land Cover maps and a wildlife density survey. It was not possible to collect information regarding: which areas wildlife cover when travelling; where they travel; and the temperature, elevation, and land-use type of habitats, therefore the range of habitats included in this study was large and unspecific. More data on the behavior patterns of the species regarding where they travel, which areas they use for hiding, foraging for food, resting should be collected and analyzed.

In spite of the limitations, the results demonstrate the importance of forests in their role as habitats of endangered or critically endangered species as well as for providing the enabling conditions to re-introduce tigers in the landscape. Protecting the forests protects the wildlife that inhabit them. Sustainable financing mechanisms can go some way to supporting and strengthening forest protection. Plantation owners can also provide support in the protection of natural resources and to the maintenance of biodiversity corridors within these plantations. Investing in natural resources in the short term can result in long term benefits. Safeguarding natural capital ensures the continued flow of ecosystem services enabling water quality to be maintained and soil to remain fertile to the benefit of plantation owners who depend on these services for sustained production of rubber or pine. Therefore as it would be in their interest to contribute resources to the protection and maintenance of ecosystem services, these financial resources could be used for forest and wildlife protection.

Ecotourism is an additional way of making substantial economic returns from investing in wildlife conservation. WWF-Cambodia believes that ecotourism can help to create additional opportunities to sustain community livelihoods in the landscape, to raise awareness among community members about the value of forests and wildlife, and to co-finance PAs.

11. SEDIMENT AND NUTRIENT RETENTION

Sediment and nutrient export in small quantities is good for the fertility of the soil and makes land suitable for growing crops. However when there is too much sediment export and too much nutrient export, these can flow into the rivers changing the acidity levels and polluting water channels. Trees help to regulate the balance by retaining sediment and nutrient export. Sediment retention and nutrient retention are referred to in this section to mean the retention of sediment export / nutrient export by trees.

Soil erosion is a significant problem in environments with high rainfall intensity. Forest soils are normally protected by the canopy and stabilized by tree roots and leaf litter. A good root system reinforces the soil and holds it in place reducing the erosive effects of wind, rain, gravity and flowing water (Walker et al. 1996). Land disturbing activities such as logging, tree burning, poor agricultural practices, cause the surface of the soil to form a compacted crust, preventing infiltration (or water on the ground entering the soil) and increasing surface runoff and soil erosion (Van Paddenburg et al. 2012).

River sedimentation occurs when erosion upstream leads to higher sediment loads (or sediment export) in rivers and deposition of sediment downstream. The process occurs naturally and river deltas are formed by sediment deposition, but changes in land use activities upstream may lead to significant increases in the amount of sediment entering a river system (Van Paddenburg et al. 2012). Excessive amounts of sediment can lead to: the deterioration of water quality, as a result of pollutants and harmful bacteria that may be attached to soil particles; algal blooms which block out light that other plants need to grow and reduce the amount of oxygen in the water available for fish; change and often destroy fish habitats and spawning beds; and clog fish gills, impairing their functioning (Walker et al 1996). A build-up of sediment can also lead to a shallower body of water resulting in increased risk of flooding and a reduction in the navigability of water channels, making it more difficult for fishing boats to travel (Fondriest Environmental Inc. 2014).

Because of the importance of the role of natural forests in retaining sediment, otherwise known as sediment retention or erosion control, this ecosystem service has been assessed in this study by measuring and mapping quantities of sediment export to show the current spread of sediment export and how the amount and spread of sediment is likely to change in 2030 under each future scenario.

Nutrients are required for plants to grow. Nitrogen, phosphorus and potassium in particular are the most important contributors to the growth of plants including crops for food. Soil is a major source of nutrients however farmers also add nutrients to the soil when applying fertilizers (which tend to be made up of mostly nitrogen and phosphorus) to enhance agricultural productivity. Forests maintain the levels of nutrients in the soil by retaining nutrients in networks of tree roots thus limiting the runoff of fertilizers into nearby rivers and streams. Deforestation, and the consequent, loss of these root networks can result in a reduction in nutrient retention (the function trees perform to retain nutrients in the soil) and an increase in the flow of nutrients into water systems (NSW 2004; An et al. 2008). This can lead to water contamination, affecting human health. Flooding, which can also increase if there are fewer tree root networks to absorb excess surface water, is likely to increase fertilizer runoff and affect water quality in rivers (Bhagabati et al. 2012).

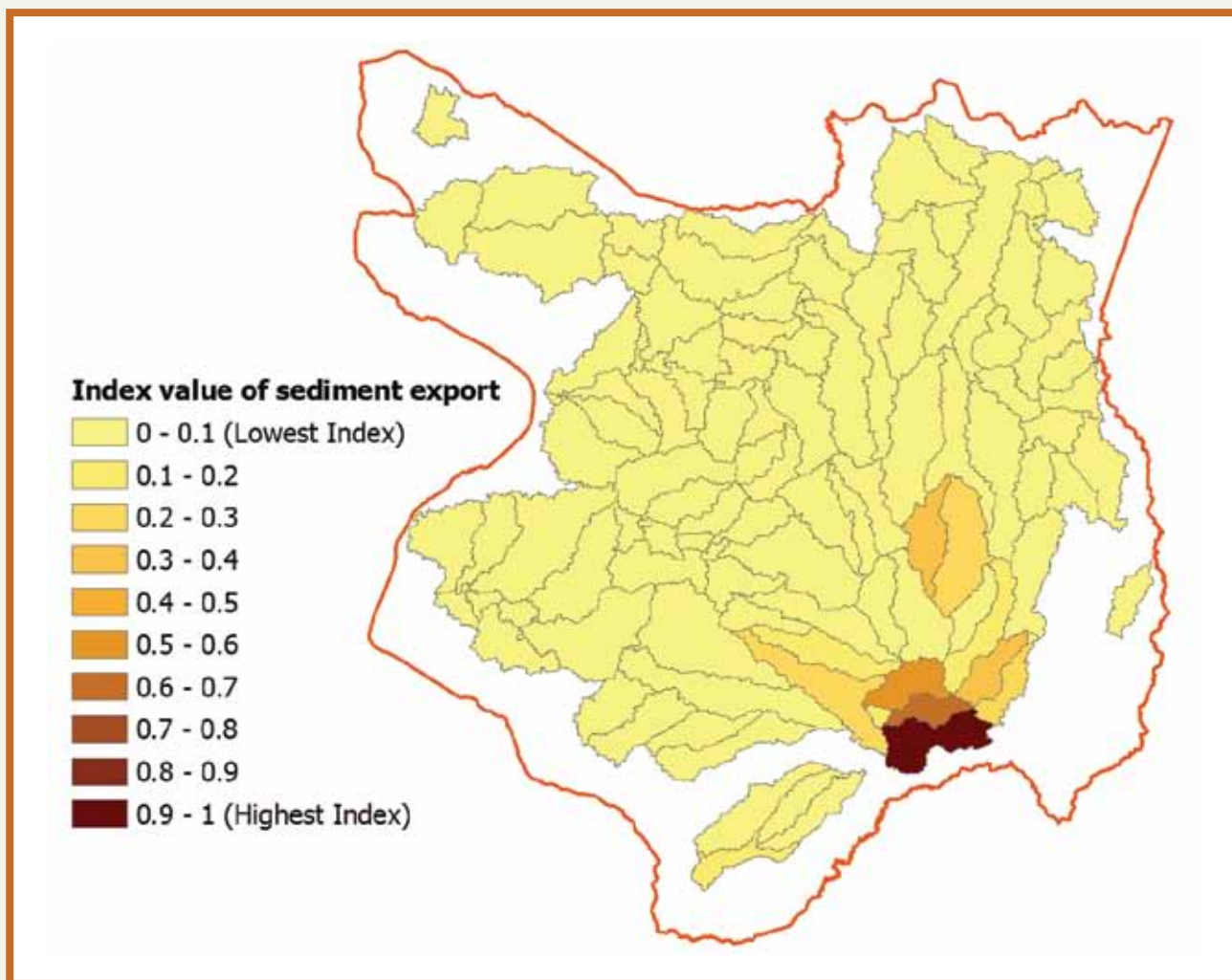
This study estimated the relative importance of nutrient retention, per sub-watershed, as an annual average, using a 'water purification: nutrient retention' model to simulate nitrogen and phosphorus loading into streams and water bodies. The model used can map the amount of nitrogen and phosphorus nutrients (the typical nutrients in fertilizers) that go unabsorbed by the trees.

Where trees are deforested on higher slopes, larger amounts of sediment and nutrient export are accumulated downstream therefore this puts more pressure on trees downstream to retain the sediment and nutrients. Where there are no trees downstream to retain the sediment and nutrients, the water quality of rivers/waterways downstream are affected and sedimentation can occur.

11.1 Results of the Baseline Mapping of Sediment Retention

Only sub-watersheds within the administrative boundary were assessed in terms of their sediment retention. Many sub-watersheds with high levels of sediment export are located in the southern part of Mondulkiri (figure 21). The areas with high sediment export are areas where land has been degraded and soil has entered the water supply it. Areas with low sediment export, shown in pale yellow / yellow in Figure 21 are located in natural forests that are regulating soil processes, for example the sub-watersheds located in PPWS have low quantities of sediment export.

Figure 21: Baseline map of sediment export by sub-watershed (by sub-watershed)



11.2 Results of the Baseline Mapping of Nutrient Retention

The sub-watersheds in dark brown in Figures 22 and 23 indicate that they have the highest amount of nutrients. Some sub-watersheds experience higher amounts of nitrogen than phosphorus because currently fertilizers with higher amounts of nitrogen than phosphorus are being used in paddy fields, floating rice fields, pine tree plantations and rubber plantations. These sub-watersheds in dark brown are most exposed to the chemicals from fertilizers which, as a result of deforestation, are not able to be retained by tree roots and subsequently runoff into streams. This is especially the case where slopes in the form of hills / mountains facilitate nutrient runoff enabling nutrients from fertilizers to enter water channels downstream. This can then lead to the contamination of water downstream. A way to resolve this problem is to maintain the trees in particular those at the top of hills and slopes (upstream) to reduce the risk of runoff and pollution of water downstream.

