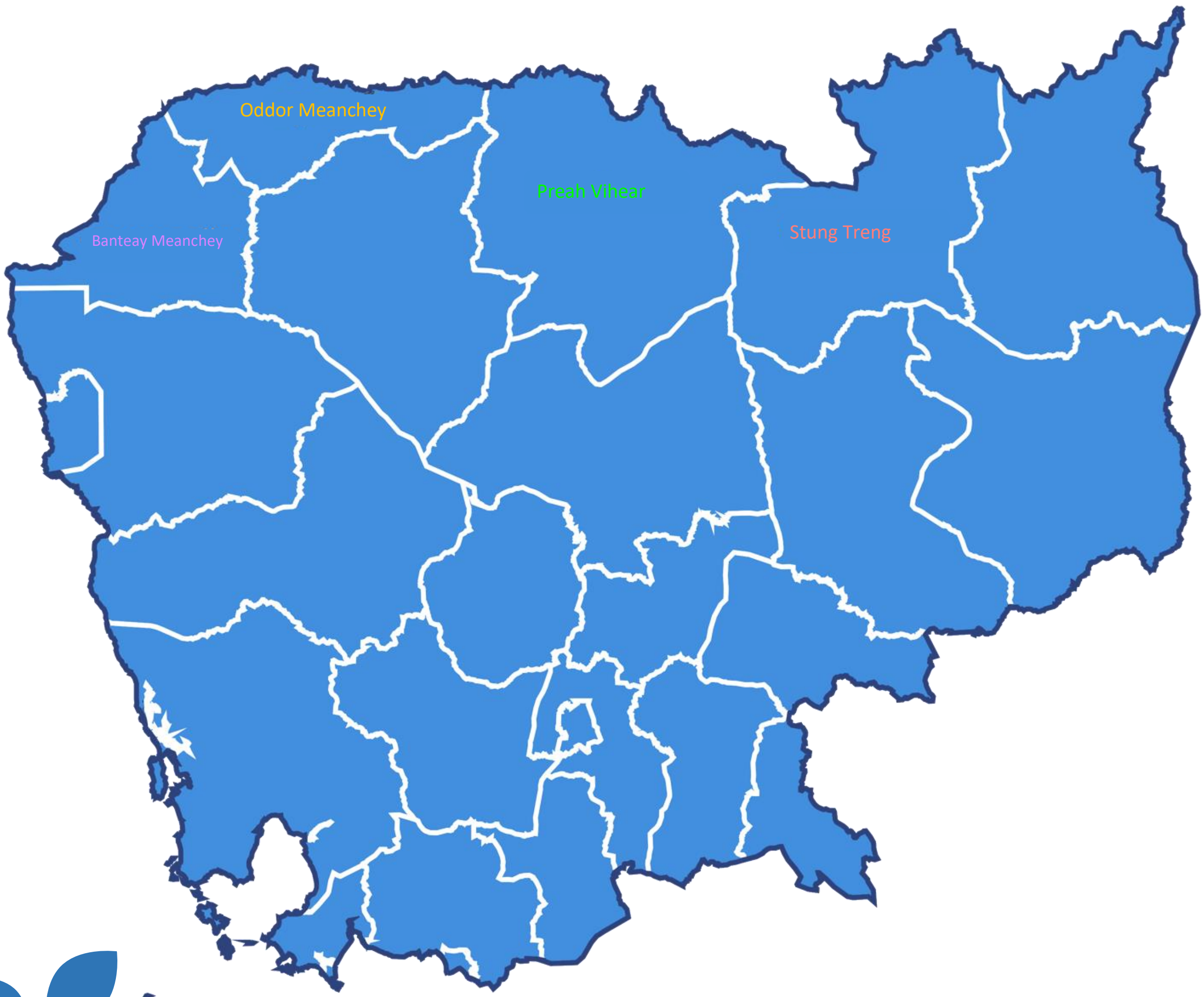
Exploring Methodologies for Analysing Forest Biodiversity and Ecosystem Services in Banteay Meanchey, Oddar Meanchey, Preah Vihear and Stung Treng



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Since its inception in 2008, UN-REDD, the UN interagency flagship programme on forests and climate, has, with support of Norway and other donors, contributed to slowing deforestation, promoted as a guiding principle the informed and meaningful involvement of all stakeholders, including indigenous peoples, local communities and women, established firm social and environmental safeguards, and contributed to the sustainable development of its 65 partner countries.

The United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) is a global Centre of excellence on biodiversity. The Centre operates as a collaboration between the United Nations Environment Programme and the UK-registered charity WCMC. Together we are confronting the global crisis facing nature.

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ACRONYMS AND ABBREVIATIONS

BCC	Biodiversity Conservation Corridor
BII	Biodiversity Intactness Index
CEMIS	Cambodia Environment Management Information System
CFs	Community Forests
CPAs	Community Protected Areas
DEM	Digital Elevation Model
ELSA	Essential Life Support Area
FA	Forestry Administration
FAO	Food and Agriculture Organization of the United Nations
FiA	Fisheries Administration
FRL	Forest Reference Level
GDEKI	General Directorate of Environmental Knowledge and Information
GDP	Gross Domestic Product
IBAs	Important Bird Areas
IPLC	Indigenous Peoples and Local Communities
InVEST	Integrated Valuation of Ecosystem Services and Trade-offs
IUCN	International Union for Conservation of Nature
KBAs	Key Biodiversity Areas
LULC	Land Use and Land Cover
MAFF	Ministry of Agriculture, Forestry and Fisheries
MoE	Ministry of Environment
NDC	Nationally Determined Contribution
PAs	Protected Areas
REDD+	Reducing Emissions from Deforestation and Forest Degradation plus additional forest-related activities that protect the climate, namely sustainable management of forests and the conservation and enhancement of forest carbon stocks
SDGs	Sustainable Development Goals
SEPAL	System for Earth Observation, Data Access, Processing and Analysis for Land Monitoring
SIS	Safeguard Information System
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

1. INTRODUCTION

1.1 Mapping and tracking environmental and social trends in forests

Forests provide many environmental benefits, including supporting biodiversity and providing habitats for wildlife. Yet, they also do much for people. They also support human well-being by offering ecosystem services, like providing clean water and regulating the climate. The conservation, restoration, and sustainable management of forests can, therefore, help ensure that people and nature thrive side by side.

Understanding and monitoring the health of forests and the benefits they provide is essential for their effective and sustainable management. It is also key to ensuring forest policies meet their environmental, social, and economic objectives. Actions in the forest sector can have both positive and negative impacts. For example, protection and restoration can positively impact biodiversity and ecosystem services but negatively affect people who depend on the forests for their livelihoods, including ethnic minorities, indigenous peoples and local communities (IPLCs) and women. Identifying and monitoring the impacts of forest actions over time is needed to understand whether actions have the desired impacts, including impacts on local stakeholders, such as forest-dependent people, and to determine any improvements that can be made to better meet sustainability objectives. Wider monitoring of environmental and social trends linked to forests and to stakeholders affected by forest policies can also provide data to facilitate reporting on international commitments like the Sustainable Development Goals (SDGs), REDD+ Safeguards Information Systems (SIS), and the contribution of forests to Nationally Determined Contributions (NDCs) to the Paris Agreement.

Nonetheless, there are many challenges related to mapping and tracking environmental and social trends and impacts related to forests at both national and local levels. These encompass often limited data available, including spatial data, and the practicality of collecting and compiling new data. It is also difficult to determine how to prioritize which drivers of change, actions, and impacts to focus on. However, there are also opportunities to combat some of these challenges by exploring how to use existing and emerging information in new ways, including complementing national and local data with international or regional datasets and integrating these approaches into regular monitoring processes.

1.2 Trends in Cambodia's forests

Cambodia's 181,035 km^2 of land area includes a significant proportion of forests, which cover roughly 46% of its land area. According to Cambodia's 2018 National Land Use and Landcover Assessment (MoE, 2020), forested areas are classified as evergreen, semi-evergreen, deciduous, other forests, bamboo, etc. Cambodia has also experienced a decline in forest cover, which decreased from 73.04% in the early 1960s to 46.86% in 2018 (MoE, 2020). Several key drivers of deforestation and forest degradation in Cambodia include agricultural expansion, large-scale agro-industry, commercial logging and infrastructure development (MoE and MAFF, 2017). These are motivated by increasing global demand for products like rubber, as well as population growth and increased demand for agricultural land. Uncertain land tenure, which often disproportionately impacts women and Indigenous Peoples and local communities, rural poverty, and lack of implementation and enforcement of land and environmental regulations compound these challenges (MoE and MAFF, 2017). This promotes encroachment into forest lands, with subsequent effects on forest conservation and the provision of forest ecosystem services to people, as well as potential implications for the enjoyment of human rights such as the right to a clean, healthy and sustainable environment. Climate change also represents another threat to the health of Cambodia's forests. According to climate change projections for the country, increases in temperature, precipitation and seasonal shifts will impact forests (MoE and MAFF, 2017). Cambodia's Second National Communication to the UNFCCC (GSSD, 2015) mentioned that exposing trees to a longer dry season may decrease forest productivity and increase fire risk. The effects of climate change on forests will also have a variety of repercussions for the communities that depend upon them.

Forest integrity – referring to the maintenance of forest cover and condition – is associated with the provision and maintenance of multiple ecosystem services, including fresh water supply, soil biodiversity and climate regulation, among others. Given the significance of forests to the provision of a healthy environment and to rural livelihoods in Cambodia, a reduction in productive forests and biodiversity may result in a reduction in livelihood possibilities and wellbeing for forest-dependent and adjacent communities (MoE et al., 2021), and beyond. Hence, it is essential to evaluate forest cover change in Cambodia to identify its impacts and to implement appropriate management strategies.

Cambodia is developing innovative approaches to forest management and monitoring. As of mid-2023, Cambodia has 65 protected areas and the total area now under protection is approximately 7.2 million ha or 40% of the country (MoE et al., 2021). The government is decentralizing management responsibilities through community forestry, allowing local authorities, particularly forest communities to protect forests and improve their livelihoods. The National Forest Program (2010) aims to have 2 million ha of community forest by 2029. This community-based model has made much progress in developing management plans and implementing sustainable forest management and has helped to stabilize the health of community forests. A total of 499 community-based forestry sites were established by 2015, under the jurisdiction of MAFF, spanning 910 villages. By July 2019, this number increased to 636 sites covering 437,255 ha (AFoCO, 2020). Spatial analysis shows that community forests in the country have higher forest cover and lower forest loss than other forests (RECOFTC, n.d.).

1.3 This report

The purpose of this report is to document the outcomes of an exploration of methods and data for mapping a set of priority social and environmental trends related to forests in four provinces of northern Cambodia: Bantay Meanchey, Oddar Meanchey, Preah Vihear and Strung Treng. This exploratory mapping has been designed to complement analysis of recent forest disturbance in these provinces using a Near Real Time (NRT) approach, including the University of Maryland's Global Analysis and Discovery (GLAD) alerts of forest disturbance (Hansen et al., 2016) and the System for Earth Observation Data Access, Processing and Analysis (SEPAL) platform (see Box 1).

To complement monitoring of forest cover change, a series of additional analyses were undertaken and are presented in this report. They show the distribution of some key environmental and social benefits from forests in the four provinces. They also reveal the potential implications of recent forest disturbance.

The analyses conducted in Cambodia have been supported by the UN-REDD project ''Sustainable Forest Trade in the Lower Mekong Region SFT-LMR)''. This project works with partners in Lower Mekong countries to strengthen forest governance and to promote legal and sustainable trade in timber. In Cambodia, the project aims to strengthen systems for forest monitoring, including tracking environmental and social trends and impacts in the forest sector, and building on the range of existing systems already available. The work presented in this report was undertaken by a partnership of the General Directorate of Knowledge and information (GDEKI), Ministry of Environment (MoE), Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP) and the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), with inputs from key national and provincial stakeholders.

Box 1: System for Earth Observation Data access, Processing and Analysis (SEPAL)

SEPAL is a cloud-based platform for accessing, processing, and analyzing geospatial data for land monitoring. The platform is freely accessible to users with an internet connection, and it is compatible with mobile phones and tablets. It is possible for users to create image mosaics, classifications, and time series analyses. Some applications include peatland and soil moisture monitoring, and detecting forest cover change in developing countries.

RStudio and Jupyter notebook and labs are installed and maintained in SEPAL, but it also facilitates access to cloud resources including Google Earth Engine. These resources give SEPAL additional functionality – allowing the processing of large amounts of data without the need for high performance computing infrastructure and high network bandwidth.

https://sepal.io/

This report includes the following sections:

1. Background – providing an overview and describing the prioritization of social and environmental issues and trends related to forests for this study
2. Prioritized analyses – describing the exploration of data and methods and introducing the resulting maps for the prioritized topics
3. Conclusion and next steps – discussing the potential to build upon the analyses presented

2. BACKGROUND

2.1 Prioritizing topics

A long list of potential social and environmental topics and analyses were developed based on the findings of a national stakeholder consultation workshop. This involved representatives from Cambodian governmental and non-governmental organisations. Participants completed a survey that asked their opinions on the main environmental and social issues of concern for forests in Cambodia. This survey revealed that land tenure and IPLC rights were key issues, although potentially more challenging to analyse spatially. It also highlighted the demand for further assessment of the economic value of forests and forest ecosystem services. Participants were also asked to identify key data and information systems related to these issues and trends.

Based on the results of the consultation workshop, as well as other key considerations (e.g. data availability), the project partners led by the General Directorate of Environmental Knowledge and Information (GDEKI) selected 3-5 priority topics and spatial analysis methods, to complement the forest degradation analysis. The selection took into consideration data availability, data requirements, similar analyses already conducted, and the methods to be used. The shortlisted topics for analysis are shown in Table 1.

Table 1: Shortlisted topics for analysis

Topic	***Description***	***Ranking***
Biodiversity		
Important areas for biodiversity conservation and management including, Protected Areas (PAs), Biodiversity Conservation Corridors (BCCs), Community Protected Areas (CPAs), Community Forests (CFs) and Key Biodiversity Areas (KBAs)	Using NRT forest disturbance to show potential deforestation in these areas.	1
Areas with high biodiversity quantity and vulnerability using proxies (threatened forest species richness and rarity-weighted species richness)	Number of threatened species dependent on forest habitats and sum of number of species weighted by their rarity (inverse to size of their range). Based on the IUCN Red List (IUCN, 2023). Overlap with NRT forest disturbance analysis for 4 provinces.	1

Hydrological ecosystem services		
Annual Water Yield	Using InVEST Annual Water Yield model, estimate the effect of forest change on the water supply service. The Annual Water Yield model provides an estimate of total water yield for a catchment. Identify key forest areas where this service is high.	1
Sediment retention	Using InVEST Sediment Retention Model, estimate the effect of forest change on sediment retention. Identify key forest areas where this service is high.	1
Restoration opportunities		
Forest importance for multiple benefits for people, biodiversity and climate	Show potential priority areas for forest restoration/protection based on ability to produce multiple benefits. Multi-criteria analysis of forest cover and set of other parameters to indicate importance for people (e.g., ecosystem services), climate (e.g., carbon, adaptation), and biodiversity (e.g., biodiversity layers above).	1
Carbon		
Distribution of forest biomass carbon	Mapping current forest biomass carbon according to national LULC data. Identification of areas within proximity of NRT forest change.	2

Based on the shortlisted topics for analyses, which were updated frequently depending on a range of factors, including access to data, four key analyses were selected. One priority identified was trends of forest loss in important areas for biodiversity conservation and management, especially Key Biodiversity Areas (KBAs) and Protected Areas (PAs). Hydrological services, especially water quantity, were also considered since the four provinces are affected by both floods and droughts. High deforestation rates have occurred in the provinces in the past. Therefore, another priority was to examine potential areas for restoration. It should be noted that topics more specifically related to social issues (such as dependency on forests, water security and community management) are considered in terms of ecosystem service provision to people and categories of community-based management (e.g. CPAs) in these priority analyses, and that data availability (e.g. on IPLCs and tenure) remains challenging.

2.2 Overview of the four provinces

Four provinces were selected to explore the methods and data available under the project. These are Bantay Meanchey, Oddar Meanchey, Preah Vihear and Stung Treng in the north of Cambodia, close to the border of Thailand and Lao PDR (Figure 1). Table 2 presents basic information on forests in the four provinces.