Figure 22: Baseline map of phosphorus export
(by sub-watershed)

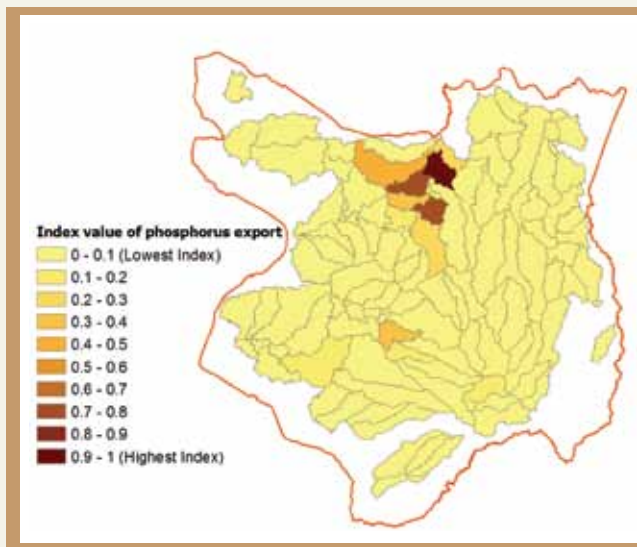
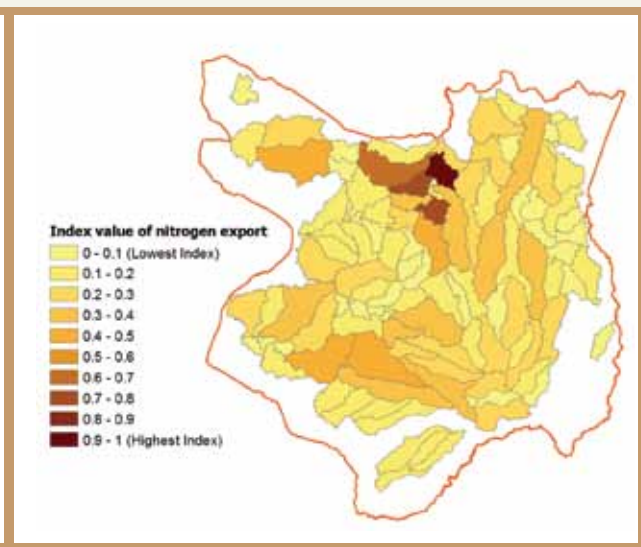


Figure 23: Baseline map of nitrogen export
(by sub-watershed)



11.3 Results of the Future Scenario Mapping for Sediment and Nutrient Retention

Conservation scenario

The areas in blue on the Conservation map of Sediment Export in Figure 24 indicate increases in sediment export in 2030 compared with 2010; these are darkest in areas where there are no trees, for example located just outside the pine tree plantation in the south of the province. While 51 sub-watersheds experience increases in sediment export, a higher number, 62 sub-watersheds, experience a decline in sediment export while two sub-watersheds experience no change in sediment export levels as compared with the baseline (Figure 25). In the same way that the changes in sediment levels in the province in 2030 are minimal, the increase in phosphorus and nitrogen levels in this scenario, represented in blue in the Conservation maps for Total P Export (phosphorus export) and Total N Export (nitrogen export), are also very small. The increase in nutrients, depicted in blue, are likely to be the result of the fertilizer use in the rubber and pine tree plantations located in this area.

The results show insubstantial changes in the levels of sediment and nutrients in Mondulkiri, which is likely to be due to the very slight decline in forest cover under this scenario demonstrating the role of forests in retaining sediment and nutrients, thus reducing the likelihood of sedimentation and fertilizer runoff occurring.

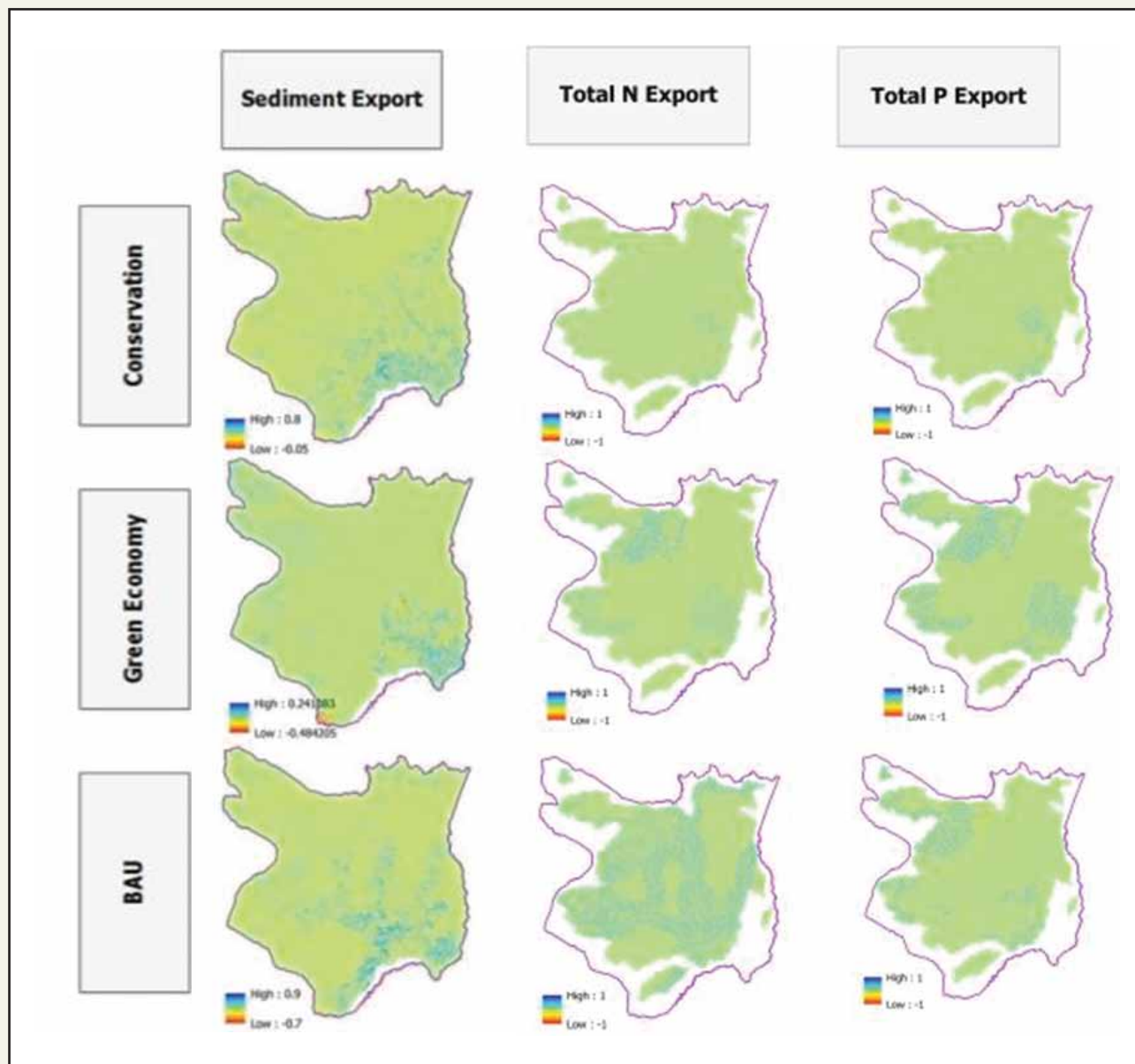
Green Economy scenario

Under this scenario, in 2030 forest cover represents 53% of the total land area, a decline from the baseline figure. As a result of the tree loss there are increases in sediment export, especially in the southeast of the province, as indicated in blue on the GE map in Figure 24 for Sediment Export. Under this scenario, in 2030, 88 sub-watersheds experience increases in sediment export as compared with the baseline, while 26 experience reductions in sediment export, as Figure 22 shows.

The areas with lower levels of sediment export are located in the southwest of the province and are depicted in red on the GE map of Sediment Export in Figure 24. These low levels of sediment export are located in rubber plantations as rubber trees can also provide some retention of sediment. Trees, at the top of slopes, need to be well managed, and better protected, to ensure that they maintain their sediment retention properties and limit sediment and runoff entering and polluting water channels downstream.

Under this scenario, existing rice fields have expanded (not at the cost of deforestation of natural forest however) therefore there is a higher prevalence of areas allocated for agriculture, particularly rice paddy fields, and therefore an increase in the use of fertilizers.

Figure 24: Gains and losses in sediment export, total nitrogen export and total phosphorus export in each future scenario (in pixels)



The GE maps for Total N Export and Total P Export in Figure 24 show an increase in nitrogen and phosphorus, although not as high an increase as in the BAU scenario where there are more unabsorbed nutrients than under any other scenario. In the GE maps the areas with increased nutrients are mostly concentrated in the northwest, southwest and southeast of the province.

BAU scenario

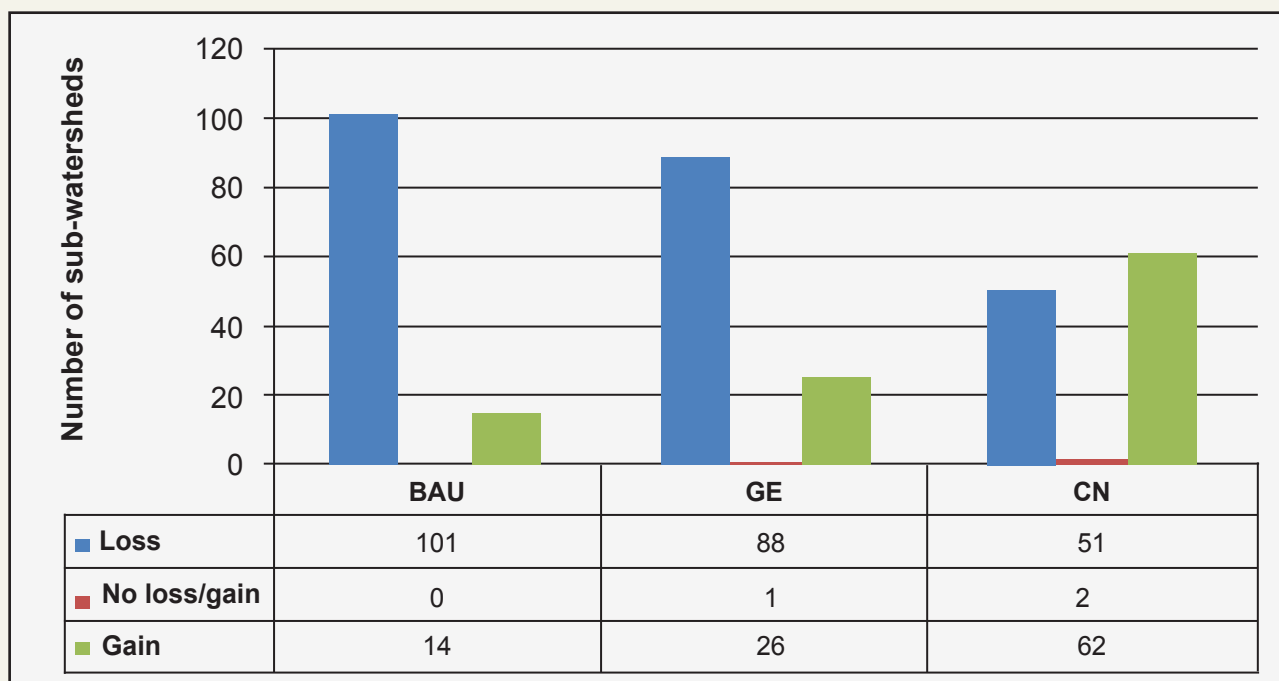
Sediment export and nutrient exports are higher under the Business as Usual scenario. The areas in blue on the BAU map for sediment export in Figure 24 show increases in sediment export where deforestation has taken place for new settlement and agricultural areas in the 5km buffer zones around roads. The BAU map of Total N Export show higher amounts of nitrogen export in areas where trees have been replaced by roads and small scale farms. Nitrogen-based fertilizers are more commonly used for village garden crops than phosphorus based fertilizers in this area hence the higher prevalence of nitrogen than phosphorus in the BAU maps.



However phosphorus accumulates in the northwest of the province in 2030, as demonstrated in the increased blue areas in the Total P Export map for the BAU scenario (Figure 24). Rubber and pine tree plantations in the northwestern part of the province tend to use fertilizers with high concentrations of phosphorus. Consequently phosphorus export accounts for 23% of nutrients distributed in this area.

Figure 25 shows that a greater number of sub-watersheds have more sediment export in 2030 under a BAU scenario than any other scenario; over 100 sub-watersheds have higher amounts of sediment export (or losses in sediment retention) as compared with the baseline. The higher losses in natural forests and increased allocation of land for economic development activities including increased agriculture results in higher levels of nutrients than any other scenario. This can lead to disruptions in the nutrient, soil and hydrological cycles.

Figure 25: Baseline map of the number of sub-watersheds experiencing losses and gains of sediment retention under each future scenario as compared with the baseline (by sub-watershed)



11.4 Conclusions

For a province with local populations so dependent on clean water for drinking and for use in agricultural processes, soil erosion and sedimentation due to the clearing of forests is highly likely to have detrimental impacts on families' wellbeing and household incomes, especially in the south of the province where there is a higher prevalence of villages. A Conservation scenario shows the lowest number of sub-watersheds with increases in sediment export and nitrogen and phosphorus exports. It is certainly an improvement to the current trajectory Cambodia faces: represented as the BAU scenario. In the medium or long term the BAU scenario is more likely to result in potentially irreversible disruptions in ecosystem functions.

The BAU is the most unsustainable of the three scenarios. With an increasing population, and a growing demand for rice, the Green Economy approach is considered to more adequately meet socioeconomic as well as environmental needs. A Green Economy approach is premised on reducing the rate of deforestation and implementing more strategic and collaboratively designed land use plans that enable a better balance between economic development and conservation.

The GE approach minimizes the damage to water quality from sedimentation and nutrient pollution as compared with the BAU scenario, as a result of reduced deforestation, increased sustainable agricultural practices (such as terraced farming), maintenance of trees in strategic locations and reduced risk of fertilizer runoff and sedimentation. This approach, compared to the current trajectory, is more likely to maintain the health of the rivers and streams, on which life depends.

12. MAPPING AND VALUING COMBINED ECOSYSTEM SERVICES

12.1 Introduction

Researchers of RUPP mapped six priority ecosystem services and assigned a value to three of these ecosystem services to identify the priority areas for each individual ecosystem service and the priority areas for the combination of all six ecosystem services (henceforth called: combined ecosystem services). The six ecosystem services were combined by assigning them equal weighting before grouping them. As part of this ecosystem services assessment, the changes in the combined ecosystem services were assessed, measured and mapped for each future scenario.

The successful management of ecosystem services and trade-offs is a key component of any spatial development strategy that aims to increase the supply of ecosystem services for the well-being of humans (Haase et al. 2012). Therefore, identifying the locations and values of ecosystem services in a given area can support decision-makers in government and the private sector to better understand and identify future environmental impacts of land use change, such as road development projects and rubber plantations. Therefore natural capital assessments can be used to support spatial planning processes at both provincial and national levels. The results of this report can support and underpin the development of Monduliri's first spatial plan.

12.2 Results of the Mapping of the Combined Ecosystem Services

The study analyzed the sum values (or total amount) of the six ecosystem services assessed, by commune and by sub-watershed. Figure 26 shows the combined ecosystem services baseline map by commune. The communes in dark brown have a higher amount of combined ecosystem services, whilst the ones in yellow or pale yellow have the least amount of combined ecosystem services. When mapping ecosystem services by commune, the researchers at RUPP discovered that the larger the commune, the higher amount of forest cover and the higher the level of ecosystem services, skewing the results and providing insufficient detail that would enable these results to be useful and integrated into a spatial plan or land use plans for the province.

In spite of this, the commune maps are consistent with the others: Bu Chri (in dark brown on Figure 26) is dominated by Phnom Prich Wildlife Sanctuary, which is rich in natural forest, biodiversity and ecosystem services, while Lomphat Wildlife Sanctuary features in Roya (also dark brown), which explains why these particular communes have high levels of combined ecosystem services. In contrast to this, Monourom, in the south of the province and pale yellow in Figure 26, has the highest population density and the least amount of forest cover, settlements and small scale agriculture dominate. The cluster of blue dots (which represent population centers or villages) in Figure 26 demonstrate the higher population density in this commune.

Only the sub-watersheds which feature solely in the administrative boundary of Monduliri were assessed in this study. The sub-watersheds with the highest combined ecosystem services are represented in dark brown in Figure 27. They are all located in Protected Areas and Protected Forests, usually with relatively few, if any, population centers. The sub-watersheds in pale yellow tend to be a lot smaller, and are therefore able to contain fewer trees than the larger sub-watersheds. Moreover some of these sub-watersheds in yellow are located in areas with high population density or are located just outside of or on the edges of Protected Areas, for example sub-watersheds 376, 371 and 375 which are on the outskirts of PPWS.

The areas in blue and green in Figure 28 show the areas with the highest amount of ecosystem services, and the areas in red show the areas with the lowest amount of ecosystem services. The areas in red represent the areas with no forest and therefore with the least amount of combined ecosystem services.

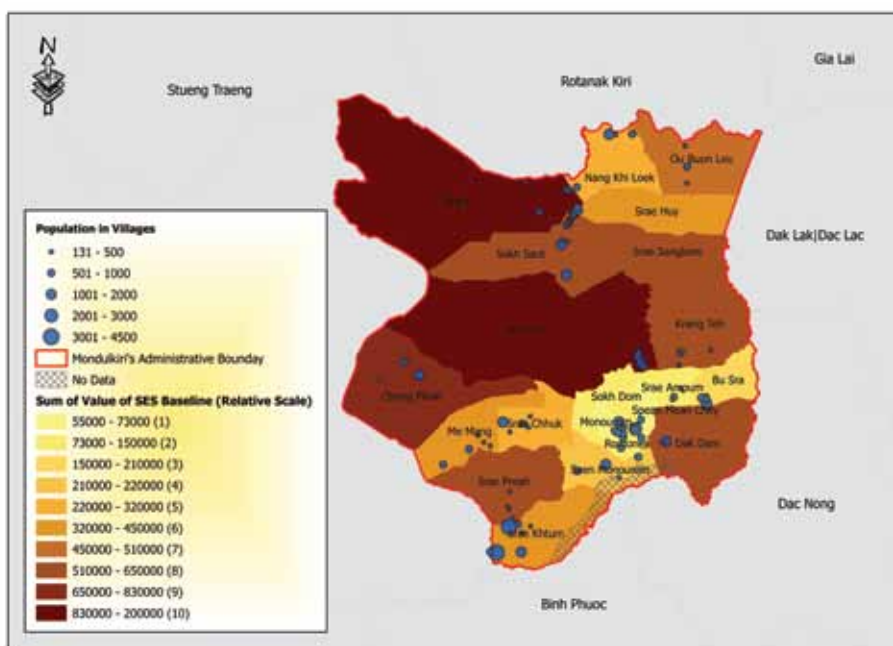


Figure 26: Baseline map of combined ecosystem services (by commune)

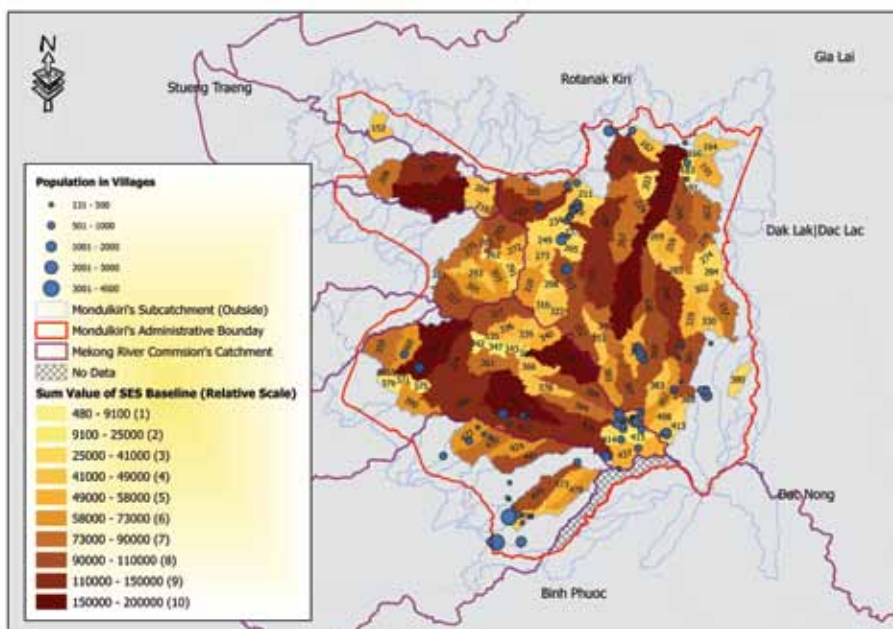


Figure 27: Baseline of the sum of the six ecosystem services (by sub-watershed)

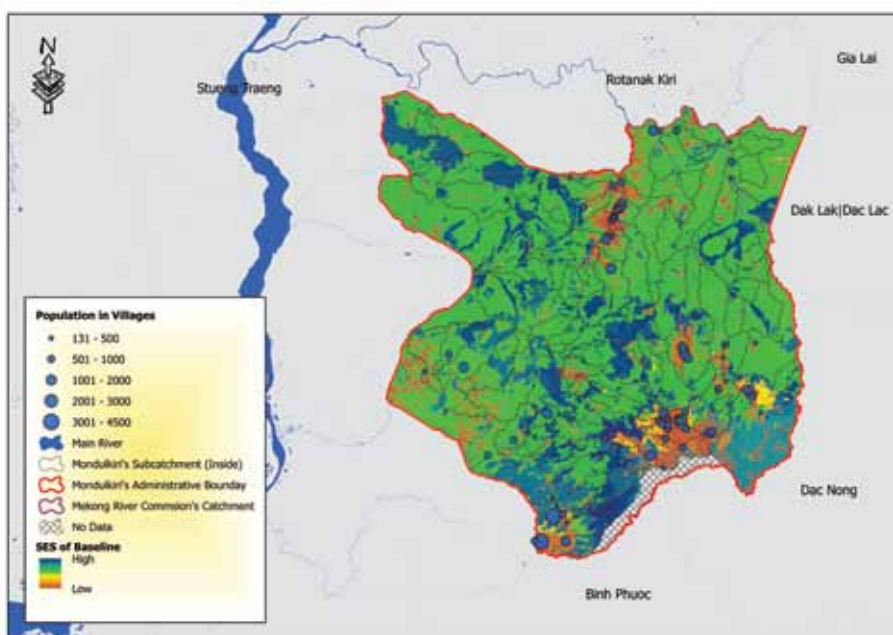


Figure 28: Combined ecosystem services baseline map (in pixels)