Figure 1: Land use and Landcover map of the four provinces of Banteay Meanchey, Oddar Meanchey, Preah Vihear, and Stung Treng

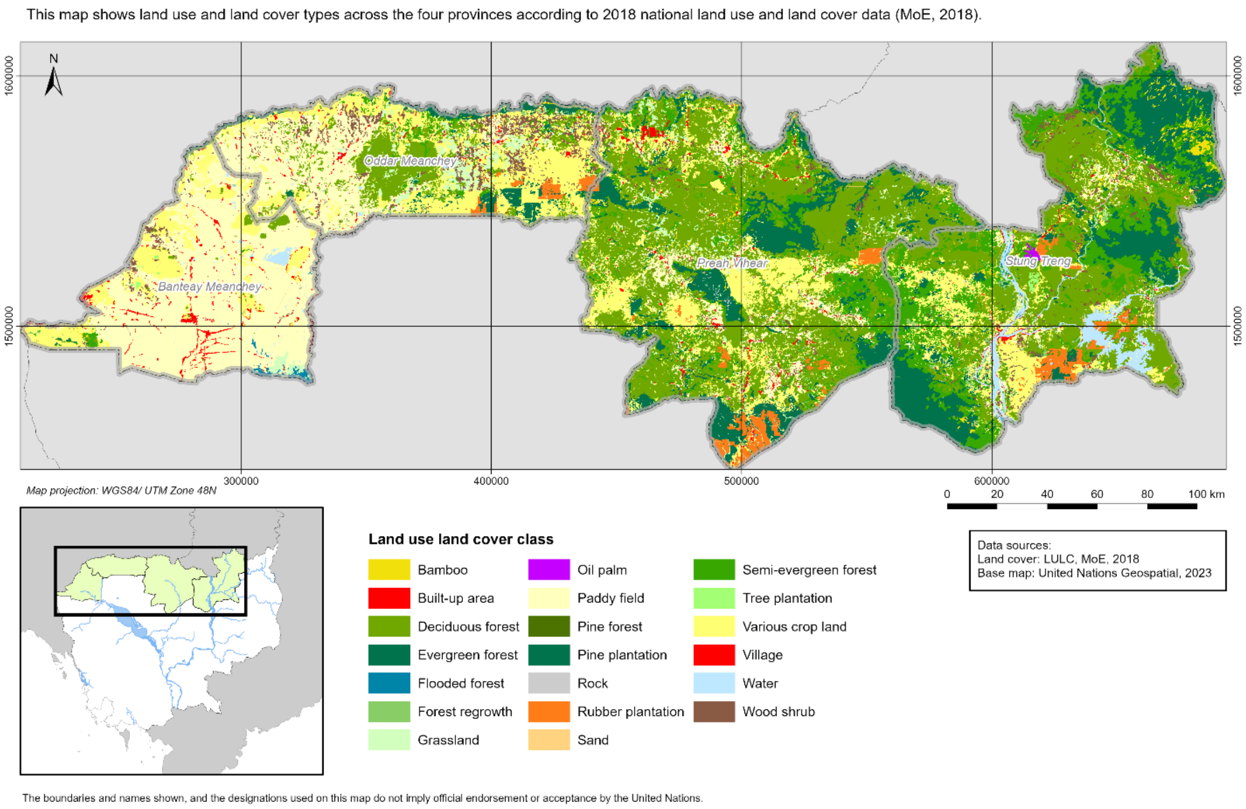


Table 2: Forest cover types in four provinces

Forest type	Bantaey Meanchey (area: Km²; %)	Oddar Meanchey (area: Km²; %)	Preah Vihear (area: Km²; %)	Stung Treng (area: Km²; %)
Evergreen forest	15 (0.24%)	453 (6.85%)	2004 (14.28%)	2556 (21.27%)
Semi-evergreen forest	27 (0.44%)	169(2.55%)	1357 (9.67%)	2424 (20.17%)
Deciduous forest	90 (1.47%)	998 (15.08%)	6598 (47.03%)	3847 (32.02%)
Flooded forest	54 (0.88%)	1 (0.02%)	0 (0%)	11 (0.09%)
Forest regrowth	7 (0.11%)	21 (0.32%)	29 (0.21%)	108 (0.90%)
Bamboo	5 (0.08%)	17 (0.26%)	99 (0.71%)	176 (1.47%)
Pine forest	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Pine plantation	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Tree plantation[1]	10 (0.16%)	0 (0%)	0 (0%)	19 (0.16%)

[1]including teak, eucalyptus, acacia, jatropha, and others

2.3 Capacity building and testing of spatial analysis methods

To obtain feedback on the developed methodologies, a working session was held in Phnom Penh with representatives from government agencies and non-government organisations, including the Ministry of Environment (MoE), the Ministry of Agriculture, Forestry and Fisheries (MAFF), and the Royal University of Agriculture. Aside from getting feedback, another aim of the session was to demonstrate the methods through a series of tutorials over the course of a week using ArcGIS. Sessions included an introduction to the InVEST modelling suite, producing a forest biomass carbon map, producing a species richness layer and more. Following the working session, inputs from participants were used to produce draft maps. These included inputs on additional available data, important considerations for different proposed methods and outcomes of group discussions.

A multi-stakeholder workshop was then held in Preah Vihear province, involving 28 participants from national and provincial government agencies, NGOs, and other organizations. Participants were asked to review and provide feedback on the draft maps. A field visit was also held, in which MoE and Wildlife Conservation Society (WCS) demonstrated the SMART monitoring platform that is operational in some CPAs and CFs. Feedback and recommendations from the workshop were incorporated into refining the maps.

Full details on the agendas for the working session and workshop can be found in Annex 1.

Box 2: InVEST Modelling Suite

The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) suite is an open-source modelling tool that can be used to map and value the goods and services that ecosystems provide and that are key to human well-being. The natural capital of the region generates ecosystem services such as the production of goods (e.g., food, medicine), supportive environmental processes (e.g., water purification, sediment regulation, nutrient cycling, carbon sequestration) and conservation of genetic resources.

The InVEST models are spatially explicit, using maps as information sources and producing maps as outputs. They are based on production functions that define how changes in an ecosystem’s structure and function are likely to affect the flows and values of ecosystem services across a landscape. The models are available as a standalone application, and models of interest can be executed, but viewing the results requires GIS software (ArcGIS or QGIS).

3. PRIORITIZED ANALYSES – CHANGES IN FORESTS AND IMPLICATIONS FOR FOREST GOODS AND SERVICES

The following section provides an overview of the five main areas of analysis produced through the SFT-LMR project. Based on the priorities selected, these analyses use spatial information to explore a set of key forest goods and services provided by the forests of the four provinces and consider the potential impacts of recent forest change.

The five key topics covered in this section are:

1. Forest cover change, based on a longer-term map of forest loss (2010-2018) and a recent map of forest loss hotspots based on NRT monitoring during January – July 2023.
2. Areas important for forest biodiversity, based on biodiversity conservation areas (such as PAs and CPAs) and species richness.
3. Forest hydrological ecosystem services, based on the InVEST model for water yield and sediment retention.
4. Forest carbon stocks, based on estimated above- and below-ground forest biomass carbon.
5. Multi-criteria analysis to identify forest areas with multiple benefits for nature, climate, and people.

3.1 Change in forests in the four provinces

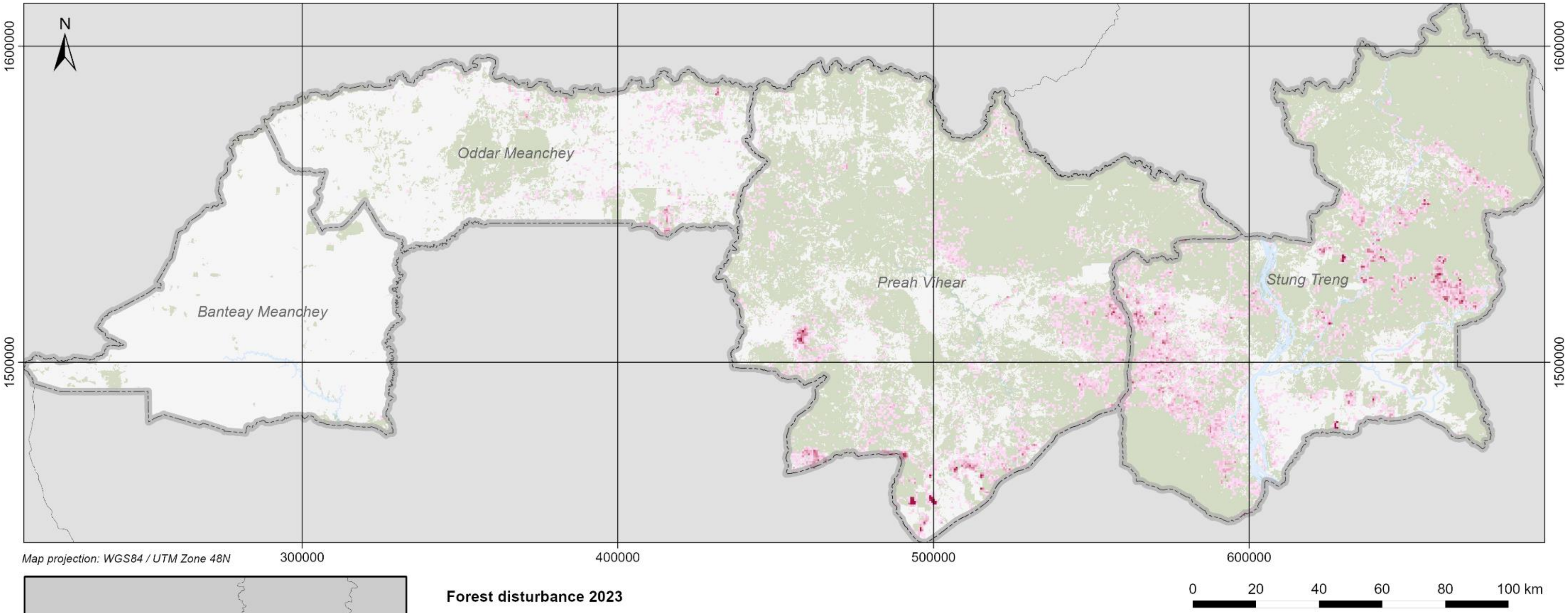
NRT forest disturbance alerts were developed by FAO, MoE, and Forest Administration technical staff for the period of November 2022 to May 2023. Results were validated in Community Forests and Biodiversity Conservation Corridors by the Forestry Administration across all four provinces and in Protected Areas by the Ministry of Environment in Oddar Meanchey and Banteay Meanchey. More time and resources are required to complete the validation of results across all four provinces.

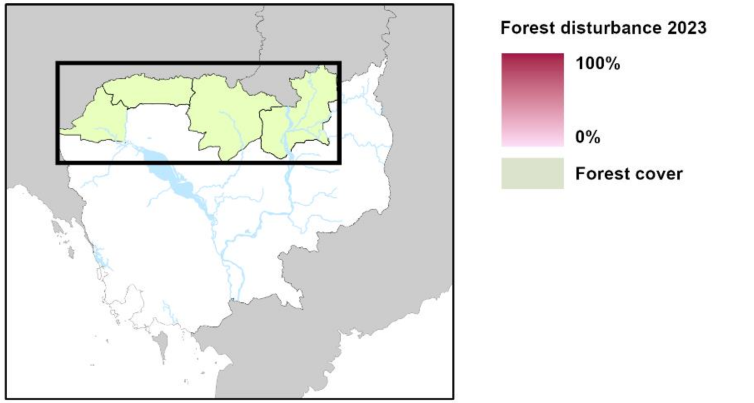
As such, the University of Maryland's Global Analysis and Discovery (GLAD) alerts (Hansen et al., 2016) were used to estimate areas of recent forest disturbance (Figure 2). With the purpose of alerting people of possible deforestation, a GLAD alert identifies potential forest canopy disturbance within a 30 x 30 metre area. Alerts are produced roughly weekly, depending on cloud coverage. They are intended to provide an early indication of potential deforestation so responders can investigate further. This map (Figure 2) shows areas of forest disturbance in 2023 only, along with forest cover in 2018, and indicates some significant pockets of disturbance in the more heavily forested provinces of Stung Treng and Preah Vihear.

This can be contrasted with a longer-term analysis of forest cover change. According to the Forest Resources Assessment (FAO, 2020), forest area across Cambodia decreased from 10,589,230ha (60% of land area) in 2010 to 8,068,370ha (46% of land area) in 2020. Forest change across the four provinces was also estimated between 2010 – 2018 by using LULC maps provided by MoE (Figure 3). Across the four provinces, this showed a decrease of 730,909 ha of forest between 2010 – 2018, equivalent to 26% of the total 2010 forested area. Results suggest that the two less forested provinces of Oddar Meanchey and Banteay Meachey have experienced the highest level of deforestation, with Oddar Meachey followed by Banteay Meanchey, then Preah Vihear and Stung Treng.

Figure 2: Forest areas affected by disturbance in 2023

This map shows forest areas that have been affected by tree cover disturbance in 2023 according to GLAD-Landsat deforestation alerts (Hansen et al., 2016). Each GLAD-L alert indicates disturbance in the forest canopy in a 30 by 30 m area, indicating potential tree loss or removal. Disturbance alert pixels were aggregated to 600 metre resolution to highlight forest areas most affected by disturbance. A percentage per pixel was given, based on the number of GLAD alerts in that area.



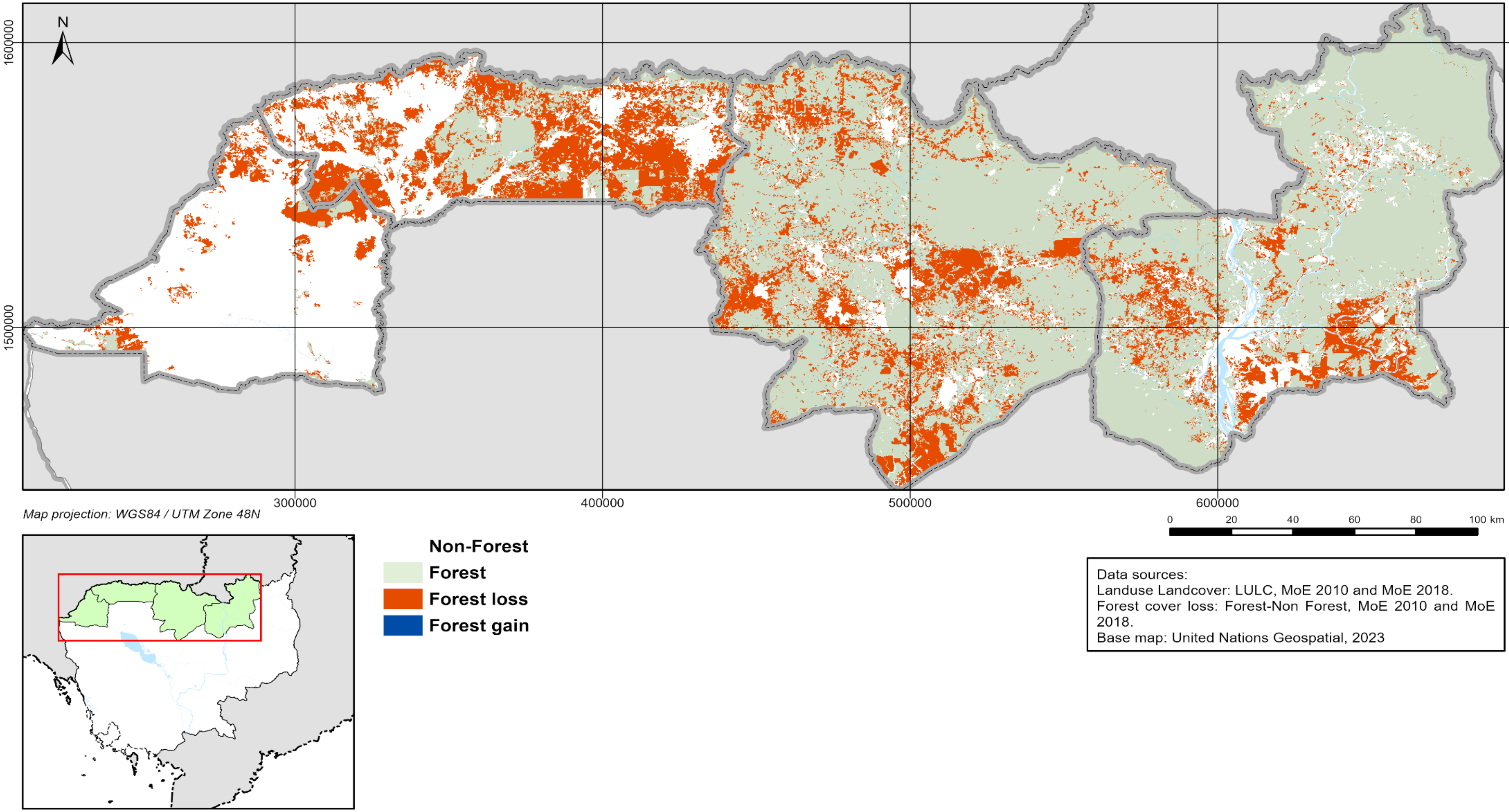


Data sources:
Forest cover: LULC, MoE 2018
Forest cover disturbance 2023: Hansen, M.C., A. Krylov, A. Tyukavina, P.V. Potapov, S. Turubanova, B. Zutta, S. Ifo, B. Margono, F. Stolle, and R. Moore. 2016. Humid tropical forest disturbance alerts using Landsat data. Environmental Research Letters, 11 (3). Accessed through Global Forest Watch on 28/07/2023. www.globalforestwatch.org
Basemap: United Nations Geospatial, 2023

The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 3: Forest cover change across four provinces between 2010-2018 according to MoE LULC maps from 2010 and 2018

This map represents estimated forest change between 2010 and 2018 in Banteay Meanchey, Oddar Meanchey, Preah Vihear and Stung Treng. This is according to land cover and land use (LULC) maps developed by the Ministry of Environment. Forest cover change includes both forest loss and forest gain. Forest loss was considered to have occurred if the conversion from forest to any other LULC category had happened between 2010 and 2018. Forest gain on the other hand was estimated based on any other LULC category from 2010 being converted into forest between 2010-2018.



The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

3.2. Forest biodiversity

Cambodia's biodiversity is among the most diverse in Southeast Asia – with the country estimated to host over 8,000 species of vascular plants (FFI, n.d), 200 species of mammals, over 500 species of birds, 250 species of reptiles and amphibians, and over 900 fish species (IUCN, 2022).

However, changes in Cambodia's forest biodiversity are apparent. Forest biodiversity is under a multitude of pressures, including the conversion of natural forests to agriculture and other land uses, hunting, climate change and invasive species. According to the IUCN Red List (IUCN, 2022), there are 376 threatened species in Cambodia, including 160 threatened forest species.

Conserving biodiversity and ecosystem functioning maintains many other essential ecosystem services. These include providing food and timber, flood and erosion control, tourism, and many essential supporting services like soil formation, nutrient cycle, and primary production. As a result, conserving biodiversity has the potential to produce multiple benefits for people, climate, and nature. Mapping biodiversity allows the identification of synergies between biodiversity and other goals, including climate change mitigation.

Identifying areas important for biodiversity

Different approaches can be used to indicate the biodiversity value of a geographical area. A combination of national and global datasets was used to assess biodiversity importance across the four provinces (Table 3).

Table 3: Datasets used in the identification of important areas for biodiversity

Data layer	***Data sources***
Land use and Landcover (LULC)	MoE
Key Biodiversity Areas	Birdlife International
International Union for the Conservation of Nature (IUCN) Red List of Threatened Species	IUCN
Protected Areas	GDEKI, MoE, Cambodia; World Database on Protected Areas (WDPA), UNEP-WCMC
Biodiversity Conservation Corridors	GDEKI, MoE, Cambodia
Community Protected Areas	MoE, Cambodia / Open Development Cambodia
Community Forests	Forestry Administration / Open Development Cambodia
SMART monitoring	WCS

First, nationally designated areas considered essential for biodiversity conservation and management were identified (Figure 4). These included **Protected Areas (PAs), Community Protected Areas (CPAs), Community Forests (CFs) and Biodiversity Conservation Corridors (BCCs). Key Biodiversity Areas (KBAs)** (Birdlife International, 2020) were also considered, as, though they are not nationally designated, are widely regarded as a good measure of global biodiversity importance. KBAs are defined using 11 criteria, including threatened ecosystem types and species, geographically restricted species, assemblages, ecosystem types, ecological integrity, importance for biological processes, and

Irreplaceability. As shown in Figure 4, nationally designated protected areas and KBAs sometimes overlap, as in northern Preah Vihear and northern Stung Treng, while in other areas there are significant differences (e.g. in Banteay Meanchey); in these cases Community Forests and ‘’other effective conservation measures’’ may play an important role in biodiversity conservation and management.