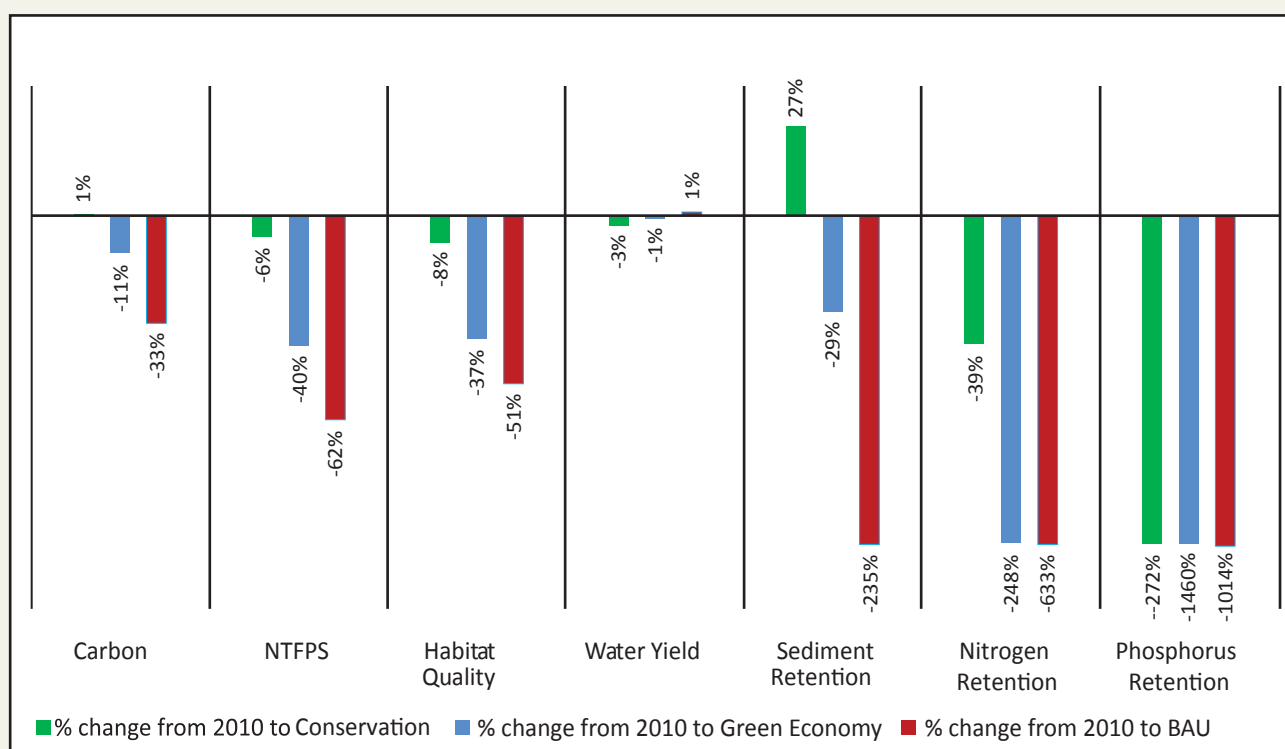
CONSERVATION SCENARIO

The Conservation scenario provides greater protection of natural forests in Mondulkiri, which not only provide provisioning and regulating ecosystem services but also cultural and spiritual benefits. They are an important part of Cambodia's natural heritage and home to an ancestral burial ground for the indigenous Phnong people.

The results show that in 2030, each commune will have lost an estimated 5% of combined ecosystem services, compared with the baseline under this scenario. Most of the communes in the landscape will have lost less than 20% of their ecosystem services by 2030 as compared with the baseline, except one commune, Srae Ampum, where the loss is approximately 30% compared to the baseline, as a result of a rubber plantation that dominates this particular commune. The prevalence of green in the Conservation scenario maps (Figure 29) indicate higher levels of forest cover and ecosystem services. The following communes have no loss or minimal reductions in ecosystem services: Me Mang, Sokh Sant, Srae Huy, Nang Khi Loek, Ou Buon Leu, Srae Sangkom, Srae Chhuk, and Monourom. Communities in these communes will continue to benefit from the benefits provided by the natural forests as these remain relatively intact.

When the combined ecosystem services are aggregated and changes in ecosystem services are measured in percentage terms, it is clear that there are some losses in ecosystem services, notably NTFPs, habitat quality and water yield, but also some gains, e.g. a 27% increase in sediment retention and a 1% increase in carbon storage. In most cases, the changes in ecosystem services under this scenario are less significant: only a 6% loss of NTFPs available for local communities and only an 8% loss in habitat quality for wildlife species (see Figure 29). Additionally, there are less significant losses in nitrogen and phosphorus retention (or nutrient retention) under this scenario than any other scenario. Therefore, there are more gains in ecosystem services under this scenario as compared with the BAU scenario. More research is needed however to assess the opportunity costs of protecting the majority of Mondulkiri's natural forests.

Figure 29: Changes in ecosystem services from baseline to each future scenario (%)



GREEN ECONOMY SCENARIO

When analyzing the results and assessing the tradeoffs, the GE scenario is likely to see an increase in rice productivity in the province in 2030 (not measured in this study) but each commune in the landscape loses 26% of the combined ecosystem services compared with the baseline. Eight communes are estimated to lose 40-60% of their combined ecosystem services by 2030, because of the loss of natural forests in these areas. Those communes are Srae Ampum, Dak Dam, Spean Mean Chey, Sokh Dom, Chong Phlah, Roya, and Sokh Sant, as can be seen in Figure 30. The rest of the communes are anticipated to lose their combined ecosystem services by approximately 20% compared to the baseline.

Under this scenario there is an increase in rubber plantations in 2030 compared with the baseline, notably in the communes: Roya, Chong Phlah, parts of Bu Chri, Srae Khtum, Srae Ampum, Sokh Dom and Dak Dam. Parts of Roya and Sokh Sent will also feature new settlement and agricultural areas, by 2030. This will result in an increase in rubber plantations, food production and house construction, but will also result in higher losses in carbon stock (by 11%), NTFPs (by 40%) and habitat quality (by 37%) as Figure 30 demonstrates. The losses in NTFPs and habitat quality (indicated in orange and red in the GE maps in Figure 31) are higher because the new agricultural areas and mono-crop plantations are unlikely to be able to compensate, year on year, the loss of NTFPs.

The agriculture and plantations are also unable to substitute the rich biodiversity that natural forests provide that are necessary for wildlife species to survive. Rubber plantations can contribute to providing carbon storage minimizing the loss of this ecosystem service, although it is important to note that rubber trees are not as effective at storing carbon as evergreen trees or old forests (Bhagabati et al 2012). By 2030 there will be a reduction in annual water yield of 1%, a relatively small but positive change as there will be less excess surface water, although more analysis is needed to determine the seasonal variations in water yield. In 2030, there is a 29% reduction in sediment retention and substantial reductions in nutrient retention, as shown in Figure 29. Therefore this scenario sees losses in almost all ecosystem services and increases in rubber plantations and agricultural areas.



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Figure 30: Maps of carbon storage, habitat quality and NTFPs in 2030 under each future scenario

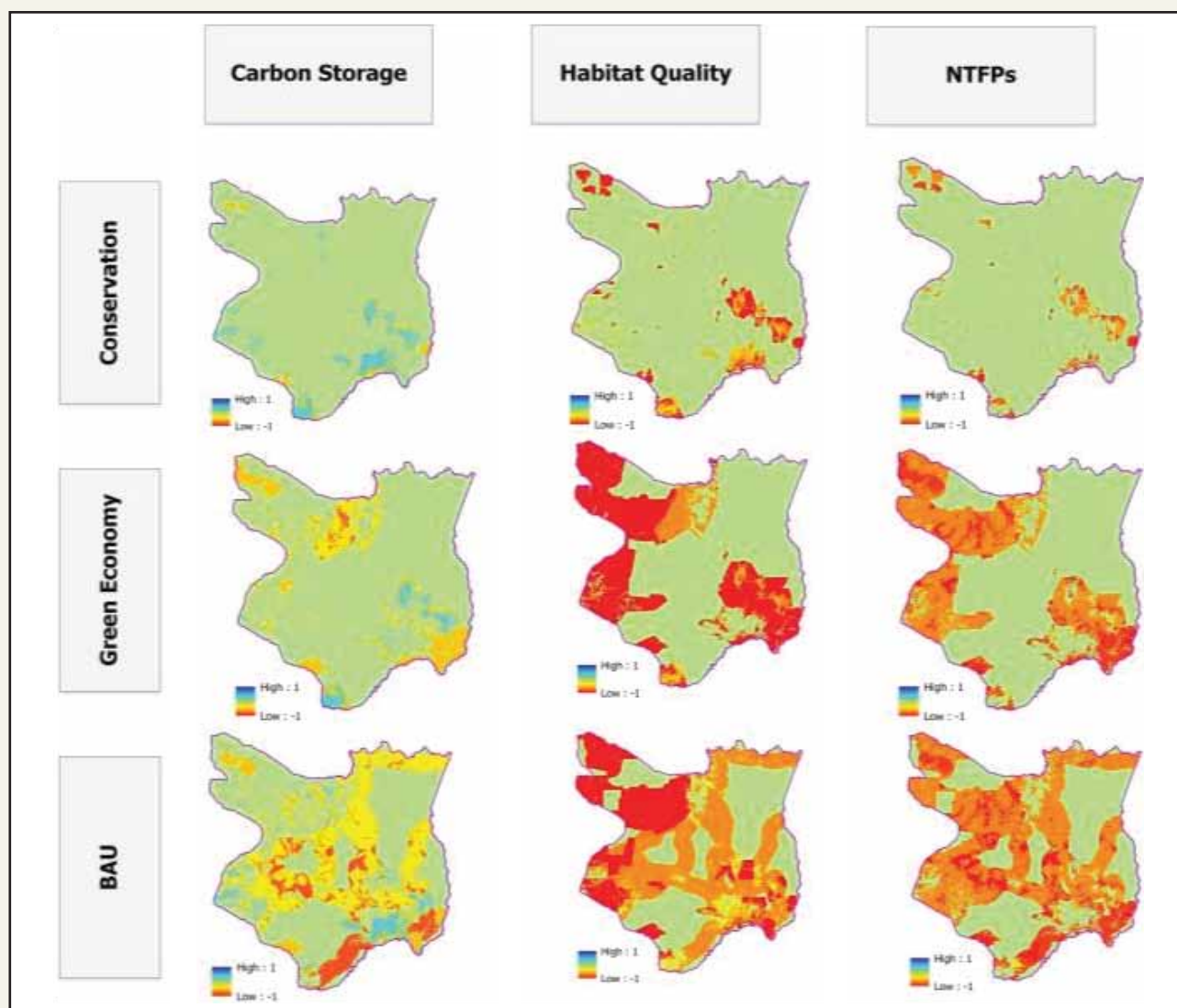
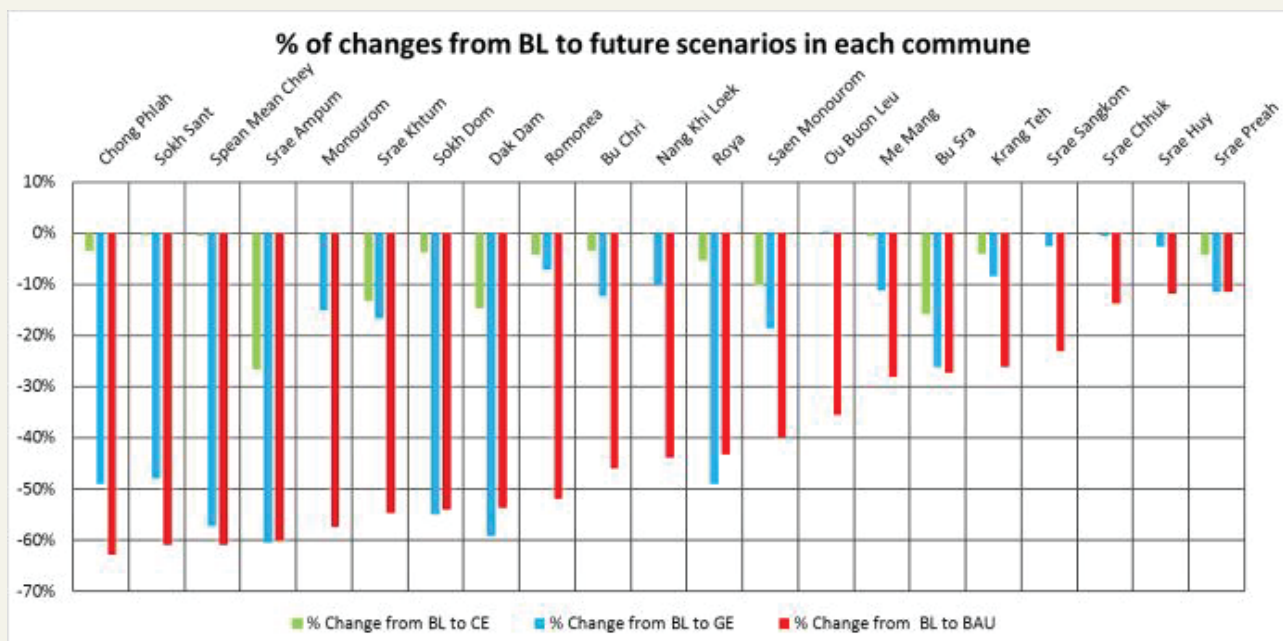


Figure 31: Losses from baseline to each future scenario (in % terms)



BUSINESS AS USUAL SCENARIO

In 2030 there is an increase in rubber plantations, road networks, settlements, and agricultural areas but a loss in combined ecosystem services; on average each commune loses 41% of combined ecosystem services compared with the baseline. Nine communes will lose an estimated 50% of their combined ecosystem services: Chong Phlah, Sokh Sant, Spean Mean Chey, Srae Ampum, Monourom, Srae Khtum, Sokh Dom, Dak Dam, Romonea, as shown in Figure 31. Under this scenario, rubber plantations emerge in Roya, parts of Sokh Sant, Chong Phlah, Me Mang and Dak Dam, while a pine tree plantation is cultivated in Monourom.