Next, the International Union for the Conservation of Nature **(IUCN) Red List of Threatened Species** (IUCN, 2022) was used to assess biodiversity quantity and vulnerability. The IUCN Red List provides information on species extinction risk globally, including through data on species range and population size. Red List data were analysed to estimate threatened forest species richness and rarity-weighted threatened forest species richness, which are both widely used as proxies for biodiversity. Here, forest species are defined as those dependent on forest, excluding species that use forest in addition to other habitats, and the selection included birds, mammals, reptiles and amphibians.

Figure 5 shows species richness for Critically Endangered, Endangered and Vulnerable categories of forest species. This provides a proxy of biodiversity quantity across the landscape, with higher values indicating a higher number of- threatened species likely to be present within each cell. Figure 6 shows rarity-weighted species, which gives an indication of the relative importance of each 10km grid cell to the global distribution of species. This gives a measure of biodiversity vulnerability. High values indicate the presence of species with small range areas globally, meaning that the area covered in the study area is a relatively higher proportion to the species range. The top two categories of both layers were selected to be indicative of biodiversity importance.

To identify forest areas, **Land Use and Land Cover (LULC)** from 2018 (MoE, 2020) was used to estimate forest extent. This was overlayed with threatened forest species richness, rarity-weighted threatened forest species richness and important areas for biodiversity conservation and management layers.

According to the analysis, high biodiversity value is indicated in the central and northern areas of Preah Vihear province, in the Upper Stung Sen catchment (which aligns with a KBA), in the Kulen Promtep wildlife sanctuary and Chhaeb wildlife sanctuary (also aligned with a KBA). High values are also indicated in the northern half of Stung Treng province, especially in Virachey National Park and Vensai Siempang National Park. Oddar Meanchey and Banteay Meanchey results indicate there may be less biodiversity significance for forest species (and indeed these two provinces have lower forest cover), although the east of Oddar Meanchey has relatively high species richness.

Finally, a binary layer was produced showing areas that either fall within one of the designated areas biodiversity conservation management areas (as above) or inside the top two categories of either threatened forest species richness or threatened forest rarity-weighted species richness. This was also combined in Figure 7 to show this as a binary biodiversity importance layer in relation to 2023 GLAD forest disturbance alerts, suggesting that clusters of disturbance in areas of biodiversity importance in central and northern Preah Vihear may be a concern.

Significant effort has been given to **ecological field surveys** to collect biodiversity data at particular sites in Cambodia by NGOs in collaboration with MoE. A subset of ecological survey results was further used to provide an illustration of how these could be used to complement global data on species ranges, using data shared by the Wildlife Conservation Society (WCS) for Preah Vihear province (Annex 2). The maps produced show how local data could be used to validate global data on species presence, though currently this is limited. Further survey data over longer time periods would be needed in order to verify global data and determine whether hotspots of species richness are accurate.

Biodiversity conservation: Step-by-Step

1. **Identify areas designated for biodiversity conservation and management**: A layer was created to highlight areas considered important for biodiversity conservation and management. This included Key Biodiversity Areas, Protected Areas, Community Protected Areas, Community Forests and Biodiversity Conservation Corridors.

2. **Identify areas of high species richness:** A layer was produced to identify areas based on threatened forest species richness derived from the IUCN Red list of threatened species. The top two quantiles were selected to show areas with the highest number of threatened species dependent on forests.

3. **Identify areas of endemic species richness**: Another layer was developed to show the rarity-weighted threatened forest species index. This gives an indication of the relative importance of an area for a given forest-dependent species. Similarly, the top two quantiles were selected to represent areas with the highest number of sensitive species.

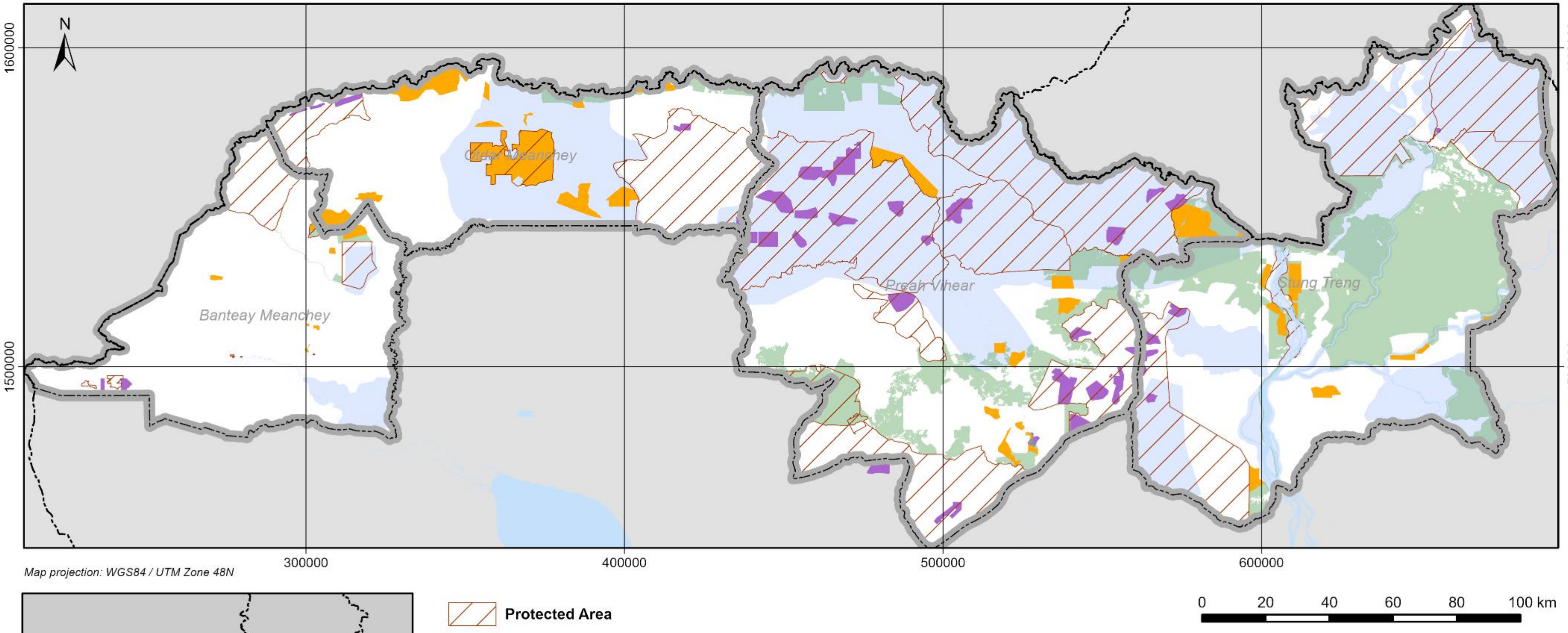
4. **Combine layers to highlight areas important for biodiversity conservation:** The layers produced to show biodiversity conservation areas, rarity-weighted threatened forest species richness, and threatened forest species richness were overlayed to create a layer (0-3) showing forest within 1, 2 or 3 of these areas.

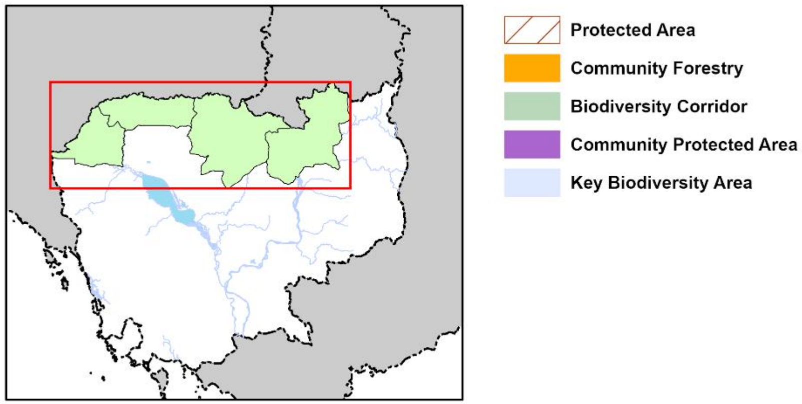
5. **Produce a binary map to highlight areas important for biodiversity conservation**: A Binary biodiversity conservation map shows forests within these areas. This map is used as an input layer into the map of converging multiple benefits.

Resources: https://unep-wcmc-gis-tutorials.readthedocs.io/en/latest/ProcessingIUCNRedList_ArcGIS.html

Figure 4: Distribution of important areas for biodiversity conservation and management

This map shows the distribution of areas considered to be important for biodiversity conservation and management in Banteay Meanchey, Oddar Meanchey, Preah Vihear and Stung Treng provinces. In this instance, this includes Protected Areas (PAs), Key Biodiversity Areas (KBAs), Community Forestry (CF), Community Protected Areas (CPAs), and Biodiversity Conservation Corridors (BCC).





Data sources:
Biodiversity corridors: Department of GIS, General Directorate of Knowledge and Information (GDEKI), Ministry of Environment (2017)
Key Biodiversity Areas (KBAs): BirdLife International (2022). The World Database of Key Biodiversity Areas. Developed by the KBA Partnership: BirdLife International, International Union for the Conservation of Nature,
Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Re:wild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, Wildlife
Conservation Society and World Wildlife Fund. [Accessed 31/01/2023)].
Community Protected Areas: Department of GIS, General Directorate of Knowledge and Information (GDEKI), Ministry of Environment (2016).
Protected Areas: Department of GIS, General Directorate of Knowledge and Information (GDEKI), Ministry of Environment (2021).
Basemap: United Nations Geospatial, 2023

The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 5: Estimated threatened forest species richness

This map shows the distribution of potential threatened species richness across the provinces of Banteay Meanchey, Oddar Meanchey, Preah Vihear, and Stung Treng. This is based on distributional ranges of threatened species estimated using IUCN Red List of threatened species extent of occurrence data (IUCN, 2022). Threatened species included forest-dependent mammals, birds, reptiles and amphibians classified as "Critically Endangered", "Endangered", "Vulnerable" and "Near Threatened. Generally, this method will result in an overestimation of species richness (Rocchini et al. 2011), though the use of this data allows for full coverage, whereas in-situ data is not available.

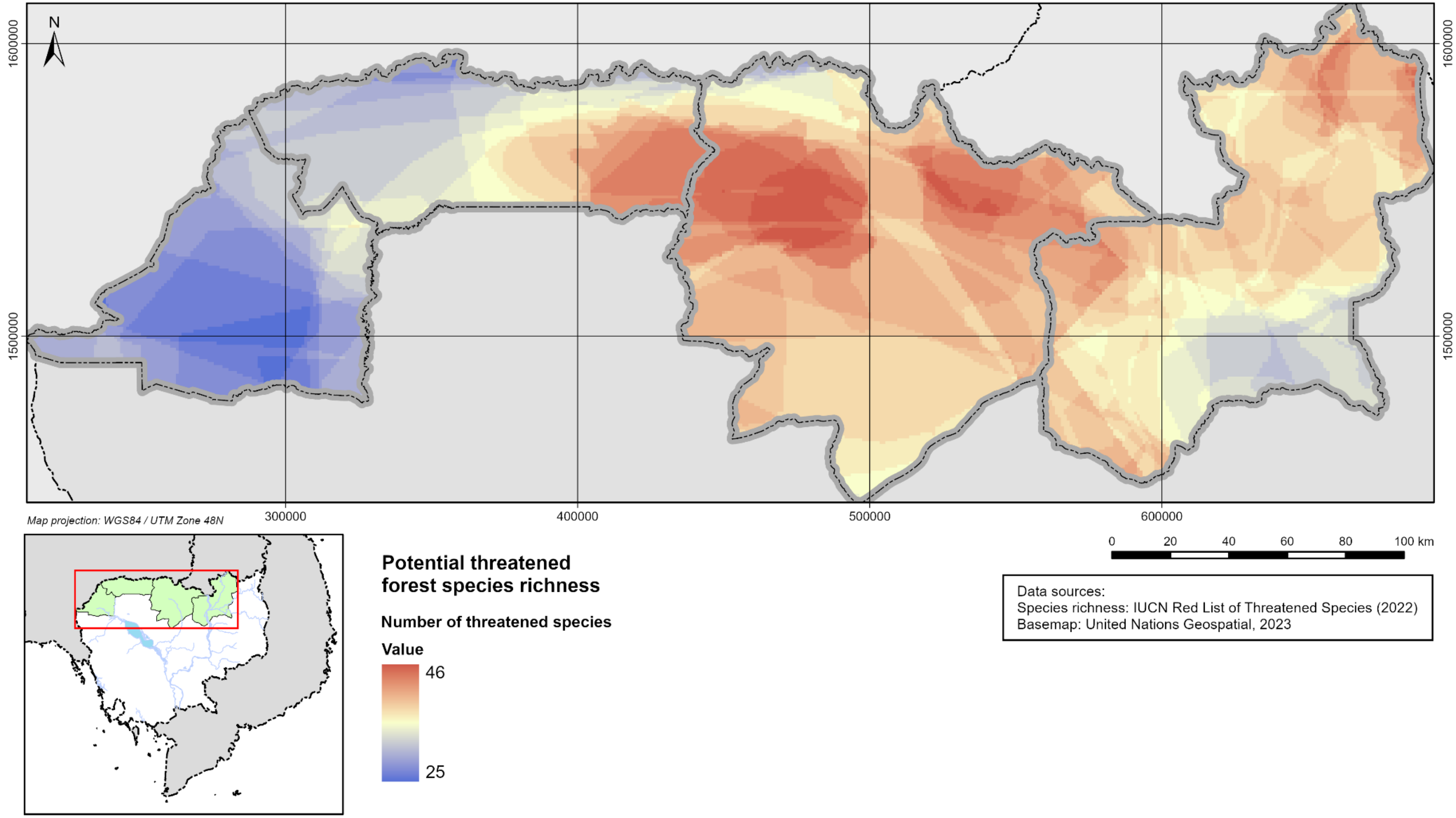


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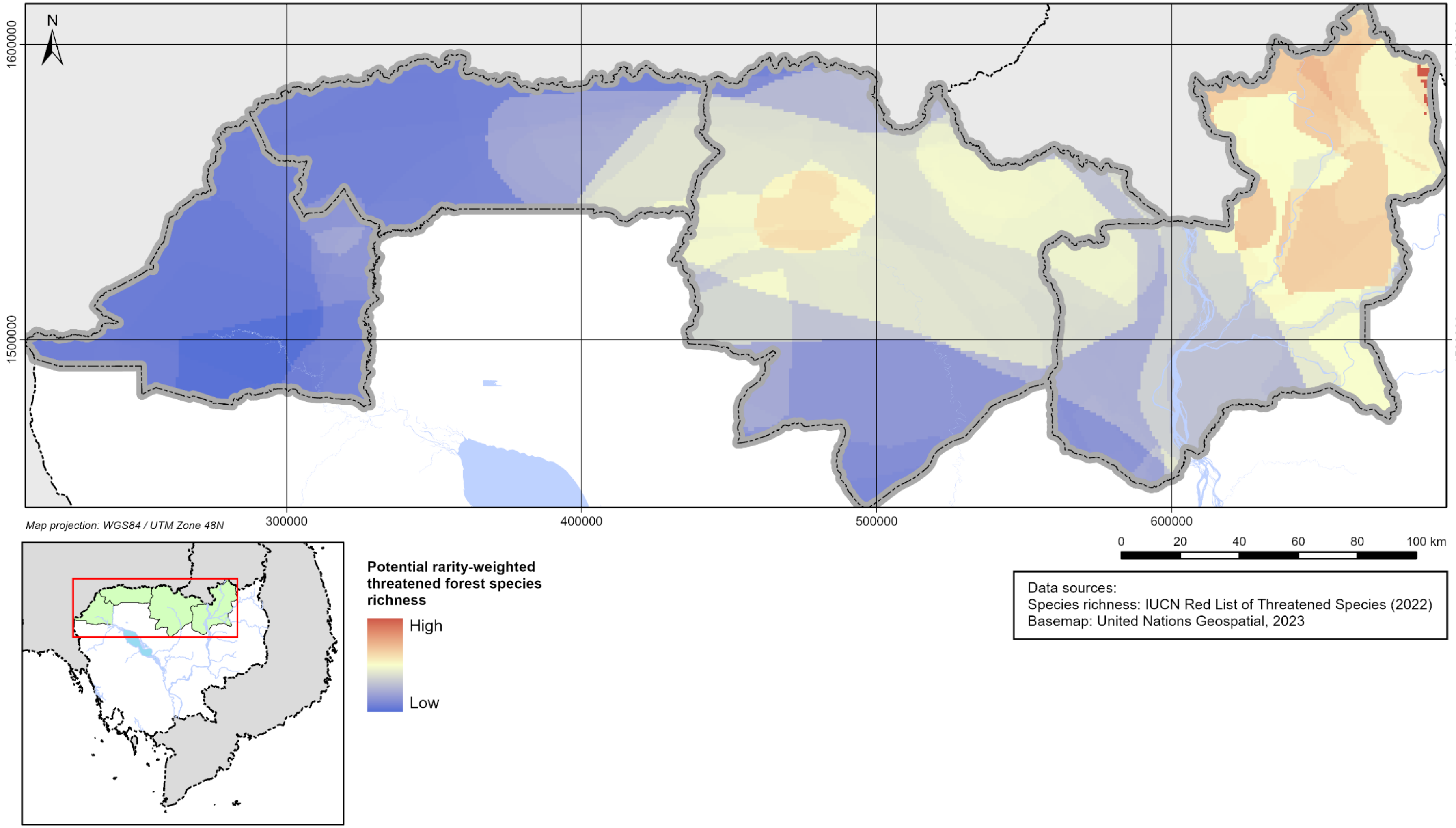
Figure 6: Estimated rarity-weighted threatened forest species richness

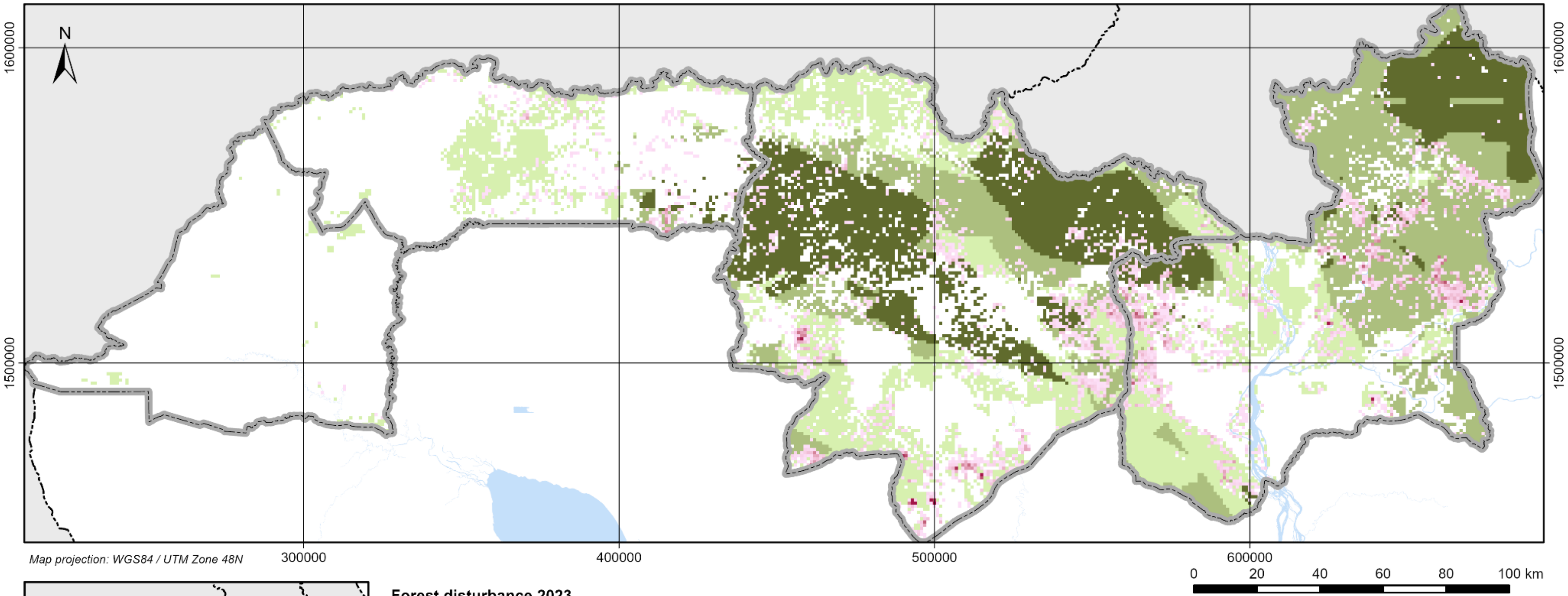
This map shows rarity- weighted threatened forest species richness across the provinces of Banteay Meanchey, Oddar Meanchey, Preah Vihear, and Stung Treng. This is where species richness is weighted according to the proportion of range within the study area compared to the global range of occurrence. This is based on distributional ranges of threatened species estimated using IUCN Red List of threatened species extent of occurrence data (IUCN, 2022). Threatened species included forest-dependent mammals, birds, reptiles and amphibians classified as “Critically Endangered”, “Endangered”, “Vulnerable” and “Near Threatened”. Generally, this method will result in an overestimation of species richness (Rocchini et al. 2011), though the use of this data allows for full coverage, whereas in-situ data is not available.