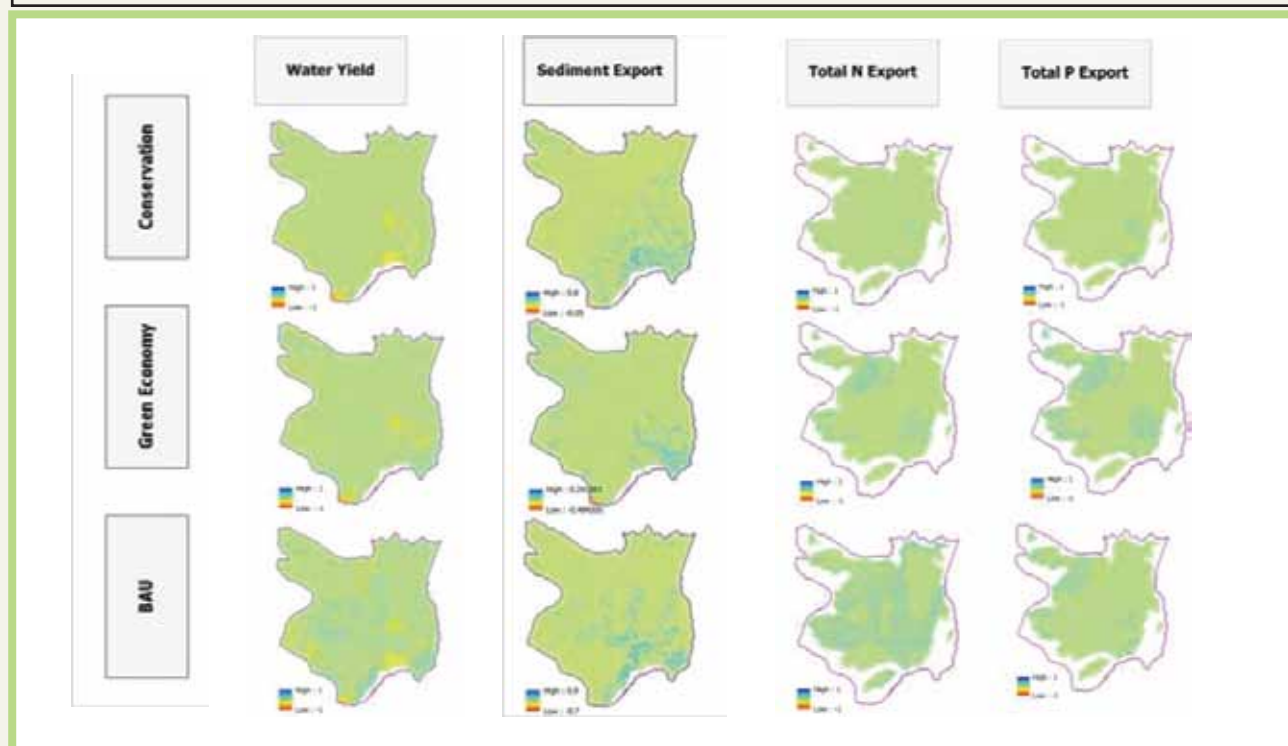
By 2030, there will be an increased amount of: rubber and pine trees planted and harvested; paved roads; settlements; and food production from the new agricultural areas near the new roads. However, there are tradeoffs, most notably a steep decline in every priority ecosystem service measured in this assessment as a result of the significant forest loss. By 2030, under a BAU scenario, there is a 33% reduction in carbon stored (Figure 29), visually represented by the dominance of red, orange and yellow in the BAU maps for carbon storage in Figure 30.

The reduced forest cover, and reduced biodiversity as a result, reduces the land cover suitable for housing wildlife species by 51%. This is most likely due to a reduction in the food sources (or prey as in the case of vultures and tigers) of wildlife species as well as the loss of habitats. This severe loss in habitat quality increases the likelihood of Asian elephants becoming critically endangered and reduces the chances of tigers surviving in this landscape. It also makes it even more likely that other endangered species, such as Banteng and Eld's Deer, will become critically endangered or even extinct in the Eastern Plains Landscape.

The huge loss of natural forest under this scenario results in a 62% decline in NTFPs (Figure 29), as the prevalence of orange and red in the NTFPs map under the BAU scenario in Figure 30 highlights. Unless alternative income sources can be found to make up for the loss, household incomes are likely to be significantly reduced as a result of this decline in NTFPs. It is likely to severely affect the people dependent on NTFPs for survival.

Although this scenario is likely to achieve economic gains, it is highly unlikely that such gains will make up for the losses in ecosystem services in the long term. To replace these lost ecosystem services would require significant financial resources. Failing to substitute these lost ecosystem services in terms of the value contributed to local households would lead to local communities becoming more impoverished.

Figure 32: Maps of sediment export, water yield and nutrient export (nitrogen export and phosphorus export) in 2030 under each future scenario



12.3 Results of the Valuation of Combined Ecosystem Services

An economic valuation of carbon storage, NTFPs and water yield was carried out, both for each ecosystem services and as a combination of all three. Table 5 reports the difference in the annual value of forest ecosystem services in 2030 relative to their annual value in 2010.

The three ecosystem services were aggregated and assigned an economic value, and the results in Table 5 show the changes in their economic value between 2010 and 2030 for each development scenario. By 2030, under the Conservation scenario, there is an increase in the value of the three combined ecosystem services of approximately US\$14.5 million. In 2030, under a GE scenario there are losses in all three ecosystem services as a result of land use change and forest loss representing a loss to the economy of approximately \$370 million to the economy. The most severe loss in ecosystem services comes under the BAU scenario which sees a loss in ecosystem services worth approximately \$1.1 billion. Losses under a BAU scenario are approximately three times greater than under a GE scenario. The increase in the value of ecosystem services in 2030 under a Conservation scenario is as a result of an increase in planned rubber plantations which increase the carbon storage in the province by 2030 relative to 2010; but the provision of NTFPs and water have decreased in 2030. The BAU scenario, which allows for more deforestation than either of the other two scenarios, results in the highest economic losses, which is likely to affect the local populations the most. The individual and aggregated annual values of the three categories of ecosystem services are represented in Table 5.

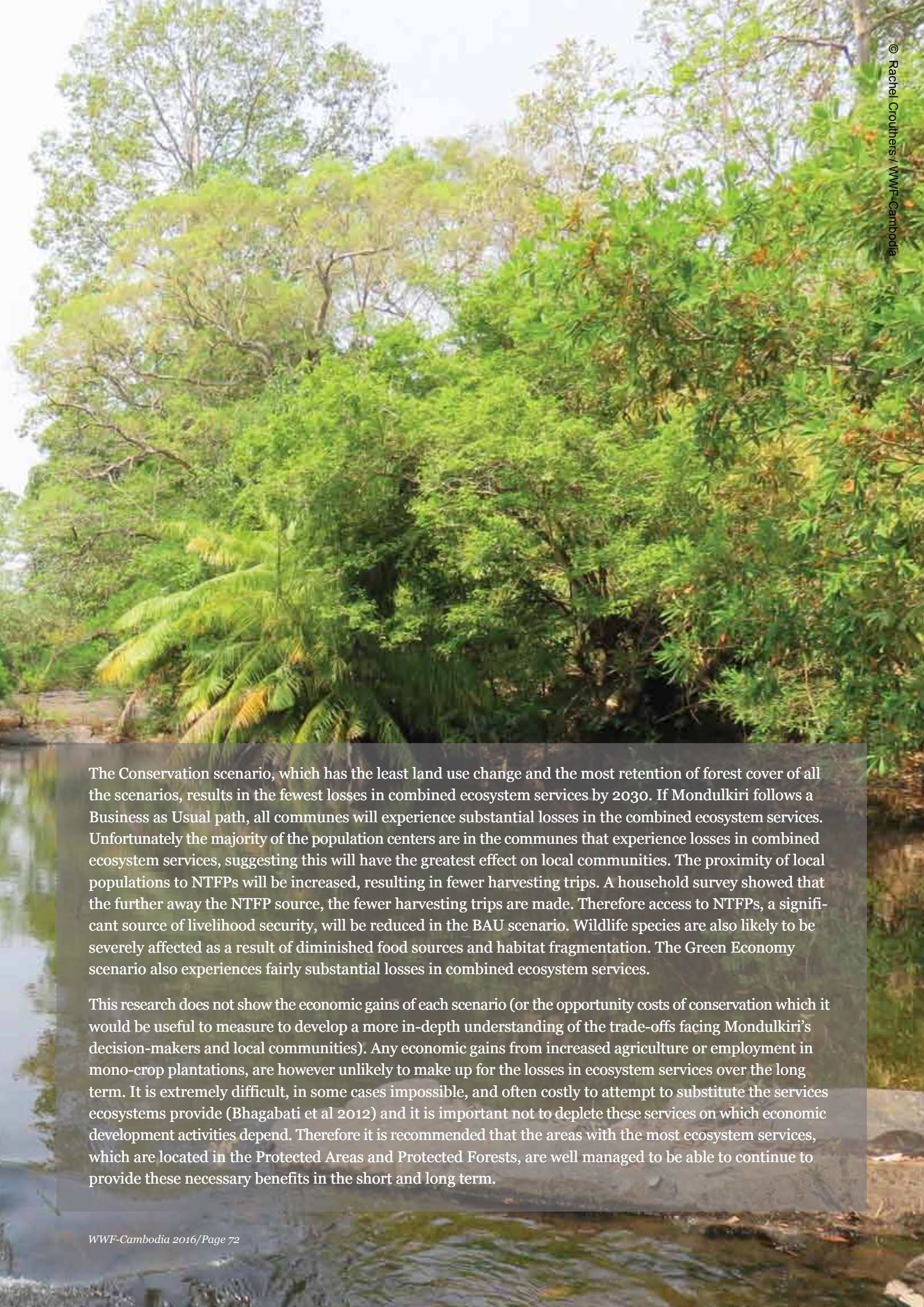
Table 5: Changes in ecosystem service annual values in 2030 relative to 2010 (US\$, 000s)

	Conservation scenario	Green Economy scenario	Business As Usual scenario
NTFPs	-3,551	-10,685	-21,479
Water yield	-1,303	-6,001	-6,827
Carbon (Social Cost of Carbon) ¹²	+19,350	-360,250	-1,067,250
Total	+14,496	-376,936	-1,095,556

12.4 Conclusions

The assessment identified the areas with the highest and lowest amount of combined ecosystem services. Although the communes Bu Chri and Roya had the highest amount of combined ecosystem services, this is likely to be as these communes are larger in size than the others and can capture a larger amount of natural forest and biodiversity. The least amount of combined ecosystem services in the baseline map are in Monourom and Srae Khtum; these communes are dominated by the lack of forest and high population density.

The scenario maps show the increases and decreases in combined ecosystem services in Mondulhiri in 2030 as per these three different trajectories. The spatial maps for each ecosystem service when placed side by side shows marked differences between the three different future scenarios (Figures 30 and 32). The bar charts detailing the losses in ecosystems services in percentage terms (Figures 29 and 31) highlight how large or small these losses are for the province and for each commune.



The Conservation scenario, which has the least land use change and the most retention of forest cover of all the scenarios, results in the fewest losses in combined ecosystem services by 2030. If Mondulkiri follows a Business as Usual path, all communes will experience substantial losses in the combined ecosystem services. Unfortunately the majority of the population centers are in the communes that experience losses in combined ecosystem services, suggesting this will have the greatest effect on local communities. The proximity of local populations to NTFPs will be increased, resulting in fewer harvesting trips. A household survey showed that the further away the NTFP source, the fewer harvesting trips are made. Therefore access to NTFPs, a significant source of livelihood security, will be reduced in the BAU scenario. Wildlife species are also likely to be severely affected as a result of diminished food sources and habitat fragmentation. The Green Economy scenario also experiences fairly substantial losses in combined ecosystem services.

This research does not show the economic gains of each scenario (or the opportunity costs of conservation which it would be useful to measure to develop a more in-depth understanding of the trade-offs facing Mondulkiri's decision-makers and local communities). Any economic gains from increased agriculture or employment in mono-crop plantations, are however unlikely to make up for the losses in ecosystem services over the long term. It is extremely difficult, in some cases impossible, and often costly to attempt to substitute the services ecosystems provide (Bhagabati et al 2012) and it is important not to deplete these services on which economic development activities depend. Therefore it is recommended that the areas with the most ecosystem services, which are located in the Protected Areas and Protected Forests, are well managed to be able to continue to provide these necessary benefits in the short and long term.

There were methodological limitations to this study that future research can improve. It is important to highlight the challenges faced, in order for future studies to take these issues into account. One challenge was the limitations of the data used. For annual water yield, nutrient retention and sediment retention, some of the input data required for the model, used data from other countries which have similar physical, social and environmental conditions as Cambodia which does not represent the local situation and the targeted area. The data sources used and approach undertaken were discussed and explained by local experts, stakeholders and local communities in a series of workshops in 2014-2015, and their feedback on this was sought before it was applied in the model. Therefore this assessment was only able to estimate the relative importance among all sub-watersheds in the study area as observed data for calibration, verification and evaluation was missing.

Due to the uncertainty of the input data it would be necessary to validate the results before serious actions can be taken. The findings, of these two hydrological ecosystem services should therefore be regarded as preliminary assessments of the current state and potential changes in freshwater ecosystem services under the baseline and future scenarios. They can serve as a feasibility study to show the potential effect on the landscape if further deforestation takes place in Mondulhiri and the potential for watershed service based programs in the region. Future modeling of water yield needs to take into consideration seasonal differences to provide a more holistic and accurate understanding of the situation.

These outputs can be improved; the model outputs have not been calibrated or validated with ground measurements, therefore the results should be interpreted as showing relative variation across the landscape and relative changes across scenarios. Since we are basing our recommendations upon the changes in values between different scenarios, and not the absolute values for each of the services, these analyses should be regarded as preliminary assessments of the current state and potential changes in freshwater ecosystem services under the baseline and future scenarios. The results can serve as a pre-feasibility assessment of the potential for watershed service-based programs in the region.

Figure 33: Baseline map of combined ecosystem services (in pixels)

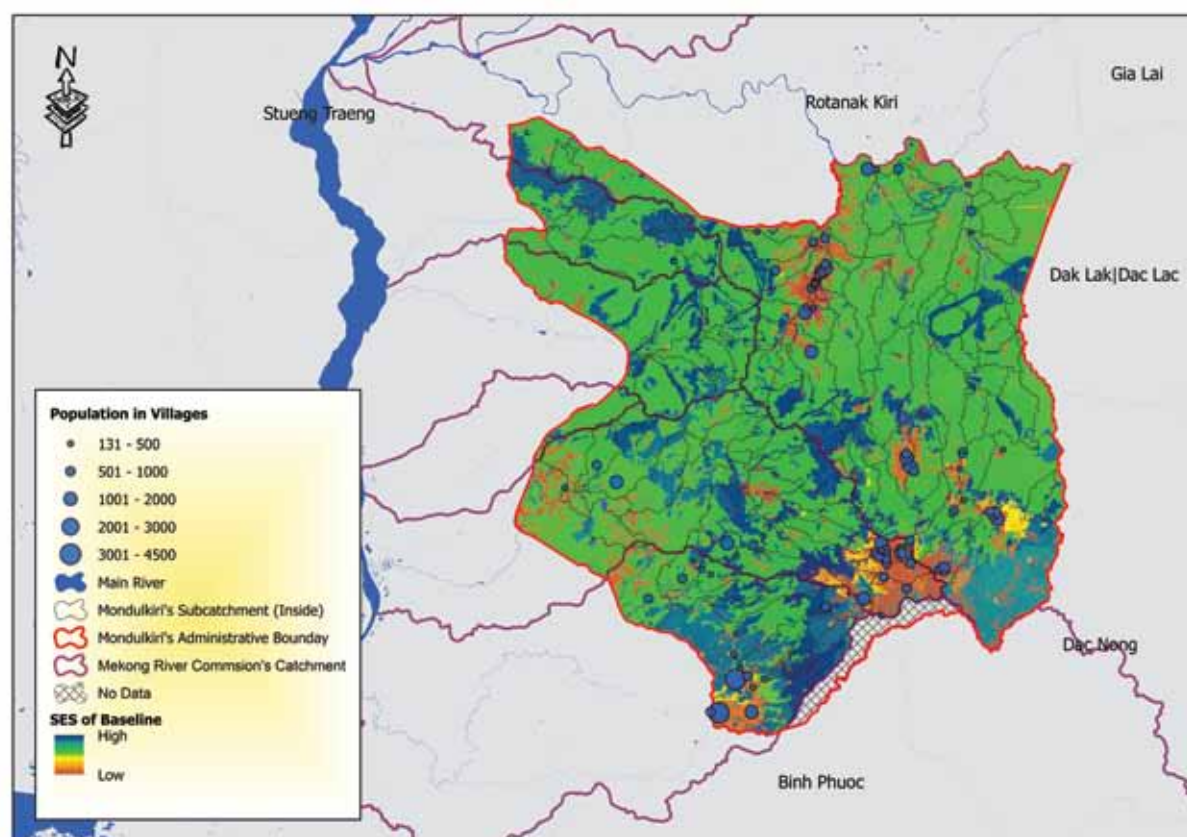


Figure 34: Conservation map of combined ecosystem services (in pixels)

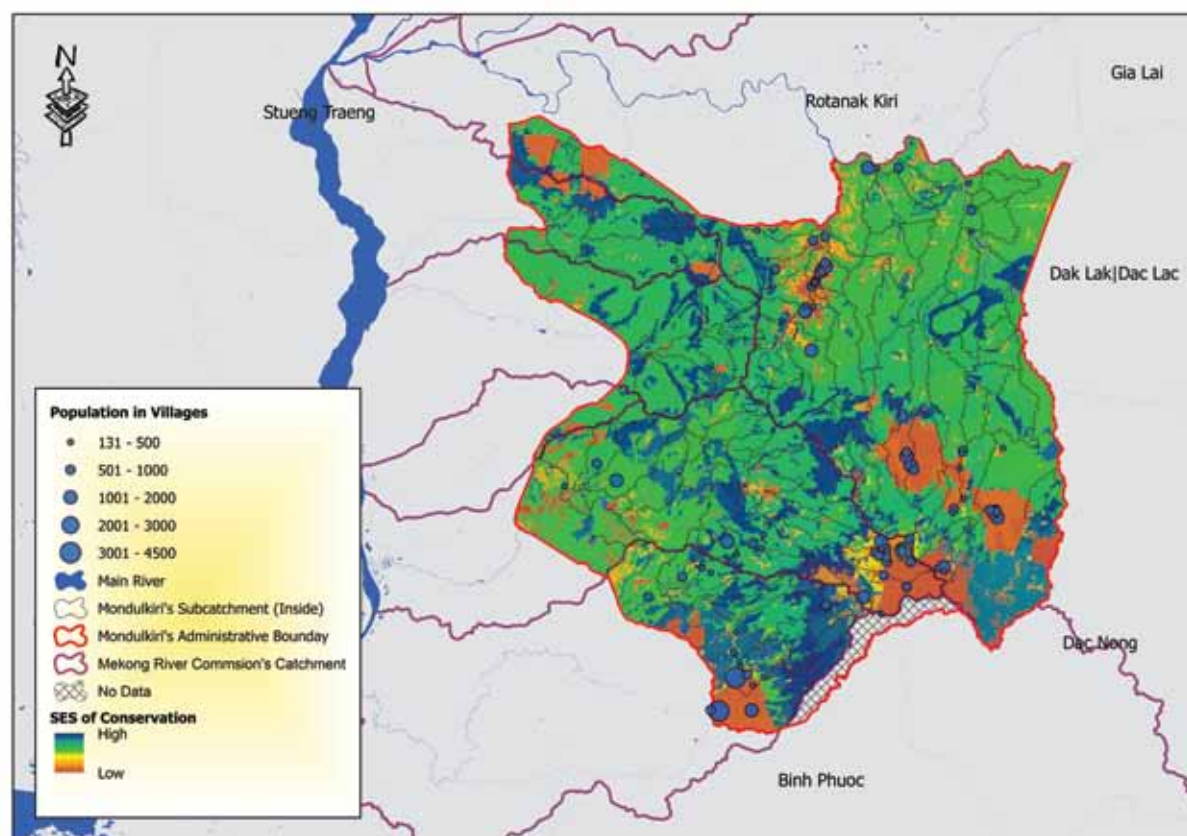


Figure 35: Green Economy scenario map of combined ecosystem services (in pixels)