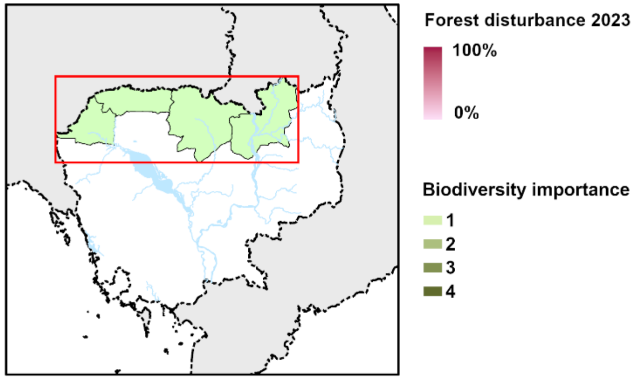


The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 7: Distribution of GLAD forest disturbance alerts in relation to important forest areas for biodiversity

This map shows areas of forest biodiversity significance in relation to forest disturbance in 2023 according to GLAD-Landsat deforestation alerts (Hansen et al., 2016). Forest extent was based on the 2018 land use/ land cover map (MoE, 2018). Forests were deemed important for biodiversity if they were in the highest two quantiles of either species richness or rarity-weighted species richness (see figure 5 and 6) and/or within areas important areas for biodiversity conservation and management (see figure 4). Values range from 1-3 based on whether forest areas fall within 1, 2 or 3 of these categories.





Data sources:
Biodiversity corridors: Department of GIS, General Directorate of Knowledge and Information (GDEKI), Ministry of Environment (2017)
Key Biodiversity Areas (KBAs): BirdLife International (2022). The World Database of Key Biodiversity Areas. Developed by the KBA Partnership: BirdLife International, International Union for the Conservation of Nature, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Re:wild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, Wildlife Conservation Society and World Wildlife Fund. [Accessed 31/01/2023)].
Community Protected Areas: Department of GIS, General Directorate of Knowledge and Information (GDEKI), Ministry of Environment (2016).
Protected Areas: Department of GIS, General Directorate of Knowledge and Information (GDEKI), Ministry of Environment (2021).
Tree cover disturbance 2023: Hansen, M.C., A. Krylov, A. Tyukavina, P.V. Potapov, S. Turubanova, B. Zutta, S. Ifo, B. Margono, F. Stolle, and R. Moore. 2016. Humid tropical forest disturbance alerts using Landsat data. Environmental Research Letters, 11 (3). Accessed through Global Forest Watch on 07/08/2023. www.globalforestwatch.org
Base map: United Nations Geospatial, 2023

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3.3 Forest Hydrological Ecosystem Services

Forests are among the most vital ecosystems for the provision of hydrological services. Forests regulate the water cycle – a function that becomes a service when people get water related benefits from the regulation – such as ground water recharge and water supply (quantity, timing and quality) to industries and households. These services are crucial for human wellbeing. Hydrological ecosystem services also include the role that ecosystems play in reducing water damage, through flood and erosion control (Carvalho-Santos et al., 2014).

Cambodia's economy is underpinned by ecosystem services, including water flow regulation and erosion reduction (Maurice et al., 2020). For example, agriculture significantly depends on water flow regulation, erosion reduction and nutrient retention services provided by forests, which contributed to 22% of GDP in 2018 (Maurice et al., 2020). A World Bank study found that standing forest in the Pursat River Basin in Cambodia provides benefits of at least US$99 million through ecosystem service provision, such as water and sediment flow regulation (Maurice et al., 2020). Therefore, forests help to sustain hydropower in Cambodia, a vital source of energy to the garment and other economic sectors.

Estimating hydrological ecosystem services provided by forests

The InVEST model was used to analyse two key forest hydrological ecosystem services - **water yield** and **sediment retention**. National LULC data from 2018 were used to represent the present-day forest areas that may be providing hydrological ecosystem services. LULC inputs from 2010 (MoE, 2010) were used to model change in areas likely providing ecosystem services over time. Other model inputs on different biophysical parameters used global data sources (Table 4), since local inputs were not feasible to collect in the time available. However, these inputs can be replaced with national data to improve model outputs.

Table 4: Data inputs to InVEST annual water yield and sediment retention

Data layer	***Data sources***	***Period***
Rivers	HydroSHEDS	2013
Elevation	HydroSHEDS	2008
Catchment boundaries	HydroBASINS	2013
Land cover/use	GDEKI, MoE, Cambodia	2010; 2018
Rainfall	CHIRPS	2018
Evapotranspiration	Global potential evapotranspiration	2019
Depth to root restricting layer	Global gridded soil information	2017
Plant available water content	Soil water capacity	2017
Rainfall erosivity	Global rainfall erosivity	2017
Soil erodibility	Harmonized world soil database	2012

Water yield

Annual water yield refers to the difference between total annual precipitation and evapotranspiration in a watershed, assuming no net storage in vegetation and soils over the course of the year (Vigerstol et al., 2021). It is affected primarily by the amount of precipitation and temperature but also varies with vegetation type and extent.

The InVEST Water Yield model (also known as the "Reservoir Hydropower Production model") was used to estimate the average annual water yield across the four provinces. InVEST uses a relatively simple rainfall-runoff model, whose biophysical parameters are shown in Table 4. The resulting estimates of water yield can provide an understanding of the importance of different parts of the landscape for water provision. Note that the model produces an annual average, but does not illustrate seasonal variations or extremes, which are important in Cambodia given the distinct wet and dry seasons. It also does not consider surface to deep water interactions.

More complex models and methods are available that can give more accurate estimates of water yield changes. However, these models have high data input requirements and take a long time to perform the analysis. Whilst InVEST results compare fairly well to more complex models, they should be treated in relative rather than absolute terms (Cong et al., 2020). If the quantitative results were to be used for decision support, calibration and validation with field measurements would be required.

Figure 8 shows the estimated annual forest water yield per sub-catchment. There is relatively high forest water yield towards the north of Stung Treng and a decreasing trend to the west. These results are influenced both by the higher rainfall to the east and by the distribution of forest, which is more prevalent in Stung Treng and Preah Vihear, and least prevalent in the two western provinces.

To estimate the impact of changing forest cover on annual water yield (Figure 9), the model was also run using spatial data on the difference in forest extent between 2010 and 2018 (MoE, 2018) (see also Figure 3 for forest cover change 2010-2018). Forest loss between 2010 and 2018 is associated with an estimated decrease in annual water yield. This is particularly the case in Oddar Meanchey, which experienced significant forest cover loss in 2010-2018. Similarly, the results suggest a decrease in annual water yield for some sub-catchments towards the south-west of Stung Treng, where forests are estimated to play an important role in water yield (Figure 8).

Forest water provision: Step-by-step

1. **Input data into InVEST water yield model:** The model can be used to identify areas of the landscape that contribute to maintaining water balance. This is a simple rainfall-runoff model that requires information on annual precipitation, potential evapotranspiration, soil properties, land use/ landcover, and sub-catchment boundaries.

2. **Map annual water yield**: Annual water yield for 2018 was mapped and a mean value was calculated for each sub-catchment. To determine forest's contribution to annual water yield, a scenario where all forest was converted to bare ground was also run. The difference between these two outputs was considered to be forest's contribution to annual water yield.

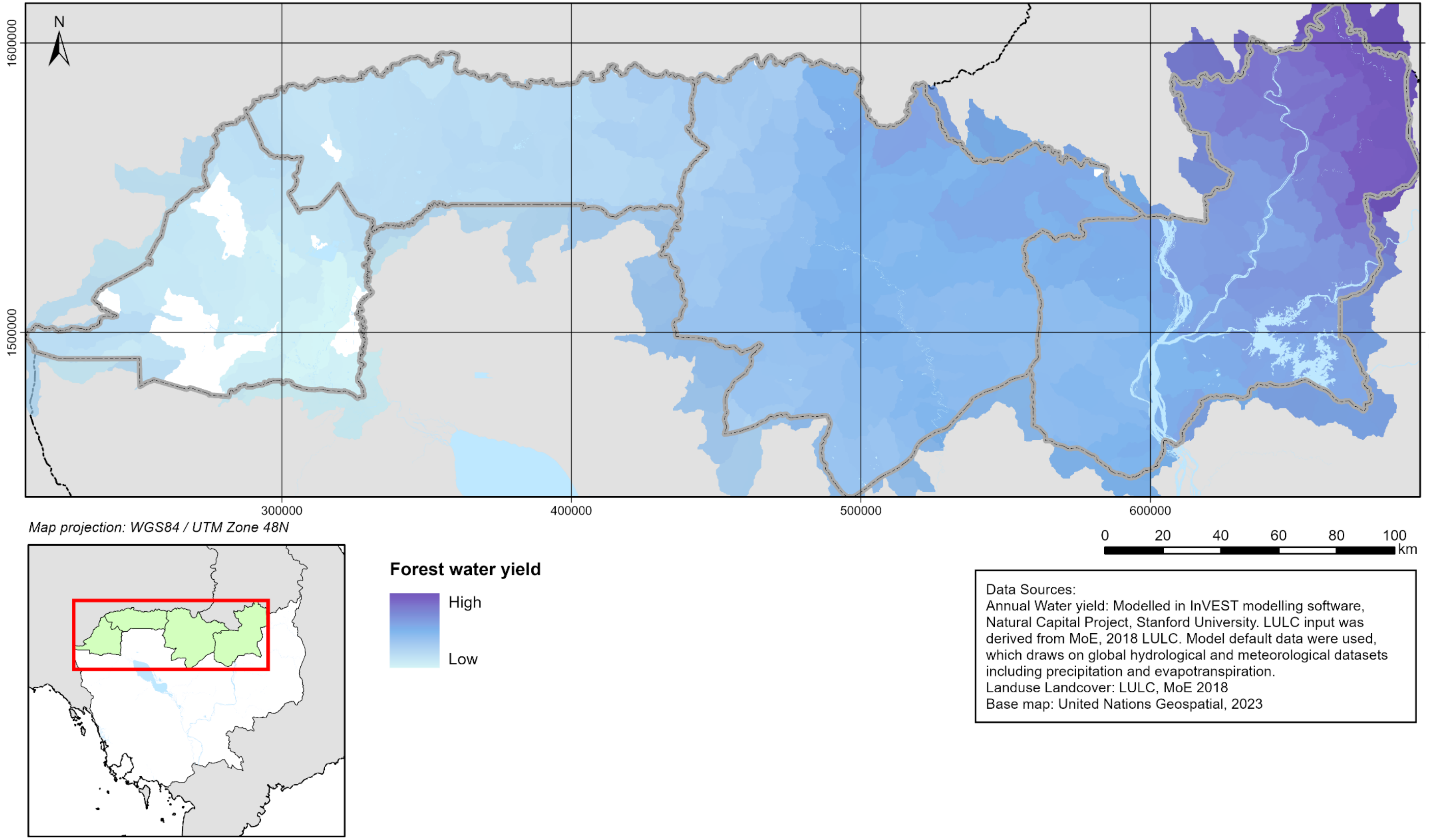
3. **Produce a binary map to highlight areas important for water provision:** The top two quantiles were selected to highlight areas where forest contributes positively to water yield.

4. **Produce map of scenario conditions:** The model in this case was run using 2010 LULC to show the impact of forest change on water yield. Estimated annual water yield using 2018 LULC was subtracted from that using 2010 LULC to determine the difference in annual water yield between the two cases. Scenarios could also be generated to represent future changes in conditions.

Resources: http://releases.naturalcapitalproject.org/invest-userguide/latest/en/annual_water_yield.html

Figure 8: Estimated annual water yield of forests (from 2018 MoE LULC map)

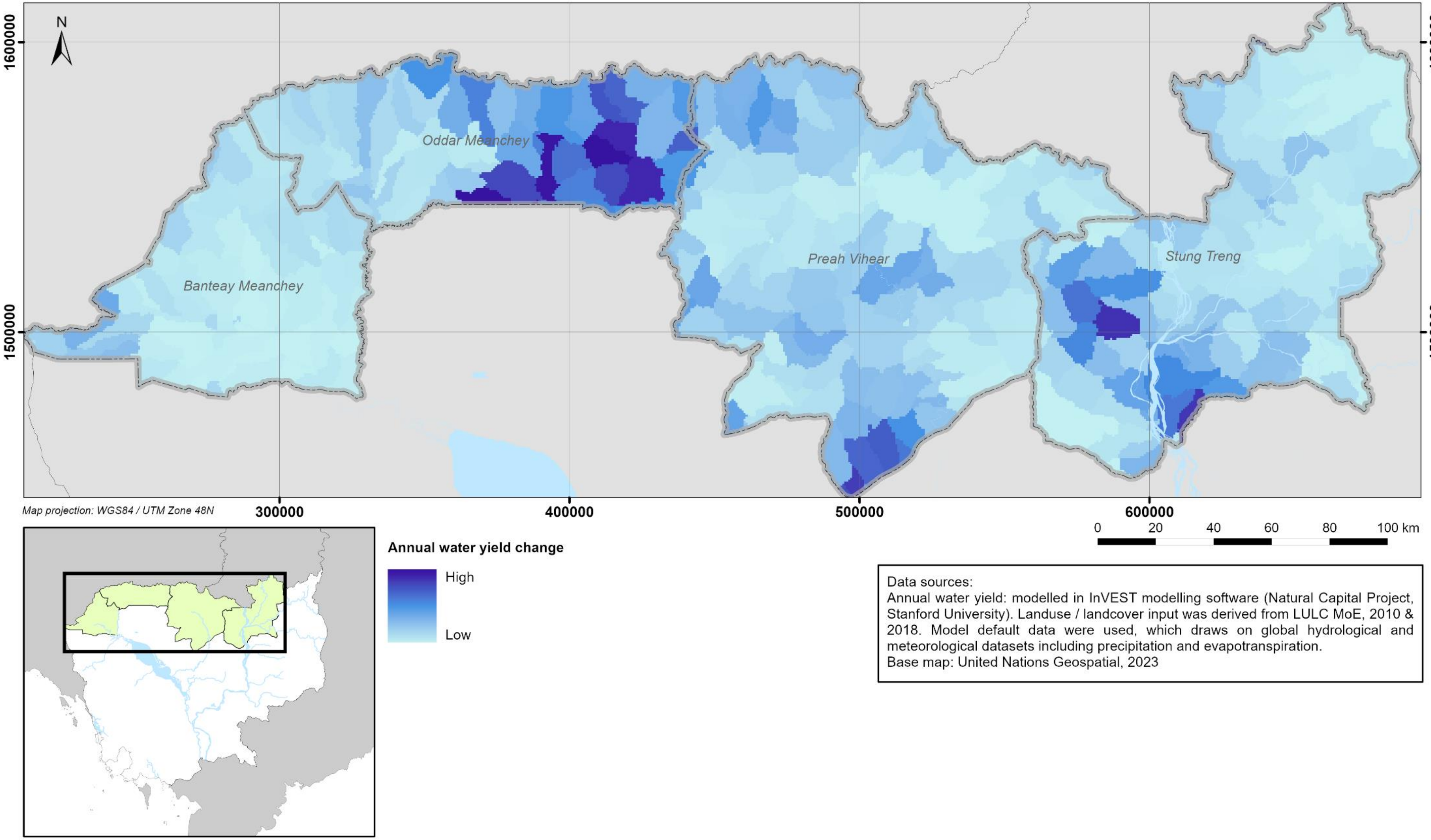
This map shows the estimated forest annual water yield across sub-catchments according to 2018 forest extent (MoE, 2018), as well as climatic and other variables from the same year. This was estimated using the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) modelling software (Natural Capital Project, Stanford University) annual water yield model. The annual water yield model calculates the relative contribution of each land parcel to annual average water yield, therefore identifying areas of land that contribute the most to water supply. Pixel values were aggregated to sub-catchments to provide a mean value for each.