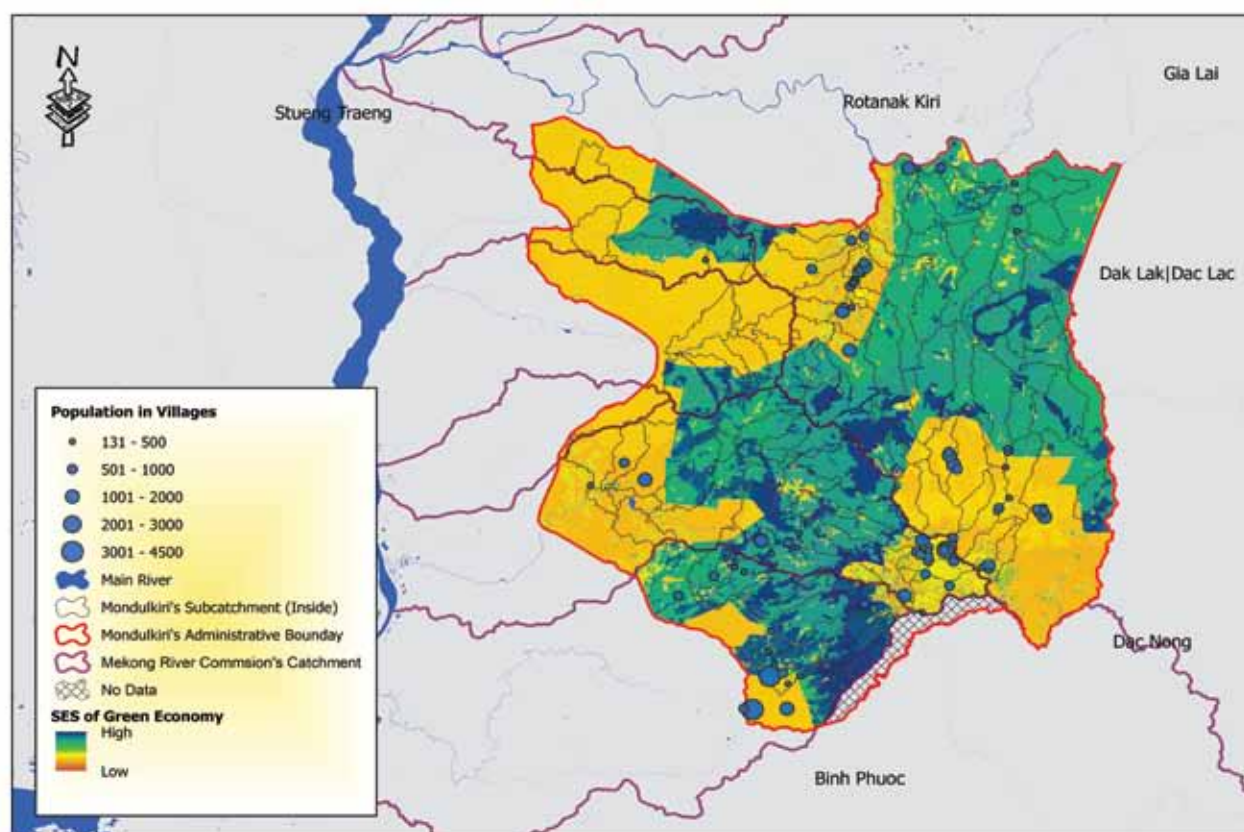
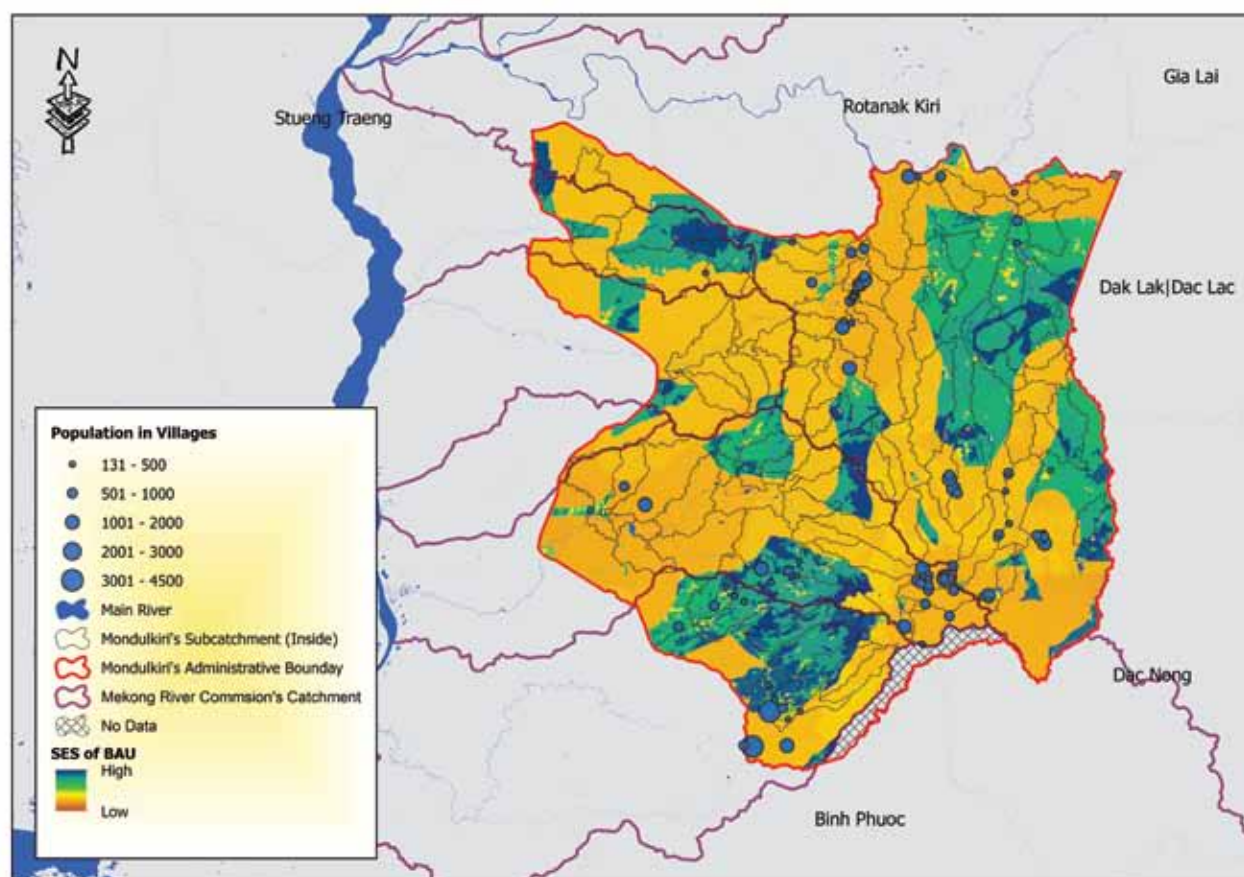


Figure 36: BAU map of combined ecosystem services (in pixels)



13. POLICY RECOMMENDATIONS

The overarching policy recommendation resulting from the Mondulkiri ecosystem services assessment and valuation; and policy analysis, is that the Royal Government of Cambodia (RGC) integrates the Green Economy scenario findings into land use planning processes in Mondulkiri.

Moving towards a Green Economy involves taking into account the tradeoffs between conservation and development by strengthening the protection of geographical areas that are 'hotspots' for ecosystem services and ensuring economic development activities take place outside of these 'hotspots'.

A Green Economy approach to conservation and economic development will enable Cambodia to be more resilient and ensure that Cambodians continue to receive the benefits that ecosystem services provide. Adopting a GE trajectory can enhance Cambodia's climate change preparedness, reduce social inequalities and income disparities, and ensure the country maintains its regional competitiveness.

A Green Economy approach to development provides a more sustainable growth pattern and is aligned with government policies, notably Cambodia's National Green Growth Policy, National Plan on Green Growth and the National Strategic Development Plan 2014-2018 (RGC 2013a; RGC 2013b; and RGC 2013c) and the Environmental Code (in process).

A GE approach requires: 1) ecosystem-based land use planning and management; 2) improved governance; and 3) sustainable sources of finance.

ECOSYSTEM-BASED LAND USE PLANNING AND MANAGEMENT

Ecosystem-based land use planning and management is designed to protect and conserve natural resources and facilitate environmental restoration (Cohn and Lerner 2003). The process encourages decision makers and stakeholders to agree on which areas of land should be set aside for conservation and which set aside for economic development activities. This in turn helps to achieve a balance between keeping Protected Areas as intact as possible for conservation and designating areas for development.

This approach can provide an important platform to facilitate a balanced and green development pathway for Mondulkiri. This ecosystem approach can improve decisions around land use planning and embedding this approach in a policy and legal framework will allow decision makers to make informed decisions on how best to sustain the ecosystem services that the country's natural forests provide. Legal support for this approach would provide PA managers with a strong mandate to protect and maintain the ecosystem services in PAs and PFs and show how these hotspots of ecosystem services are intrinsic to the economic performance of small-holder farms and other private sector activities outside PAs and PFs.

RECOMMENDATION: The Royal Government of Cambodia embeds an ecosystem approach in legal frameworks and adopts ecosystem-based management and planning at provincial level, underpinned by: regular ecosystem services assessments and valuations; capacity building; integration of the results into spatial planning processes; and improved monitoring and law enforcement.

Ecosystem services assessments and valuations are ideal for better identifying and understanding the value of ecosystem services and can be incorporated into spatial and land use planning processes at commune, district and provincial levels. They can assist in the incorporation of land use changes, sustainable resource use, environmental flows, and disaster preparedness, and ensure that consideration of these is balanced against development considerations and human wellbeing.

Most businesses greatly depend on natural capital, for example, the supply of freshwater is vital for manufacturing, or the flooding control forests provide is important in the protection of facilities from flooding or erosion. The private sector should be encouraged to assess their impacts and dependencies on natural capital and incorporate these considerations into internal decision-making, and as stakeholders in spatial planning. The Natural Capital Protocol, is a standardized framework for natural capital assessments that aims to support business managers to inform their decisions by discussing how we interact with nature or more specifically natural capital. It allows businesses to measure, value and integrate natural capital into their existing business processes.

STRENGTHENED GOVERNANCE

Transparency, accountability and equity in natural resources governance strengthen the rule of law and empower marginalized communities. Efforts are required to strengthen governance at national and local levels to ensure that laws and land use plans are collaboratively developed and effectively implemented. This would enable natural forests in PAs to continue to provide the benefits that humans need to survive.

Greater emphasis on law enforcement in Protected Areas and Protected Forests is needed to: enforce land use or spatial plans; and reduce illegal logging, illegal hunting, and other illegal uses of natural resources. Officials should work across Ministries and across different levels of governance to address the different drivers of deforestation. Channeling resources to strengthen and improve the effectiveness of law enforcement would benefit both local people and the natural environment. Better governance of these areas would also enable responsible and sustainable private investments to flourish and the interests of local communities to be respected.

The cornerstone of successful ecosystem-based planning and management processes is participation from key stakeholders (from government, private sector, civil society, and local communities), from national to commune level, to ensure shared ownership and consensus among diverse interest groups. A collaborative approach to land use planning can: help raise awareness of the environmental challenges and laws among all stakeholders; lead to the mediation or resolution of disputed land claims; provide a forum to develop and strengthen PA management plans to ensure that they take into consideration the needs of local populations in the landscape; result in greater buy-in and increased respect for the plans decided upon; and lead to more effective implementation of plans as all stakeholders have taken part in the planning process.