The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 9: Estimated change in annual water yield as a result of landcover change

This map represents the estimated change in annual water yield across the provinces of Banteay Meanchey, Oddar Meanchey, Preah Vihear, and Stung Treng as a result of landcover change between 2010 and 2018. Results are aggregated to give a mean value for each sub-catchment. This was estimated using the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) modelling software (Natural Capital Project, Stanford University) annual water yield model. The annual water yield model calculates the relative contribution of each land parcel to annual average water yield.



The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Sediment retention

Forests play a role in the control of erosion and retention of sediment. Sedimentation is of particular concern for water quality and the ability of infrastructure (including reservoirs, hydroelectric dams and irrigation systems) to supply water.

The InVEST Sediment Retention model estimates the capacity of forest in a land parcel to retain sediment by using information on geomorphology, climate, vegetative coverage and management practices. That is, it estimates the contribution of forests to avoided erosion. Figure 10 shows the results of the sediment retention model using forest extent from landcover in 2018 for the four provinces. This shows particularly high sediment retention capacity in the northern parts of Stung Treng and along the border with Thailand in the north of Oddar Meanchey and Preah Vihear, as well as some areas in the centre of Preah Vihear province. Some of these areas are already under protection (see Figure 4), such as in northern Preah Vihear and Stung Treng. In addition, given that many of these areas potentially significant for sediment retention are along Cambodia's borders, further exploration of transboundary management of forests and landscapes in these areas may be important to consider.

Forest Sediment retention: Step-by-step

1. **Input data into InVEST Sediment Delivery Ration (SDR) model:** The model can quantify the amount of erosion across a landscape. The model inputs include a Digital Elevation Model (DEM), annual average rainfall to determine rainfall erosivity, soil type to determine soil erodibility values, land use/ landcover and river sub-catchment boundaries.

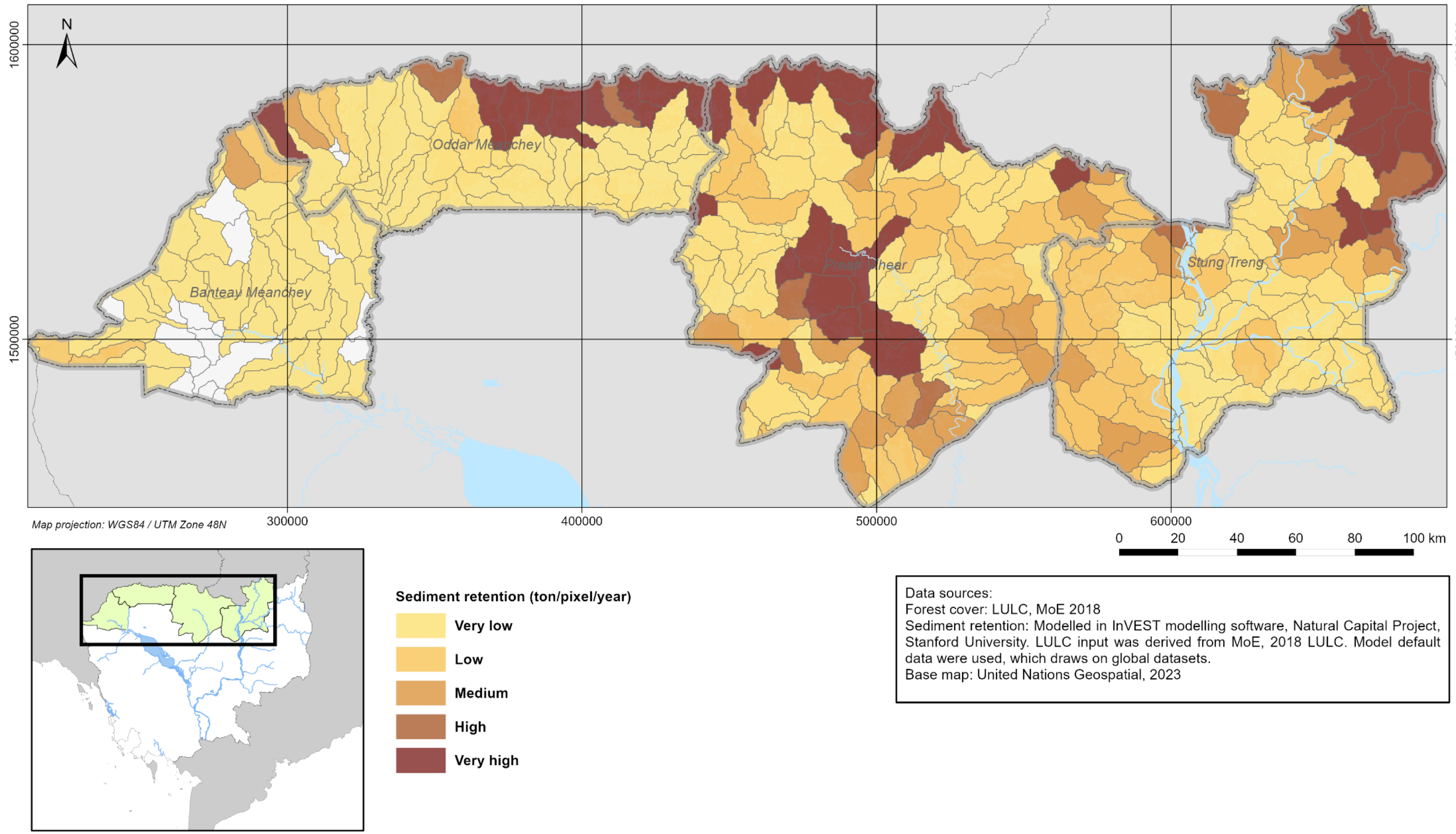
2. **Map model outputs:** The model output of avoided erosion can be used to show vegetation's contribution to erosion prevention. In this case, outputs were masked by forest cover to show only forest's contribution to sediment retention. An average value per sub-catchment was calculated.

3. **Produce a binary map to highlight areas important for sediment retention:** Values in the top band were selected to represent areas where forest contributes greatly to erosion prevention.

Resources: http://releases.naturalcapitalproject.org/invest-userguide/latest/en/sdr.html#sediment-retention-services

Figure 10: Forest sediment retention aggregated to each sub-catchment

This map shows the estimated capacity of forested areas to retain sediment across sub-catchments according to 2018 forest extent. This was estimated using the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) modelling software (Natural Capital Project, Stanford University) sediment retention model, which uses information on topography, climate and forest type and coverage to estimate avoided erosion. Pixel values were aggregated to the sub-catchments to provide a mean value for each. This indicates the importance of forest areas for water quality and avoided sedimentation of water infrastructure such as reservoirs.



Data sources:
Forest cover: LULC, MoE 2018
Sediment retention: Modelled in InVEST modelling software, Natural Capital Project, Stanford University. LULC input was derived from MoE, 2018 LULC. Model default data were used, which draws on global datasets.
Base map: United Nations Geospatial, 2023

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Important areas for hydrological ecosystem services and forest disturbance

Figure 11 shows forest areas potentially important for hydrological ecosystem services together with forest disturbance. The forest areas most important for water yield and sediment retention according to the results of the analyses presented above (Figures 8, 9 and 10) were combined to create a binary layer representing forests important for hydrological ecosystem services. Dark blue on the map indicates that forest is important for both services, whilst light blue suggests that it is particularly important for only one of the services. It is important to note the limited area of forests that are potentially important for providing both services, concentrated in Stung Treng, central Preah Vihear, and small strip in northern Preah Vihear.

This binary layer was then combined with the GLAD alerts from 2023. The alerts within these forest areas have been highlighted, showing that a number of alerts have occurred in important areas for hydrological services in Stung Treng province in particular, as well as in the small strip in northern Preah Vihear province.

Hydrological Ecosystem Services Provision: Step-by-step

1. **Produce a map of forest contribution to water yield**: Using the InVEST water yield model and based on the most recent LULC map, rainfall and evapotranspiration from that year, and data describing other biophysical properties of the landscape, including elevation, rivers, catchment boundaries and soil properties. The top two quantiles were selected to highlight areas where forest contributes positively to water yield.

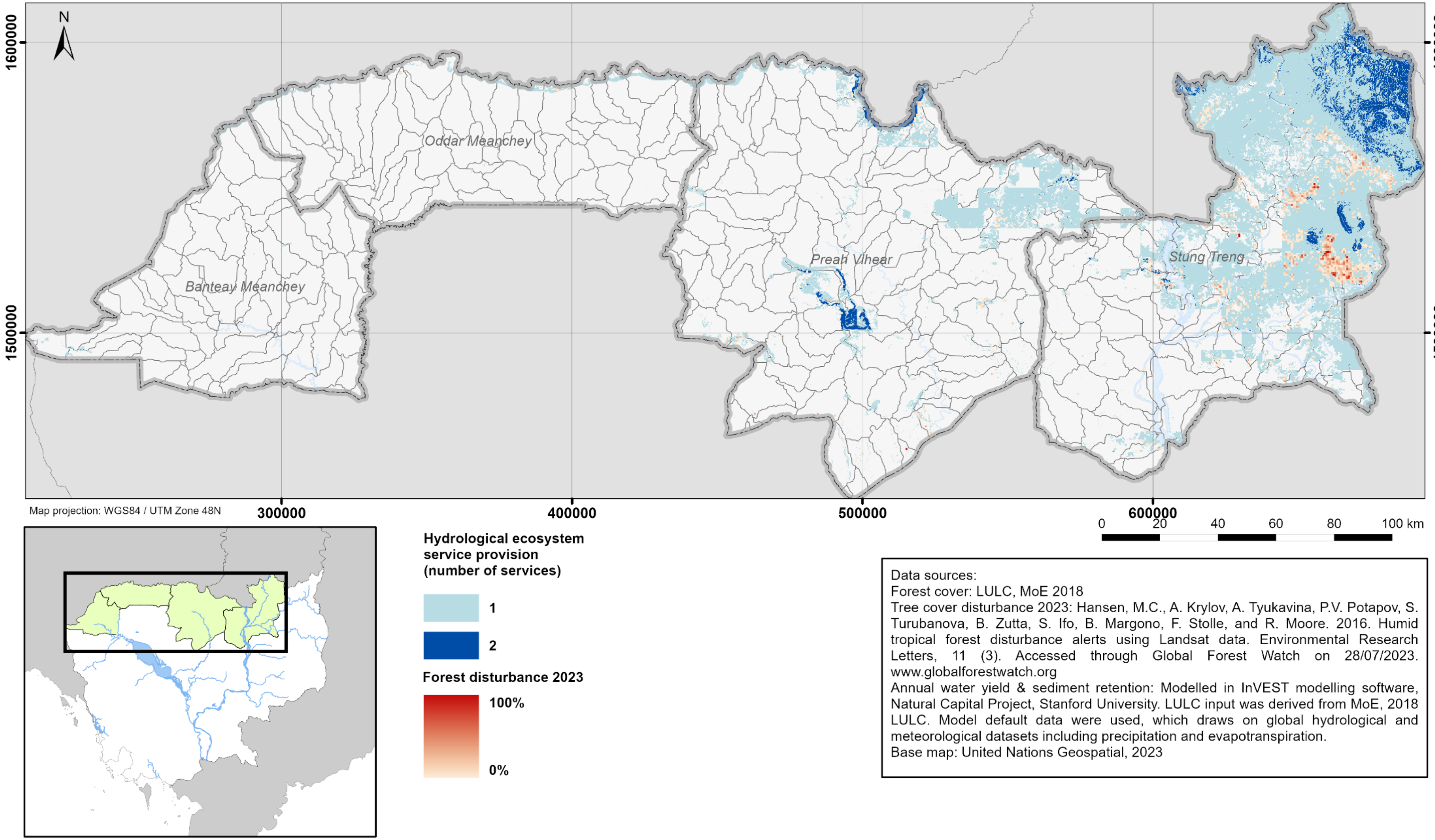
2. **Produce a map of forest sediment retention capacity:** Using the InVEST sediment retention model, based on the most recent LULC map and data describing other biophysical properties of the landscape, the top two quantiles were selected to highlight areas where forest contributes positively to erosion prevention.

3. **Produce a binary map to highlight areas important for hydrological ecosystem services:** A Binary map of hydrological ecosystem services was produced highlighting forest areas important for erosion prevention and water provision. This was used as an input layer to map converging multiple benefits.

Resources: http://releases.naturalcapitalproject.org/invest-userguide/latest/en/annual_water_yield.html
http://releases.naturalcapitalproject.org/invest-userguide/latest/en/sdr.html#sediment-retention-services

Figure 11: Distribution of GLAD forest disturbance alerts in relation to forests that are important for hydrological ecosystem service provision

This map shows the areas of forest that are most important for providing hydrological ecosystem services in relation to forest disturbance 2023 according to GLAD-Landsat deforestation alerts (Hansen et al., 2016). This is based on the analyses of annual water yield and sediment retention using InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) modelling software (Natural Capital Project, Stanford University). Light blue areas signify importance for one hydrological ecosystem service, while dark blue areas indicate significance for both sediment retention and water supply services.



Data sources:
Forest cover: LULC, MoE 2018
Tree cover disturbance 2023: Hansen, M.C., A. Krylov, A. Tyukavina, P.V. Potapov, S. Turubanova, B. Zutta, S. Ifo, B. Margono, F. Stolle, and R. Moore. 2016. Humid tropical forest disturbance alerts using Landsat data. Environmental Research Letters, 11 (3). Accessed through Global Forest Watch on 28/07/2023. www.globalforestwatch.org
Annual water yield & sediment retention: Modelled in InVEST modelling software, Natural Capital Project, Stanford University. LULC input was derived from MoE, 2018 LULC. Model default data were used, which draws on global hydrological and meteorological datasets including precipitation and evapotranspiration.
Base map: United Nations Geospatial, 2023

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3.4 Forest biomass carbon stocks

Around one-third of carbon stored in terrestrial ecosystems in Cambodia is found in evergreen forests (Kapos et al. 2010). Many of these forests are formally protected, but considerable loss still occurs (Figure 3).

Cambodia has participated in REDD+ efforts under the UNFCCC since 2008. A National REDD+ Strategy (MoE and MAFF, 2017) has been developed that seeks to improve the management of forest lands to contribute to national and global climate change mitigation, whilst conserving biodiversity and alleviating poverty. The key objectives of the National REDD+ Strategy include improving the monitoring and management of forest resources and forest land use and strengthening the implementation of sustainable forest management. Further, the Nationally Determined Contribution (GSSD, 2020) commits to "reducing the historic emissions from forest sector by half in 2030". REDD+ projects have been implemented in the country including, Tumring REDD+ project covering 67,791.17ha, the Seima Protection Forest project covering 166,983ha, and the Southern Cardamom REDD+ project covering 445,399ha[1]. Also, there are further projects still under development. These projects intend to increase forest protection and carbon storage, but also enhance livelihoods and financial security.

Mapping carbon provides a way to estimate the overall amount of carbon stored in vegetation and other carbon pools and understand the distribution of those carbon stocks across a landscape. Identification of areas of higher and lower biomass carbon can support planning, such as the design of interventions to protect or restore these areas. Combined with other types of information – such as on ecosystem services and biodiversity – it can also identify areas that have strong potential for both carbon and additional benefits.

Identifying important areas for forest carbon

Carbon in forests is stored in biomass (above and below ground), woody debris and leaf litter, as well as in soils. Mapping efforts have mostly concentrated on aboveground biomass since it is the easiest to measure. However, other pools can be significant, especially soil carbon. Below-ground biomass can be estimated from above-ground biomass using root-shoot ratios for the forest type. The most accurate way to estimate biomass carbon is through extensive field inventories, but these are time and resource intensive, with a need to measure and identify each tree in a plot. Remote sensing analysis using satellite imagery can provide estimates covering a larger area, using smaller amounts of field data for calibration.

Various global carbon density maps are available, each using different methods (Table 5). Some are more accurate in some parts of the world than others, which can be biased towards where field data was used to validate the estimates. Therefore, estimates from global maps must be assessed for accuracy in the area of interest. Geographic coverage and scalability are amongst the aspects assessed for carbon datasets in a 'Dashboard for assessing the utility of global data for national planning', available at www.spacescoalition.org/resources.

[1] Cambodia REDD+ Programme. (2018). *Project listing*. [Online]. https://cambodia-redd.org/. Available at: https://cambodia-redd.org/policies-and-strategies/redd-project-database/project-listing.html [Accessed 20 May 2023].

Table 5: Global datasets of biomass carbon

Data layer	*Data sources*	*Period*	*Resolution*
Aboveground live woody biomass density	Harris et al., 2021	2000	30 m
Above and Belowground carbon density	Spawn and Gibbs, 2020	2010	30 m
Above and below ground live biomass carbon density	NatureMap (n.d.)	2019	N/A
CCI biomass change	European Space Agency (Santoro and Cartus, 2021)	Mid 1990s, 2010, 2017, 2018	100 m
Biomass change for terrestrial woody vegetation	Chloris	2003-2019	4.6 km
Soil Organic Carbon	Soilgrids (Poggio et al, 2021)	N/A	250 m
Vulnerable soil organic carbon density	García-Rangel et al. (in prep)	2020- 2050	N/A

Carbon density maps can also be produced by assigning biomass estimates to national or local landcover maps. This method is used in this study, and requires estimates of the average biomass content of each landcover class (e.g., vegetation type). It has the disadvantage that it does not account for degradation of biomass stocks, e.g., through fire or logging. Cambodia's 2021 Forest Reference Level (FRL) provides biomass and respective carbon estimates for each forest class (MoE and MAFF, 2021). The biomass carbon density values are produced using the national FRL carbon density values for different forest classes. These are based on surveys carried out across Cambodia – they represent average values (table 6). The values for carbon stored in each forest class were then used to assign estimates of biomass carbon density according to the LULC map for 2018 (MoE, 2020).

Table 6: Above and below ground biomass carbon stock values in Cambodia[2]

Forest type	C ton ha^{-1}	Source
Evergreen forest	85.72	FAO, 2019
Semi-evergreen forest	91.19	FAO, 2019
Deciduous forest	39.97	FAO, 2019
Forest regrowth	42.30	CFI, 2008
Flooded forest	44.97	FAO, 2019
Tree plantation	56.40	IPCC, 2003; MoE and, UNDP, 2003
Mangrove	66.70	FAO, 2019
Rear Mangrove	115.55	Tran, 2015

[2] From the Cambodia FRL report based on field survey estimates of biomass in different forest types around Cambodia.