SUSTAINABLE FINANCING MECHANISMS

To support the Royal Government of Cambodia in improving the management of natural forests and sustain the benefits provided by ecosystem services, the government is encouraged to identify and promote sustainable financing mechanisms for the effective management and protection of Protected Areas. Examples of these include: ecotourism, community-based enterprises dependent on NTFPs, REDD+, voluntary carbon markets, etc. The first carbon credits from a climate change mitigation project in Keo Seima Wildlife Sanctuary, Monduliri (WCS 2016), could be the first of many such initiatives that tap into existing voluntary carbon markets in efforts to protect Monduliri's forests. Similar financing opportunities could provide national, subnational and local stakeholders more incentives to protect these important 'hotspots' of ecosystem services sustaining the benefits provided by them.

It is recommended that the private sector be held to account especially if their activities impact negatively on the surrounding area. To ensure that the due compensation is provided to mitigate the impacts of any environmentally harmful activities, companies should be incentivized to participate in sustainable financing mechanisms, such as payment for ecosystem services, trust funds, conservation offsets, etc., through command and control regulation or creating market-driven motives.

¹³ Interested stakeholders can visit the following website for more information: <http://naturalcapitalcoalition.org/protocol/>

14. CONCLUSIONS

As a country rich in natural resources that sustain the wellbeing of the nation's population and contribute significantly to the country's economy, Cambodia is at a competitive advantage in the Greater Mekong region. Unfortunately Cambodia's forests are under threat and if these natural resources are not well managed, it is likely to have devastating impacts on local communities, wildlife, and economic development opportunities in the future. It is therefore important for integrated spatial planning at provincial level to be introduced, implemented and enforced. To be successful this process needs to engage relevant stakeholders from the outset. The findings of this ecosystem services assessment, can be integrated in spatial and land use planning processes which would lead to more evidence-based, strategic and well-targeted land use plans. Taking into account ecosystem services would help land use planners allocate areas important for ecosystem services and areas suitable for other forms of land use.

The spatial planning process that took place in Battambang, as part of a project supported by the German Federal Ministry of Economic Cooperation and Development (BMZ) and the German Development Corporation (GIZ), followed a similar sequence of activities as those listed in Table 7 (Diepart and Nguon 2010). This ecosystem services assessment and valuation for Mondulkiri carried out the activities that feature in steps 1-3 below and can be used to support the implementation of steps 4-6 as well. Therefore undertaking ecosystem services assessments and valuations can complement spatial planning development processes.

Table 7: Description of the spatial planning processes (Diepart and Nguon 2010)

Steps	Description
1. Situation analysis	A relevant compilation of spatial information, figures and facts about land management serves as a basis for planning. This information forms the main knowledge base for the analysis and is derived mainly during the consultation forum organized at province, district and commune levels with participation of multiple actors. These fora allow for an update of land management information and for more dynamic analysis on the cause and consequence of recent land use change. They also offer an opportunity to address and solve existing or latent land conflicts.
2. Define future demographic and socioeconomic scenarios	Future demographic and socioeconomic growth scenarios are conceived to make decision-making more robust and to identify strategies for preempting undesirable future developments.
3. Visioning the future	The stakeholders involved in the planning process are then invited to define a vision for the future development of their region. The vision is a bold development statement that depicts a future ideal state of affairs. It represents something towards which the communities are striving for.
4. Design future development strategies	Future development strategies are designed to further specify how to reach the desired vision. They consist of specific objectives and the requirements to reach them. Because they chart out ways in which limited resources can best be allocated for development purposes, the strategies focus on attainable targets within a range of accessible resources.
5. Define future spatial structure and land use	Once defined, the strategic objectives are translated by the stakeholders into a future spatial structure and a land use zoning. The future spatial structure defines the relationship between urban centers and the overall future balance between open spaces (forest and agricultural land) and built-up areas. Land use zoning is a detailed mapping of different land areas where specific regulations must be enforced. These regulations are legally binding to all citizens.
6. Monitoring & Evaluation	After the public display and approval of the plan by relevant authorities, the realization of the plan must be monitored and controlled. The spatial plan is evaluated by assessing the degree to which the development and investment plans are consistent with its provisions.

The ecosystem services and valuation undertaken in Mondulkiri using InVEST, was carried out with the intention of improving the sustainability of land use planning through: the identification of 'hotspots' of key ecosystem services; estimating the value of these services; and developing future scenarios in collaboration with key stakeholders, that can assess the impacts on these ecosystem services in the future according to different scenarios. These scenarios have shown that following a Business as Usual path to development is likely to have severe impacts on key ecosystem services in the province leading to harmful consequences on human and wildlife populations alike.

By 2030 under business as usual, an increase in deforestation and rapid land transformation for economic activities such as mining-related activities, rubber plantations and agricultural development results in a significant decline in forest cover resulting in considerable losses to all six priority ecosystem services assessed. The value of ecosystem services to the Cambodian economy will also reduce dramatically, potentially shrinking the economy, if the value of these services is not replaced.

Why Green Economy?

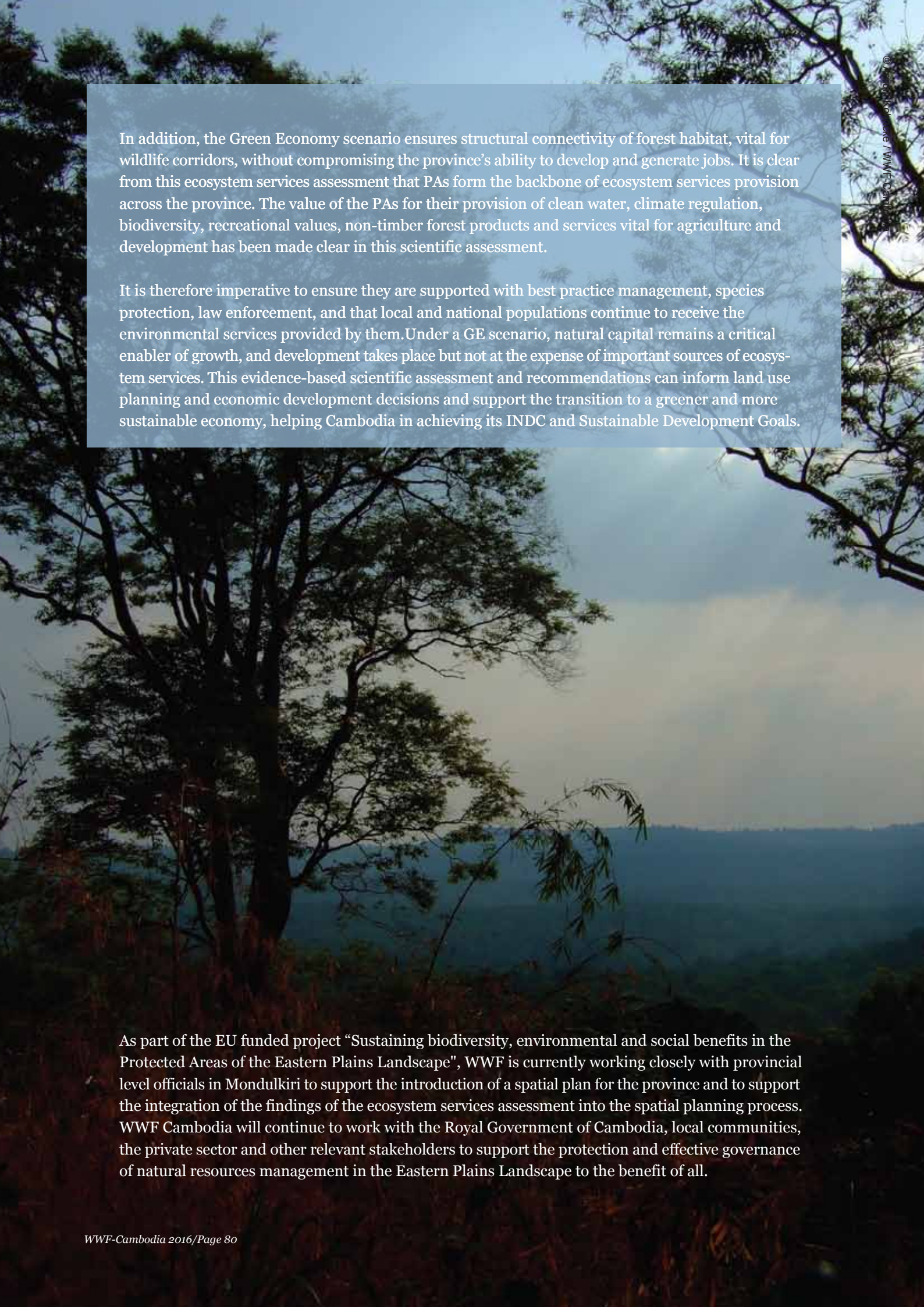
WWF Cambodia recommends the integration of the Green Economy scenario in Mondulkiri's land use and spatial planning process as this scenario strikes a better balance between conservation – protecting the areas in which there is the largest amount of ecosystem services – and economic development.

Mondulkiri in 2030 under a BAU scenario sees a province with considerably fewer natural forests and consequently fewer ecosystem services that contribute to the wellbeing and livelihoods of local households. Therefore the landscape is drastically changed and, if nothing is done to replace the lost ecosystem services, the landscape will be less resilient in coping with the increased risk of floods and longer droughts; and local people will be using water that is likely to be contaminated and harmful to fish, other aquatic life and human health. Attempting to mitigate the negative impacts is likely to be challenging, at times impossible, costly and less effective than the beneficial services natural forests provide for free.

The Conservation scenario would result in more tree cover, natural resources, ecosystem services and more suitable areas for wildlife species compared with the other two scenarios (provided these forests are well managed and law enforcement is strengthened). The GE scenario allows for the maintenance of trees in PAs (with strengthened governance, sustainable finance mechanisms etc.) while also enabling economic development outside of PAs to meet economic demands such as an increased demand for rice due to a rising population. Therefore the GE scenario sees a strategic and balanced economic development trajectory. Through integrated, evidence-based planning processes, more sustainable approaches to development are possible.

The Green Economy scenario seeks to minimize losses to ecosystems services by conserving Protected Areas and enabling economic development and food security in the productive parts of the landscape.





In addition, the Green Economy scenario ensures structural connectivity of forest habitat, vital for wildlife corridors, without compromising the province's ability to develop and generate jobs. It is clear from this ecosystem services assessment that PAs form the backbone of ecosystem services provision across the province. The value of the PAs for their provision of clean water, climate regulation, biodiversity, recreational values, non-timber forest products and services vital for agriculture and development has been made clear in this scientific assessment.

It is therefore imperative to ensure they are supported with best practice management, species protection, law enforcement, and that local and national populations continue to receive the environmental services provided by them. Under a GE scenario, natural capital remains a critical enabler of growth, and development takes place but not at the expense of important sources of ecosystem services. This evidence-based scientific assessment and recommendations can inform land use planning and economic development decisions and support the transition to a greener and more sustainable economy, helping Cambodia in achieving its INDC and Sustainable Development Goals.

As part of the EU funded project "Sustaining biodiversity, environmental and social benefits in the Protected Areas of the Eastern Plains Landscape", WWF is currently working closely with provincial level officials in Mondulkiri to support the introduction of a spatial plan for the province and to support the integration of the findings of the ecosystem services assessment into the spatial planning process. WWF Cambodia will continue to work with the Royal Government of Cambodia, local communities, the private sector and other relevant stakeholders to support the protection and effective governance of natural resources management in the Eastern Plains Landscape to the benefit of all.

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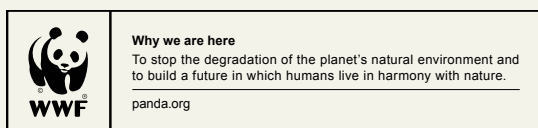
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