Figure 12 shows the results of this carbon mapping approach, with darker colours indicating higher forest biomass carbon density. CPAs and CFs are also shown on the map, with carbon represented in a different colour to more clearly show the potential carbon stored in these areas. Although this approach provides only an initial indication – with field verifications and a more thorough forest inventory recommended – this map does show a relatively high estimated carbon density in these community-managed areas. Should government, NGOs and community leaders wish to pursue REDD+ or other approaches to safeguard these carbon stocks, other information and analyses will be essential – such as driver analyses, participatory planning, and more. It should also be noted that this map focuses solely on forest biomass – other ecosystems and soils also play an important role in sequestering and storing carbon.

Although not shown in the map below, a simple comparison was performed with several other carbon datasets, (e.g., Spawn and Gibbs, 2020 and CCI (Santoro and Cartus, 2021). There are notable differences between the national carbon stocks approach and Spawn and Gibbs (2020), in terms of both the estimates of biomass carbon stocks and how they are distributed. However, the CCI biomass change dataset is more compatible with the Cambodia dataset. Both global datasets produce higher estimates of biomass carbon density than the national data, though Santoro and Cartus (2021) shows a similar spatial distribution to the national data.

Forest biomass carbon: step-by-step

1. **Identify forest areas and different forest categories**: Forested areas and categories were determined from the 2018 MoE LULC map.

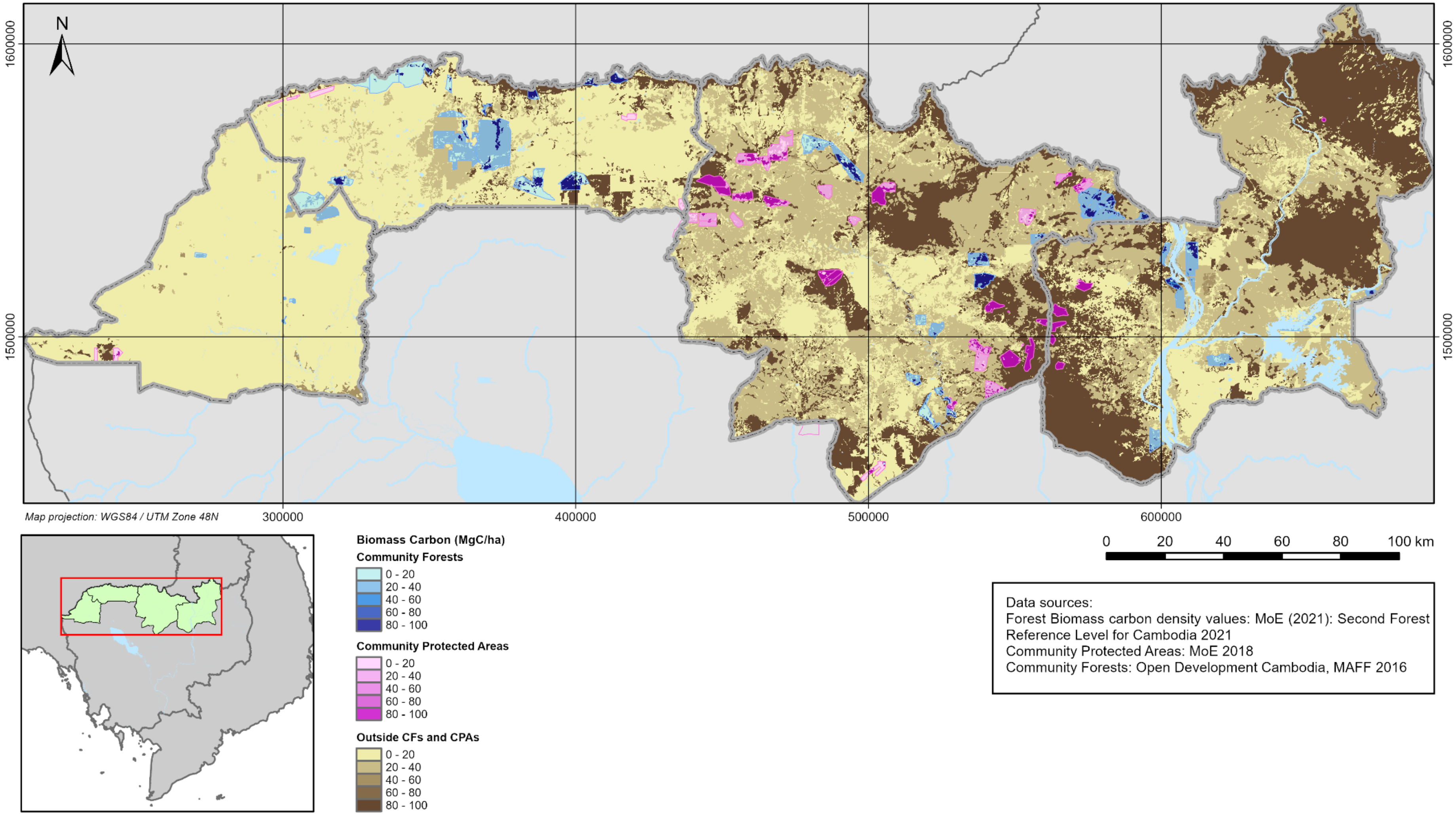
2. **Assign forest biomass carbon density values:** The National Forest Reference level was used to provide forest biomass carbon estimates for each forest type.

3. **Produce a binary map to highlight areas important for forest biomass carbon:** A binary layer was created, highlighting the top two quantiles of forest biomass carbon signifying forest with high biomass carbon. This layer was used as an input layer into the map showing convergence of multiple benefits.

Resources: https://unep-wcmc-gis-tutorials.readthedocs.io/en/latest/ComparingCarbonDatasets_QGIS.html

Figure 12: Above and below ground biomass carbon in forests

This map shows estimated aboveground and belowgound biomass carbon in forests across Banteay Meanchey, Oddar Meanchey, Preah Vihear, and Stung Treng. Forest biomass carbon density values were derived from the Cambodia FRL (2021), which is based on field sample data from survey sites across Cambodia. Forest carbon that is within Community Forests or Community Protected Areas is highlighted in blue and pink respectively.



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3.5 Forest areas with the potential to provide multiple benefits

Multi-criteria analysis (MCA) and systematic conservation planning (SCP) are two approaches to identifying potential key areas for conservation, restoration and other actions based on their likely benefits. Each approach offers a systematic way to determine potential synergies and trade-offs between different objectives, including social and environmental objectives, each method with its pros and cons (UNEP-WCMC, 2023).

Forest benefits are diverse: for example, approximately 4 million people live within 5km of forest areas and forest products account for 10% to 20% of household consumption, on average (National REDD+ Strategy 2017). Around 18% of Cambodia's GDP in 2018 came from tourism, including ecotourism, which relies on the nation's rich forest biodiversity.

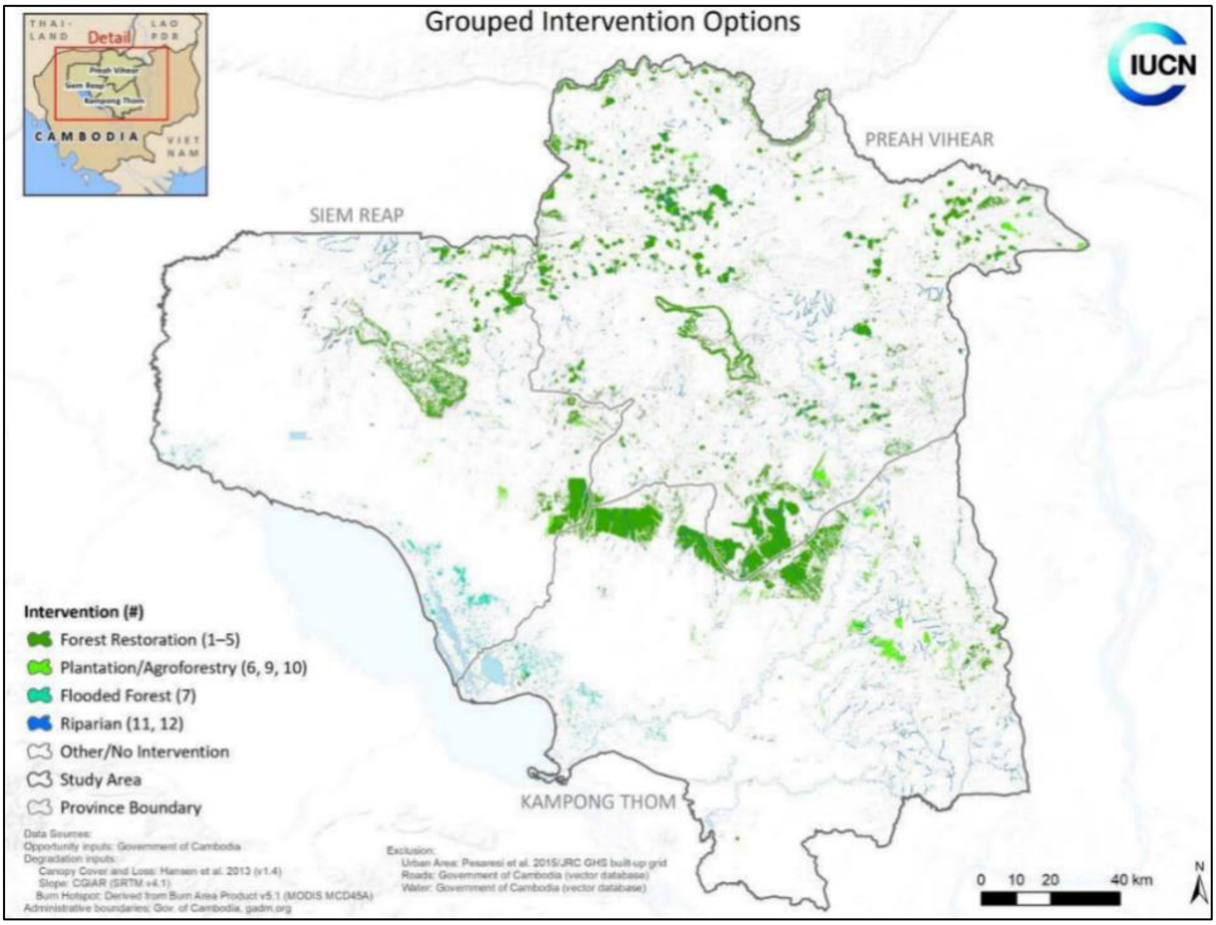
In Cambodia, numerous initiatives have mapped potential conservation and restoration opportunities. Two such analyses are highlighted here: one applying an MCA approach (the Restoration Assessment Opportunities Methodology, ROAM; Li et al., 2018) and another using an SCP approach (Essential Life Support Areas, ELSA; UNDP, 2021).

Restoration Opportunities Assessment Methodology

FAO, IUCN and MAFF applied the Restoration Opportunities Assessment Methodology (ROAM) in three target provinces of Kampong Thom, Preah Vihear and Siem Reap to identify priority areas for restoration to improve local livelihoods (Li et al., 2018). This involved consultations with relevant national and sub-nation authorities and local communities. It identified key drivers of ecosystem degradation and mapped restoration opportunities and drivers of degradation. Opportunity areas were PAs, conservation corridors, riparian buffers, community forests, community protected areas, and community fisheries. Drivers of degradation included areas of recent forest loss, frequently burned areas, and areas of high slope. Twelve options for restoration interventions were identified, and a cost-benefit analysis was conducted for each of these. The net present value was estimated for implementing restoration options in different opportunity areas. Figure 13 shows the resulting map of restoration opportunity areas.

Figure 13: Map showing distribution of intervention options and restoration priority areas for the three provinces of Kampong Thom, Preah Vihear and Siem Reap (Li et al., 2018)

The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations



Essential Life Support Areas (ELSA)

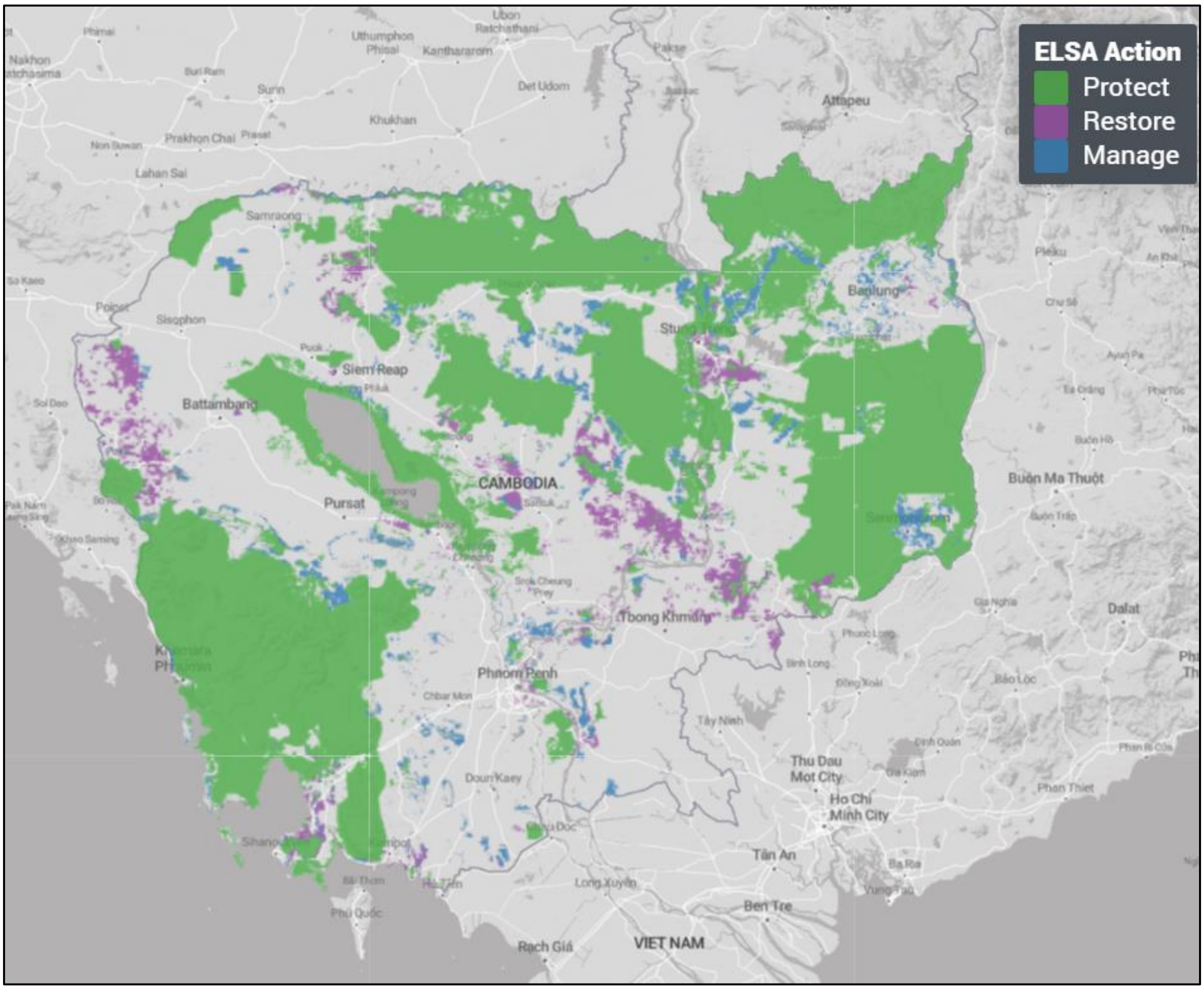
Cambodia has also developed maps of Essential Life Support Areas (ELSAs) led by GDEKI, MoE and UNDP (UNDP, 2021) (Figure 14). This brought together data layers related to biodiversity, climate change, and human well-being to highlight areas with the highest potential benefits from protection, sustainable management, and restoration of nature. ELSA aims to optimize the areas selected to maximize potential benefits across these various interventions, using specified targets for each area.

The biodiversity data layers included were Key Biodiversity Areas (KBAs), natural forest distribution, mangrove distribution, intact ecosystems, threatened ecosystems, biodiversity corridors, biodiversity and protected area management project (BPAMP) areas, Community Protected Areas (CPAs) and main rivers (including a 10km buffer zone)[3]. Data related to climate change mitigation and adaptation included predicted vulnerability to deforestation, areas with high potential carbon emissions, climate adaptive capacity, populations affected by flood and upland watersheds. For the human well-being aspect, areas were identified that were important for non-timber forest product (NTFP) provision, locations of community fisheries and fishery dependency, community forestry, watersheds classified as important for agroforestry, and tourism hotspots (see Annex 3 for full details of data and sources). Featured datasets were given a relative weighting depending on the importance determined by stakeholders and on the confidence in the data being used.

[3] https://www.learningfornature.org/wp-content/uploads/2021/10/Day-2_DataDescriptions_Cambodia_Scott_Di-2.pdf

Then other data layers were used to identify zones that were potentially suitable for protection, management and restoration. Including global human footprint, natural forest distribution; and potential national forest.

Figure 14: Map identifying Essential Life Support Areas (ELSAs)



Demonstrating a Multi-Criteria Analysis (MCA) approach

Building on the methods demonstrated by the two existing approaches highlighted above, the project also carried out an MCA. This aimed to determine forest areas that have the potential to provide the most benefits according to the criteria assessed in this study, and initially combined layers for biodiversity importance, hydrological ecosystem services, and above and below-ground forest biomass carbon. Each layer was split into six quantiles and the top two quantiles were selected to represent areas of high importance for each criterion. Areas where prioritized criteria coincided were identified based on the number of converging benefits. Areas were ranked from 1-3 according to the number of coinciding benefits.

Based on feedback from the consultation workshop, climate change vulnerability was also included as a feature. The National Council for Sustainable Development Climate Change Vulnerability Index (NCSD, 2021) was used to show where forest multiple benefits exist in areas considered particularly vulnerable to climate change, and thus the areas that could potentially benefit the most from conserving/restoring forest ecosystem services. Data related to climate change adaptation used in the ELSA analysis only includes climate change adaptive capacity from 2012 and populations affected by flood for the year of 2011. Therefore, the up-to-date climate change vulnerability index, which includes multiple climate hazards, will likely provide a better estimate of the potential for forest services to contribute to climate change adaptation. This is a composite vulnerability index, combining values of vulnerability from three main hazards (floods, drought and storms) to give a vulnerability score per commune. This uses data from Cambodia's Commune Database (CDB) as proxies of vulnerability, related to poverty, agriculture, business, education, health and environment, with data on exposure and impacts of climatic hazards (Rai et al., 2015).

The final data layers used for this pilot MCA combined both social and environmental elements to highlight forests estimated to be providing multiple benefits:

- Biodiversity importance combining different categories of conservation management areas (, including PAs, CPAs, CFs, BCCs and KBAs) and threatened forest species richness quantity and vulnerability (see Figure 7)
- Hydrological ecosystem services combining estimates of forest annual water yield and sediment retention capacity from InVEST (see Figures 8 and 10)
- Climate change mitigation using estimates of forest above and below-ground biomass carbon (see Figure 12)
- Climate change adaptation, using the NCSD Climate Change Vulnerability Index (2021), which provides an estimate of commune vulnerability to the three main climatic hazards of floods, drought and storms
- GLAD alerts, showing potential occurrence of deforestation in 2023 (see Figure 2)

Figure 15 shows the results of this analysis. This estimates where forests have the most benefits in terms of water provision, biodiversity, and carbon, in areas that are most vulnerable to climate change, and in relation to GLAD alerts. This shows that forest areas where there is likely to be a concentration of these benefits can be found in central Preah Vihear province, eastern Stung Treng, and northern border areas. Importantly, despite its lower forest cover, there are also clusters of these forest areas in Oddar Meanchey. Areas of disturbance in and around these significant forest areas may require further investigation. There are also larger forest areas of medium estimated significance for providing these benefits, where disturbance has been less prominent, such as in northern Stung Treng province, and which may benefit from ongoing protection and management.

Further validation of these initial mapping results and of areas providing these benefits is necessary to build on this analysis. For example, additional analyses and consultations with stakeholders could build on this MCA in order to prioritize areas for conservation, and sustainable management.

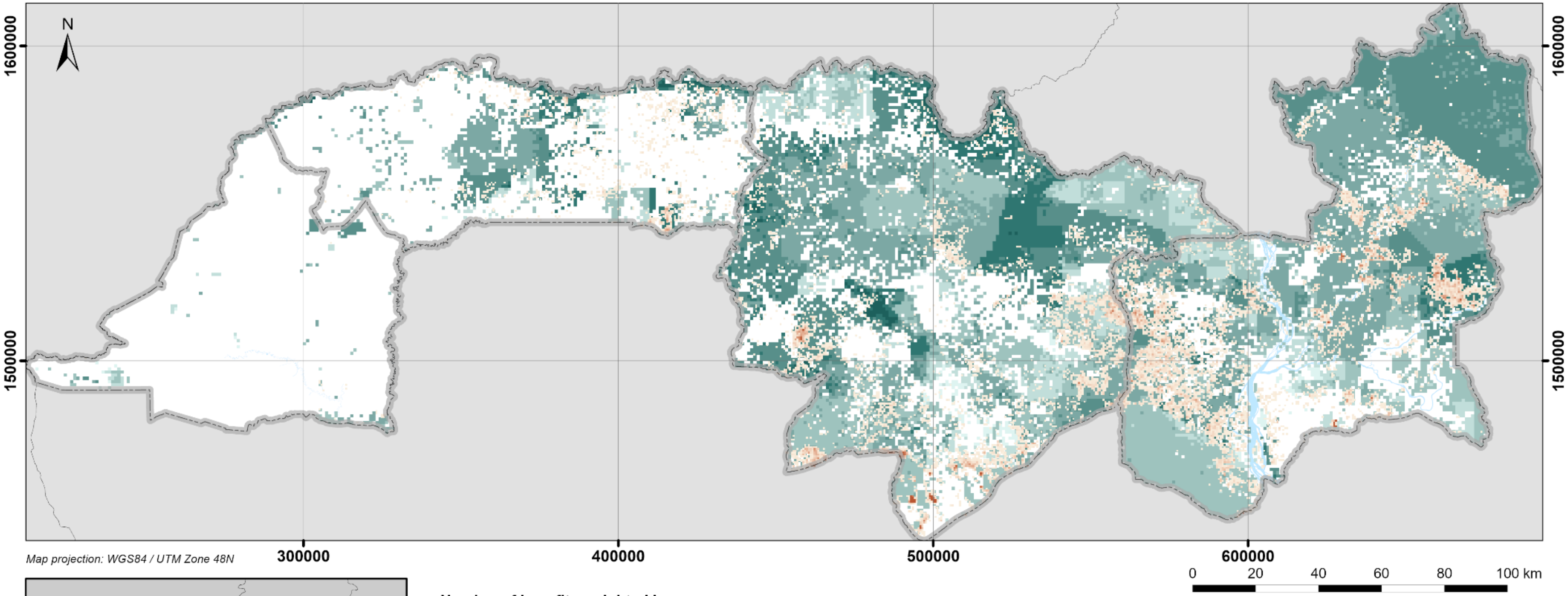
Convergence of multiple benefits: Step-by-step

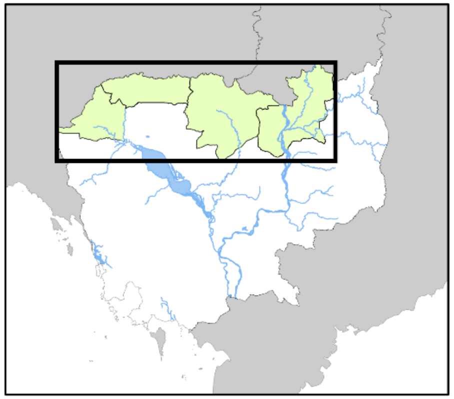
1. **Create a map layer of converging multiple benefits**: Overlay the three binary layers that show important areas for biodiversity, hydrological ecosystem services, and carbon. Sum the layers to produce values between 1-3 representing the number of converging benefits.

2. **Weight the forest benefits according to climate change vulnerability:** It was assumed that benefits derived from forests are more valuable to people who are most vulnerable to climate change. The number of benefits were multiplied by the National Council for Sustainable Development Climate Change Vulnerability Index (NCSD, 2021) to give a weighted scoring.

Figure 15: Distribution of potential multiple benefits from forests in relation to forest disturbance

This map shows forest areas of overlapping importance for biodiversity, carbon, and hydrological services, combining the layers from the previous analyses and showing forest that is important for providing 1, 2 & 3 of those services, in relation to forest disturbance in 2023. The services were hydrological ecosystem services of sediment retention and water yield, climate change mitigation in terms of forest biomass carbon, and biodiversity using proxies of species richness, rarity-weighted species richness and designated areas for biodiversity conservation. These scores have been weighted with the climate change vulnerability index to show the relative importance of these services for people.





Number of benefits weighted by commune climate change vulnerability index

High

Low

Forest disturbance 2023

100%

0%

Data sources:
Forest cover: LULC, MoE 2018
Tree cover disturbance 2023: Hansen, M.C., A. Krylov, A. Tyukavina, P.V. Potapov, S. Turubanova, B. Zutta, S. Ifo, B. Margono, F. Stolle, and R. Moore. 2016. Humid tropical forest disturbance alerts using Landsat data. Environmental Research Letters, 11 (3). Accessed through Global Forest Watch on 28/07/2023. www.globalforestwatch.org
Annual water yield & sediment retention: Modelled in InVEST modelling software, Natural Capital Project, Stanford University. LULC input was derived from MoE, 2018 LULC. Model default data were used, which draws on global hydrological and meteorological datasets including precipitation and evapotranspiration.
Biomass carbon: MoE and MAFF. (2021). Second Forest Reference Level for Cambodia under the UNFCCC Framework. [Online]. Available at: https://redd.unfccc.int/files/cambodia_2nd_frl_modification_submission_20213005.pdf [Accessed 24 July 2023].
Biodiversity: Department of GIS, General Directorate of Knowledge and Information (GDEKI), Ministry of Environment; Key Biodiversity Areas (KBAs): BirdLife International (2022). IUCN. 2022. The IUCN Red List of Threatened Species. Version 2022-2. https://www.iucnredlist.org. Accessed on 27/01/2023.
Climate change vulnerability index: National Council for Sustainable Development (NCSD). (2019). Climate Change Data Portal. [Online]. https://ncsd.moe.gov.kh/. Available at: https://ncsd.moe.gov.kh/dcc/data-portal [Accessed 15 June 2023].
Base map: United Nations Geospatial, 2023

4. CONCLUSION AND NEXT STEPS

4.1 Analysing Forest Benefits

Forests in Cambodia offer multiple goods and services that benefit society and the environment. This report aims to quantify and visualize some of these benefits and how they relate to deforestation and degradation based on available data across the four provinces of Banteay Meanchey, Oddar Meanchey, Preah Vihear and Stung Treng. The maps produced intend to explore ways to understand the potential impacts of forest change on the provision of these forest ecosystem goods and services. In addition, in-country capacity for designing and carrying out spatial analysis was also conducted through this work. Both the study outcomes and the capacity developed can help support ongoing discussions related to monitoring and tracking environmental and social impacts related to forest change, identify relevant indicators for REDD+ safeguards and inform other monitoring processes.

The ecosystem services analysed in this report were biodiversity, water supply, erosion control and carbon storage. These were prioritized by the project partners regarding consultation processes and used global, national and local datasets identified by the partners. It is important to note that Cambodia's forests are also vital for other ecosystem goods and services not covered in this study, including providing food and materials for livelihoods, recreation and tourism, and cultural heritage, among others.

The biodiversity value of the forest was determined by mapping different categories for conservation, including PAs, CPAs, CFs, BCCs and KBAs. These areas were combined with global data on threatened forest species richness quantity and vulnerability. The water provisioning service of forest areas was quantified in terms of annual water yield using the InVEST annual water yield model. The role of forests in erosion control was estimated using the InVEST sediment retention model. The climate change mitigation potential of forests was determined by mapping forest biomass carbon according to 2018 national landcover maps. Forest biomass carbon densities for different forest types were taken from Cambodia's FRL based on field survey data.

Forest carbon mapping in this study is based on national forest and land cover data from 2018. To improve forest biomass carbon estimates, a more recent LULC map could be used, with field verification of land cover and biomass estimates. Soils, litter and woody debris were not included in this analysis but can contain significant amounts of carbon. Further data collection could also take place in Cambodia on specific forest regions that are not well represented in the surveys carried out so far to estimate forest carbon biomass for different forest classes and to improve the accuracy of data.

Forests are well known for their ecosystem services of water provision, sediment retention, biodiversity and carbon. The results of our assessment of these services could be improved with better sub-national or national input data. In particular, water yield and sediment retention results should be treated as relative values until validated with field estimates of water supply and soil erosion extent from the study region. A large forest area is assessed as important for biodiversity, and better spatial and temporal coverage of field data on species distributions and abundance would be helpful to validate these maps.

The services provided by forests are threatened by deforestation and degradation. Under the SFT-LMR project, a NRT forest change analysis was conducted using the SEPAL platform. However, the results of this analysis could not be validated within the project timeframe. Instead, GLAD deforestation alerts were used in this report to represent recent potential deforestation. There is the opportunity to integrate the results of the forest change analysis using SEPAL in the future, once the results and the platform are validated nationally, and to consider linking ongoing NRT analyses with information on forest goods and services, in order to understand the potential social and environmental impacts.

The maps produced for different forest services were used to perform a series of simple overlays to highlight areas of particular significance for multiple benefits from forests, which may be priorities for conservation and sustainable management. Restoration potential was not analysed in this study, as an in-depth analysis of restoration opportunities (ROAM) was already conducted for Siem Reap, Preah Vihear and Kampong Thom provinces, which could be reproduced for further provinces in the future.

The multi-criteria analysis performed was a simple overlay method widely used globally and across sectors to identify the relationship between two or more interacting themes. Additionally, a weighting was applied according to the climate change vulnerability index of communes across provinces as a proxy for how beneficial services are likely for climate change adaptation. More variables could be integrated into such analysis to incorporate different potential benefits. The quality of the input layers to this kind of analysis, and the decisions taken on weighting the criteria, determine the validity and usefulness of the results. There are alternative methods to MCA, each with its own advantages and disadvantages, which should be carefully considered.

4.2. Informing Monitoring

The work documented in this report also aimed to investigate how available data could be used to track some key environmental and social impacts and trends in forests across the four provinces. The outputs from analyses documented in this report will be available on the Cambodia Environment Management Information System (CEMIS). This is a central portal to provide reliable environmental geospatial data and information to support decision-making processes, coordinated by MoE.

Many themes have not been addressed within this study, including other ecosystem services like nutrient cycling, tourism and recreation, and forest food products, as noted above. The topics prioritized for this study were selected by national partners and stakeholders, and informed by factors like data availability, as well as the time and resource limitations of the project. Including a broader range of stakeholder interests and values (particularly marginalised and/ or underrepresented groups such as IPLCs, women and youth) is needed to ensure that all key social and environmental benefits and impacts are considered in policy development, implementation of actions, and monitoring.

The prioritization of key ecosystem goods and services could further inform investments in refining existing datasets or generating new ones. Further, disaggregated data that relate to social characteristics (such as age, sex, ethnicity) were not always available at this stage or for all datasets, which is a limitation for understanding how forest-related benefits and impacts are distributed across different social groups (including marginalised groups such as IPLCs, women and youth). It should also be noted that spatial analysis may not always be the best or only way to highlight and track key issues related to stakeholder benefits and impacts; some of these factors may be better understood through methods such as surveying and qualitative analysis, as well as research led by local and indigenous knowledge-holders themselves.

Based on the progress made in this study, as well as the considerations outlined above, the following are ideas for follow-up work to build on the efforts of the SFT-LMR project and other initiatives in the country:

- Together with stakeholders, joint prioritisation of key ecosystem goods and services data for inclusion in monitoring efforts, such as CEMIS, with further analysis to generate a baseline of these broader social and environmental dimensions;
- Finalisation of the field validation of the NRT of forest cover and forest cover change via the SEPAL platform, and exploration of potential to integrate several key social and environmental data layers into future NRT monitoring efforts;
- Refinement of certain specific analyses using national and sub-national data where available (e.g., for the InVEST water yield model, using field hydrological data)

Through continuously increasing data availability and methods for tracking environmental and social trends in forests in Cambodia, as well as further data integration and accessibility between institutions and sectors, the ability to track and determine social and environmental impacts and trends can be improved.

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ANNEX 1: CONSULTATIONS INFORMING THE STUDY

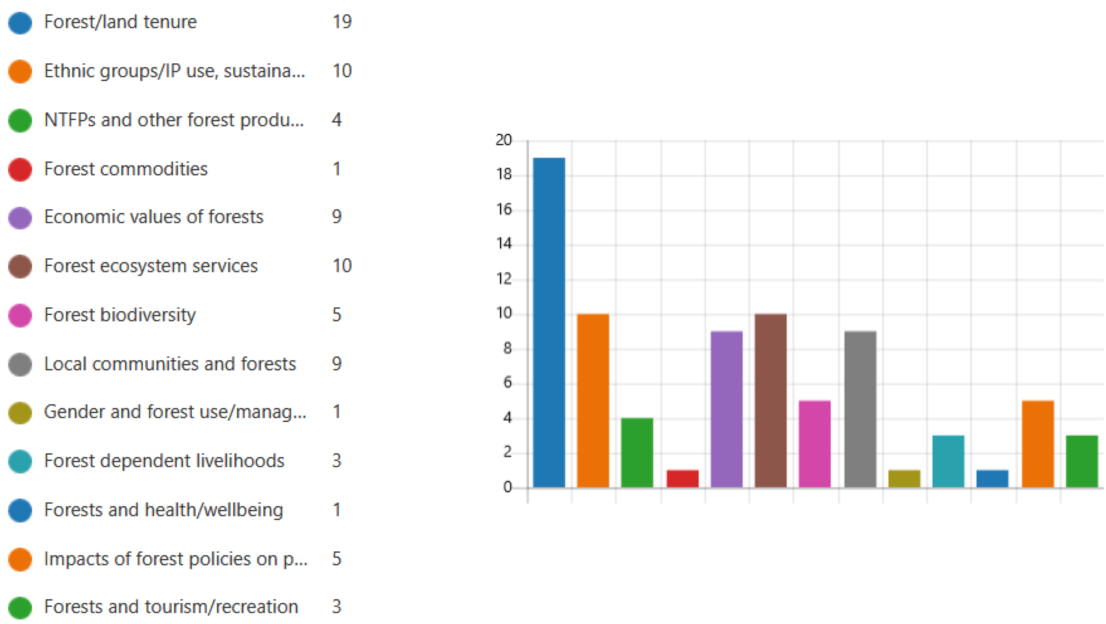
Three key consultation processes informed the development and implementation of this study, as outlined below.

1. Prioritisation of topics

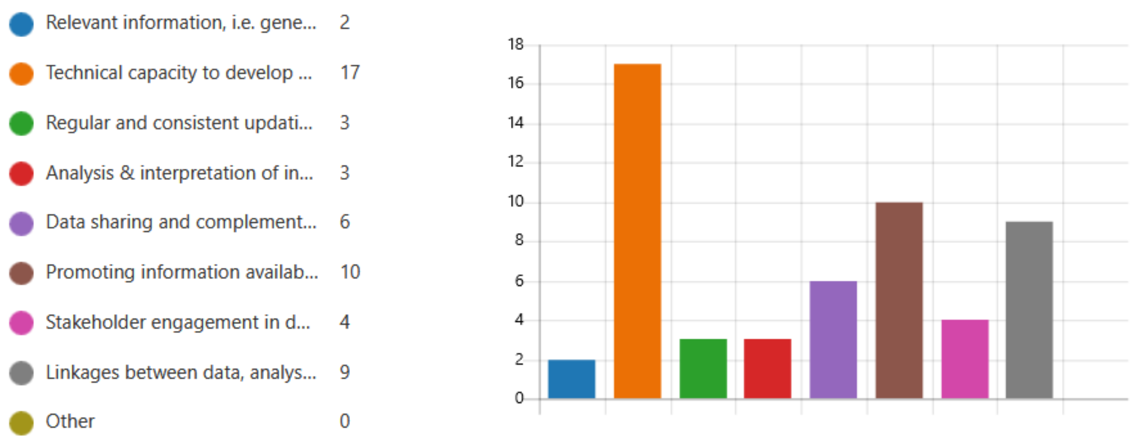
In May 2021, at the start of the SFT-LMR project, an online national consultation workshop was held to i) officially launch the project in Cambodia; ii) consult on the draft workplan with stakeholders; and, iii) discuss any other specific priorities and activities in relation with sustainable forest trade. Around 50 representatives of a range of government and civil society organisations attended and, as part of discussions, provided feedback on proposed activities related to data and monitoring.

An online survey was also shared in May-June 2021, linked to this national consultation workshop. The survey, which was sent to the workshop participants and others, focused on identifying particular gaps and opportunities for strengthening systems for tracking environmental and social impacts in the forest sector, including priority topics, data sources, capacity challenges, etc. The survey received 25 responses and contributed to the overall focus of this study. For example, a summary of responses to two questions is provided below.

Which environmental and socio-economic issues or trends are important in the Cambodia forest sector? (24 responses)



Which of these challenges or areas do you think are most important to support/strengthen? (24 responses)



As described in section 2 of this report, a process was also undertaken with the SFT-LMR project partners – including GDEKI, FAO, UNEP and UNEP-WCMC – to narrow down a list of prioritised and feasible spatial analyses.

2. Working session - Mapping environmental and social impacts in the forest sector in Cambodia

This working session, which took place from 31 January to 3 February 2023 in Phnom Penh, was jointly organized by the Department of Geospatial Service (DGIS), General Directorate of Environmental Knowledge and Information (GDEKI), MoE, and the UNEP-WCMC under the SFT-LMR project.

The working session had the following objectives:

- Present and discuss opportunities and challenges of mapping a selection of social and environmental aspects related to forests;
- Build knowledge and capacity on available methodologies for spatially analysing social and environmental trends and the strengths and limitations of different methods and datasets.

The four-day session took place at the FAO Cambodia office, with 19 participants (4 women) from MoE, Forestry Administration, the four target provinces (provincial departments for environment), and the Royal University of Agriculture. A summary agenda for the working session is provided below.

Key outcomes for the working session included the identification of spatial and other data sources to contribute to the proposed analyses, the introduction of spatial analysis techniques and the InVEST software, and the initial elaboration of workflows for a basic multi-criteria analysis. A pre-session online survey was shared with participants to gauge their level of knowledge/capacity and priorities for capacity development. A post-session survey was completed by 10 respondents and showed, for example, that:

- 7 of the 10 respondents felt that they now know a lot more about mapping environmental and social information linked to forests
- The content of the working session was rated moderate to very useful
- Forest carbon stock mapping, learning about SEPAL, and mapping species richness and important areas of biodiversity were considered the most interesting topics

Time	Activity	Presenter /facilitator
Day 1		
08:30 – 08:40	Welcoming remarks	MoE / GDEKI
08:40 – 09:00	Introductions & ice-breaker	UNEP-WCMC
09:00 – 09:10	Overview of objectives and agenda	GDEKI
09:10-09:20	Presentation: Introduction to SFT-LMR project	FAO
09:20 – 09:30	Q&A	
09:30 – 10:00	Presentation: Using social and environmental information to inform planning & monitoring in the forest sector	UNEP-WCMC / GDEKI
10:00 – 10:30	***Coffee/tea break***	
10:30 – 11:00	Presentation: SEPAL analysis in the 4 provinces	FAO
11:00 – 11:15	Discussion	All
11:15 – 11:30	Overview of the proposed analyses	UNEP-WCMC
11:30 – 12:15	Presentation: Mapping important areas for biodiversity Group discussion	UNEP-WCMC Group facilitators
12:15 – 13: 15	***Lunch***	
13:15 – 15:30	Mapping species richness – exercise	UNEP-WCMC
15:30 – 16:00	***Coffee/tea break***	
16:00 – 16:30	Species richness exercise cont.	
Day 2		
08:30 – 09:00	Recap and look at species richness layer for 4 provinces	UNEP-WCMC
09:00 – 10:30	Mapping exercise: Biodiversity overlays	UNEP-WCMC
10:30 – 11:00	***Coffee/tea break***	
11:00 – 12:30	Continue work on biodiversity overlays and report back	UNEP-WCMC
12:30 – 13:30	***Lunch***	
13:30 – 13:45	Presentation: Hydrological services related to forests	UNEP-WCMC
13:45 – 14:30	Introduction to InVEST and WaterWorld	UNEP-WCMC
14:30 – 15:30	InVEST exercise: Water yield model	UNEP-WCMC
15:30 – 16:00	***Coffee/tea break***	
16:00 – 16:30	InVEST exercise: Water yield model, cont.	
Day 3		
08:30 - 09:30	Recap on previous day	UNEP-WCMC
09 :30 – 10:00	Presentation: overview of forest carbon	UNEP-WCMC
10:00 – 10:30	***Coffee/tea break***	
10:30 – 12:30	Exercise: Mapping forest carbon stocks	UNEP-WCMC
12:30 – 13:30	***Lunch***	
13:30 – 15:00	Carbon mapping tutorial cont.	UNEP-WCMC
15:00 – 15:20	***Coffee/tea break***	
15:20 – 15:40	Presentation: Social trends and data related to forests	UNEP-WCMC
15:40 – 16:30	Group discussion	Group facilitators
18:00 ----	***Dinner***	
Day 4		
08:45 - 09:15	Presentation: restoration opportunities in Cambodia's forests	FAO

09:15 - 10.00	Group discussion: comparing Se.Plan, ROAM & ELSA restoration opportunities	FAO Group facilitators
10:00 – 10:30	***Coffee/tea break***	
10:30 – 11:00	Finish discussion and report back	FAO
11:00 – 11:30	Presentation: workflows for mapping forest importance for biodiversity, climate, and people	UNEP-WCMC
11:30 – 12:30	Group exercise: developing a workflow	Group facilitators
12:30 – 13:30	***Lunch***	
13:30 – 15:30	Workflow exercise, cont.	
15:30 – 15:45	***Coffee/tea break***	
15:45 – 16:30	Wrap-up session	UNEP-WCMC GDEKI

3. Consultation workshop - Mapping environmental and social impacts in the forest sector in Cambodia

This workshop was held during 27 - 28 March 2023 in Preah Vihear, organised by Department of Geospatial Service (DGIS), General Directorate of Environmental Knowledge and Information (GDEKI), MoE, together with the United Nations Food and Agriculture Organisation (FAO) and United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), under the UN-REDD Sustainable Forest Trade in the Lower Mekong Region project (SFT-LMR).

Following a working session held with GIS experts and staff from relevant agencies and stakeholders in Phnom Penh (31 January – 3 February 2023), a series of maps were prepared, exploring the potential impacts of hotspots of forest loss on environmental and social objectives. This workshop aimed to introduce the draft spatial analyses prepared under the project, to promote the understanding and use of spatial information by stakeholders, and to seek stakeholder feedback on the draft maps produced.

The 2-day workshop took place in Preah Vihear, Preah Vihear province with approximately 25 participants from Ministry of Environment (MoE), Forest Administration, the four target provinces (Provincial Departments of Environment), and Wildlife Conservation Society (WCS).

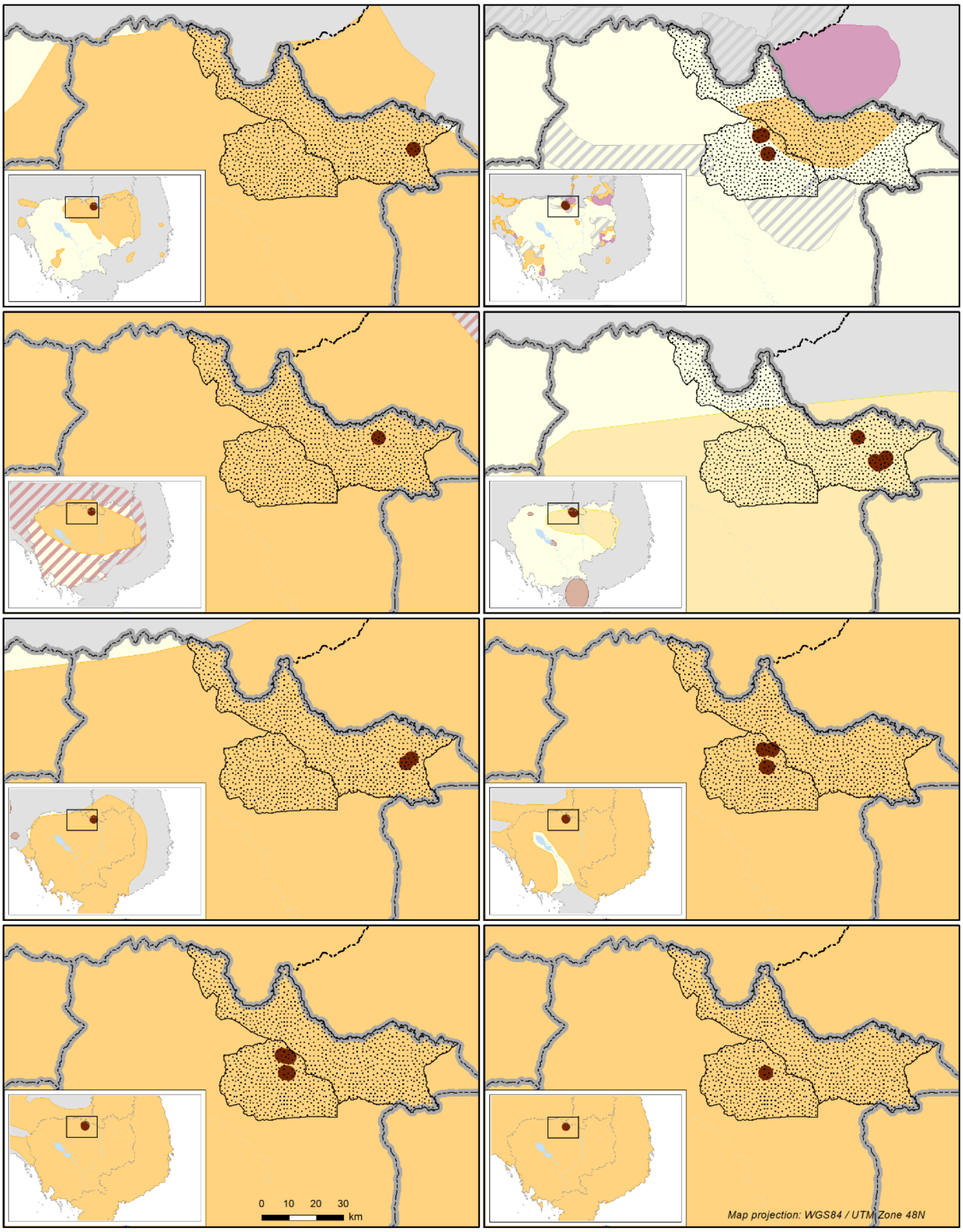
Key outcomes included feedback to improve the maps and analyses produced, including around methodology and presentation. Strong interest was also expressed by participants on the usefulness of the SEPAL and UNBL platforms. The field visit to Tmatboey Community Protected Area (CPA), which is part of a wider REDD+ project being established in Preah Vihear province, was used to demonstrate the use of the SMART monitoring system.

Time	Activity	Presenter /facilitator
DAY 1 – 27 March		
08:30 – 08:45	Welcoming remark	MoE / DGIS UNEP
08:45 – 08:50	Overview of agenda	DGIS
08:50 – 09:00	Introductions/ice-breaker	UNEP-WCMC
09:00 – 09:15	Introduction to the SFT-LMR project	FAO
09:15 – 09:30	Setting the scene: data & monitoring in the forest sector	UNEP-WCMC
09:30 – 09:45	Q&A	
09:45 – 10:00	***Coffee/tea break & photo***	

10:00 – 10:30	Near-real time monitoring for forests and introduction to SEPAL	FAO
10:30 – 11:15	Group discussion (three groups) – how can NRT respond to needs at provincial and local levels?	All
11:15 – 11:30	Introduction to social and environmental information in the forest sector, including CEMIS	DGIS
11:30 – 11:50	Overview of the analyses and introduction to the draft maps	UNEP-WCMC
11:50 – 12:00	Q&A	
12:00 – 13:00	***Lunch***	
13:00 – 13:10	Introduction to the group ''museum visit'' exercise	
13:10 – 14:10	Museum visit to provide feedback on draft maps – round 1 *(Four map stations with facilitators x 15 mins each)*	All
14:10 – 14:25	Report one key point from each map station, and any final questions/comments	All
14:25 – 14:40	Introduction to tools & platforms to support improved data & monitoring (SFT-LMR webpage), and to the ''technical cafe''	UNEP-WCMC
14:40– 15:20	Introductory presentations: what will we cover in the 2 parallel technical café sessions tomorrow? 1. Getting to know SEPAL 2. Using UNBL to explore biodiversity & ecosystem services	FAO; UNEP-WCMC
15:20 – 15:35	***Coffee/tea break***	
15:35 – 16:30	2 parallel technical café sessions: 1. Getting to know SEPAL 2. Using UNBL to explore biodiversity & ecosystem services	FAO; UNEP-WCMC
16:30 – 16:45	Recap from the session leads, 3 mins per table – what did we learn? Wrap up and reminder about field trip	FAO UNEP-WCMC
16:45 – 17:00	Closing remarks	UNEP-WCMC/DGIS
DAY 2 – 28 March		
08:00 – 09:00	Travel to REDD+ site under WCS	FAO
09:00 – 12:00	Visit CPAs, talk to local communities, and to discuss plans for forest and safeguards monitoring - Join the field patrol with CPA member with record by SMART	FAO UNEP-WCMC
12:00 – 01:00	***Lunch at the field***	***All***
02:00 – 04:00	Return the provincial town and visit to PDoE Office - Presentation on PAMP monitoring and reporting by PDoE - Overview on the result of the field trip record in PAMP	All
4:00-4:20 p.m.	Recap the main themes of the two-day discussions and take comments and suggestions from participants	UNEP-WCMC
4:20-4:30 p.m.	Closing remarks	DGIS

ANNEX 2: COMPARISON OF IUCN RED LIST SPECIES RANGES AND SPECIES RECORDED THROUGH NATIONAL SMART BIODIVERSITY MONITORING

Overlap of national wildlife survey species data in Preah Roka and Chhaeb protected areas and species ranges in the IUCN Red List of Threatened Species.



Preah Roka and Chhaeb protected areas
National wildlife survey points
IUCN species range
Possibly Extinct
Possibly Extant & Origin Uncertain (resident)
Possibly Extant (resident)
Extant (resident)
Extant (non-breeding)
Extant (breeding)

This map uses locally collected wildlife survey data to cross reference with the IUCN Red List of Threatened Species to provide some limited validation of the range extents within the IUCN Red List of Threatened species. All data points were located within the IUCN ranges. It was not possible to do any further validation due to the limited extent and limited number of species covered by the local data,

Data sources: Base layers: United Nations Geospatial, 2023. Wildlife Survey: XXXXXXX. Species Ranges: IUCN. 2022. The IUCN Red List of Threatened Species. Version 2022-2. https://www.iucnredlist.org. Accessed on 27/01/2023.

The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

ANNEX 3: DATA LAYERS USED IN THE ELSA ANALYSIS

Groups	Label-theme	Label-name	Reference
Features	Biodiversity	Natural forest	Cambodia Forest Cover 2018
		Mangrove	Cambodia Forest Cover 2018
		Under-represented Ecosystems	Cambodia Forest Cover 2018 DGIS-MoE, 2021
		Intact ecosystems	Cambodia Forest Cover 2018
		Threatened ecosystems	Cambodia Forest Cover 2018
		Biodiversity corridors	DGIS-MoE, 2017
		BPAMP priority areas - all taxa	Conservation International. 2015. Metrics for Green Growth in Cambodia: Demonstration of Metrics for Conservation and Human Well-being. Conservation International. 64 pp. Accessed 2/9/2016: http://www.metricsci.org/assets/metrics-technical-report-cambodia-2015.pdf
		KBAs	BirdLife International (2021). World Database of Key Biodiversity Areas. Managed by BirdLife International on behalf of the KBA Partnership: BirdLife International, International Union for the Conservation of Nature, American Bird Conservancy, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Re:Wild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, Wildlife Conservation Society and World Wildlife Fund. March 2021 Version. Available at http://www.keybiodiversityareas.org.
		Community protected area	DGIS-MoE, 2021
		Main river and buffer	CMAC,1999
	Climate Change	Biomass Carbon	Spawn, S.A., and H.K. Gibbs. 2020. Global Aboveground and Belowground Biomass Carbon Density Maps for the Year 2010. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1763

		Vulnerability of deforestation	Namkhan, M., Gale, G. A., Savini, T., & Tantipisanuh, N. (2021). Loss and vulnerability of lowland forests in mainland Southeast Asia. Conservation Biology, 35(1), 206-215. Conservation International. 2015. Metrics for Green Growth in Cambodia: Demonstration of Metrics for Conservation and Human Well-being. Conservation International. 64 pp. Accessed 2/9/2016: http://www.metricsci.org/assets/metrics-technical-report-cambodia-2015.pdf
		Areas with high potential emissions	Conservation International. 2015. Metrics for Green Growth in Cambodia: Demonstration of Metrics for Conservation and Human Well-being. Conservation International. 64 pp. Accessed 2/9/2016: http://www.metricsci.org/assets/metrics-technical-report-cambodia-2015.pdf
		Climate adaptive capacity 2012	Conservation International. 2015. Metrics for Green Growth in Cambodia: Demonstration of Metrics for Conservation and Human Well-being. Conservation International. 64 pp. Accessed 2/9/2016: http://www.metricsci.org/assets/metrics-technical-report-cambodia-2015.pdf
		Population affected by flood 2011	Conservation International. 2015. Metrics for Green Growth in Cambodia: Demonstration of Metrics for Conservation and Human Well-being. Conservation International. 64 pp. Accessed 2/9/2016: http://www.metricsci.org/assets/metrics-technical-report-cambodia-2015.pdf
		Upland watershed	HydroBASINs - Lehner and Grill (2013)
	Human Well Being	Important areas for food security (provision of NTFPs)	Conservation International. 2015. Metrics for Green Growth in Cambodia: Demonstration of Metrics for Conservation and Human Well-being. Conservation International. 64 pp. Accessed 2/9/2016: http://www.metricsci.org/assets/metrics-technical-report-cambodia-2015.pdf
		Community fishery	Open Development Cambodia, 2020
		Fisheries dependence	Ministry of Planning. 2010. Poverty and select CMDGs maps and charts 2003–2009. Ministry of Planning, Cambodia, Phnom Penh, Cambodia.
		Community - forestry	Open Development Cambodia, 2016

		Watershed - agroforestry	MRC, 2001
		Urban buffer	Cambodia Forest Cover 2018
		Tourism hotspot	Natural Capital Project. 2014. Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) modeling tool. Stanford Woods Institute for the Environment, University of Minnesota's Institute on the Environment, The Nature Conservancy, World Wildlife Fund. http://www.naturalcapitalproject.org/InVEST.html
Lock-in	Biodiversity	Protected Areas	DGIS-MoE, 2021
Zones		Human footprint index	Williams, B.A., et al. 2020. Change in Terrestrial Human Footprint Drives Continued Loss of Intact Ecosystems. One Earth 3, 371–382. https://doi.org/10.1016/j.oneear.2020.08.009
		Natural forest	Cambodia Forest Cover 2018
		NatureMap Potential Natural Forest	Hengl, Tomislav, Jung, Martin, & Visconti, Piero. (2020). Potential distribution of land cover classes (Potential Natural Vegetation) at 250 m spatial resolution (v0.1) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.3631254

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