FINAL REPORT

Mapping of selected Ecosystem Services of Inle Lake Protected Area, Myanmar

CLIENT UNDP Myanmar

AUTHORS Gijs Simons
Aung Thu Moe

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Authors
Gijs Simons – International consultant (g.simons@futurewater.nl)
Aung Thu Moe – National consultant

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Cover photo: Aung Thu Moe

ADDRESS
FutureWater B.V.
Costerweg 1V
6702 AA Wageningen
The Netherlands

FutureWater

TELEPHONE +31 317 460 050
WEBSITE www.futurewater.eu

Summary

Inle Lake is an important asset to Myanmar's natural and cultural heritage, as well as providing the source of income of many of the regional inhabitants through tourism, fisheries, and agriculture. However, unsustainable management of the lake's watershed has contributed to increased soil erosion and siltation, has reduced inflow and water levels, and caused significantly degraded water quality.

This report presents the methodology, results, and conclusions associated with a spatial assessment of selected ecosystem services provided by the watershed, based on an integration of satellite remote sensing, simulation modelling, and locally sourced information. The work was implemented by Gijs Simons of FutureWater and Aung Thu Moe under assignment of UNDP Myanmar, as part of its project on *Strengthening the Inle Lake Management Authority to Improve Development and Conservation*.

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1 Background

1.1 Introduction

Inle Lake, in Myanmar, is renowned for its traditional cultural and livelihood practices, which have made it one of the main attractions for Myanmar's tourism industry. The lake is, however, suffering environmental degradation from the combined effects of unsustainable resource use, increasing population pressures, prolonged drought periods under changing climate conditions, and rapid tourism development.

UNDP Myanmar with the funding support from Government of Norway, is implementing a 2-year project on *Strengthening the Inle Lake Management Authority to Improve Development and Conservation*. The project's main aim is to support the implementation of the Inle Lake Conservation 5-Year Action Plan (2015/16 to 2019/2020) by establishing and strengthening the Inle Lake Management Authority (ILMA), to coordinate, manage and develop Inle Lake effectively. This will require strong leadership and coordinated efforts of all stakeholders involved – government (State and National), non-governmental organisations and local communities. As such, it is vital to strengthen the governance of Inle Lake to rally private, civil, and government actors at various levels and to define their various roles. It is also equally important to develop local capacities to collect and monitor the information of the lake's ecosystem and establish a baseline and central database to measure, assess, and use data to support the roles of the stakeholders.

1.2 Objectives

The main objective of the assignment implemented by FutureWater was to validate and update the boundary demarcation of "Inle Lake Man and Biosphere Reserve" (MAB) and to produce the ecosystem service map/s of the whole Inle Lake region, to inform Inle Lake Management Authority (ILMA) on the conservation activities and successful implementation of the Inle Lake Conservation 5-Year Action Plan. In order to achieve this, the following sub-objectives are defined:

- Confirming and updating existing Inle Lake MAB boundary and zoning;
- Validating and producing comprehensive and updated Inle Lake MAB maps, including boundary demarcation, zoning, land-use and selected ecosystem services;
- Supporting the development of communications and educational materials, especially with technical inputs on mapping and GIS application;
- Supporting the capacity building of the key government staff on ecosystem services mapping.

1.3 Reading guide

This report describes the methodology and results associated with the comprehensive ecosystem services mapping efforts implemented, and summarizes the capacity building efforts under the project. Chapter 2 presents the relevant geographical, climatological, environmental properties of the study area and provides a brief synthesis of previous ecosystem services assessments and key threats. Chapter 3 presents the approach to the assignment. The resulting ecosystem services maps are provided in Chapter 4. Finally, Chapter 5 lists the main conclusions and recommendations regarding uptake of these maps in re-evaluating geographical boundaries of spatial units utilized in conservation policies.

2 Study area

2.1 Geography and climate

Inle Lake is the second largest lake in Myanmar and is located in Nyaung Shwe Township, Taunggyi District, Southern Shan State, at an altitude of 890 m. Inle Lake has an open water length of 17.5 km and 5 km width, excluding floating gardens (Michalon et al. 2019). The lake is recharged by 30 streams, annually providing around 110 billion m^3 of water to the lake. Coming from the north, the Namlit Chaung is the lake's main contributor. The two main streams from the west are Kalaw Chaung and Indein (or Upper Balu) Chaung, forming deltaic systems at their mouths. Topography on the lake's eastern boundary is much more abrupt than at the west, due to the mountain range. The watershed is characterized by a large, flat valley running north to south, surrounded by mountains averaging about 1200 m. The only outlet, Nam Pilu, drains south to Samkar Lake and Mobye Reservoir. The watersheds of these artificial lakes are also considered in this assignment, as they are included in various protected area delineations (Figure 1). The reservoirs feed Lawpita power plant, which produces 15 % of national electricity and plays a major role in energy supply to Yangon. Currently, an additional 'Run of the River' hydropower project (Upper Baluchaung) is being constructed to the west of the lake, with an installed capacity of 30 MW[1].

The regional climate is characterized by three seasons: dry and cool from October to February, hot and dry from March to May, and hot and humid from June to September. Average annual rainfall in the Inle Lake watershed is 1,274 mm, of which 90% occurs between May and October. Pinlaung Township (west of the Lake) is the wettest and lakeside Nyaung Shwe Township is the driest (Michalon et al. 2019). The area has a tropical to sub-tropical climate favorable for cereal crops and horticultural crops. The average annual temperature is 23°C, with the maximum temperature over 35°C during the summer season (Htwe 2015).

Inle Lake is a shallow freshwater lake, and its water level has been known to vary from 4 to 7 m depending on the season. However, in 2010, the summer monsoon came very late, which triggered historically low levels, with many stranded stilt villages and dried-up canals. Despite dredging campaigns, the Lake has never returned to pre-2010 water depth, since the record low of 2010. 2016 was also a drought year (Michalon et al. 2019). During surveys performed in March 2014 and in December 2015, the lake level did not exceed 2.3 m depth (Re et al. 2018).

2.2 Land use / land cover

A 2010 survey indicated that agricultural land occupied 42% of the area, forest with sparse canopy 16%, while other forms of land use and water surface areas accounted for 35%. Forest with dense canopy remained only on 7% of the catchment (MoECaF 2014a). However, it is likely that these percentages have changed over recent years, and the current assignment builds on more recent satellite-derived land cover data from the SERVIR-Mekong Regional Land Cover Monitoring System (RLCMS) for the ecosystem services mapping procedure (Figure 2).

[1] https://wle-mekong.cgiar.org/changes/our-research/greater-mekong-dams-observatory/

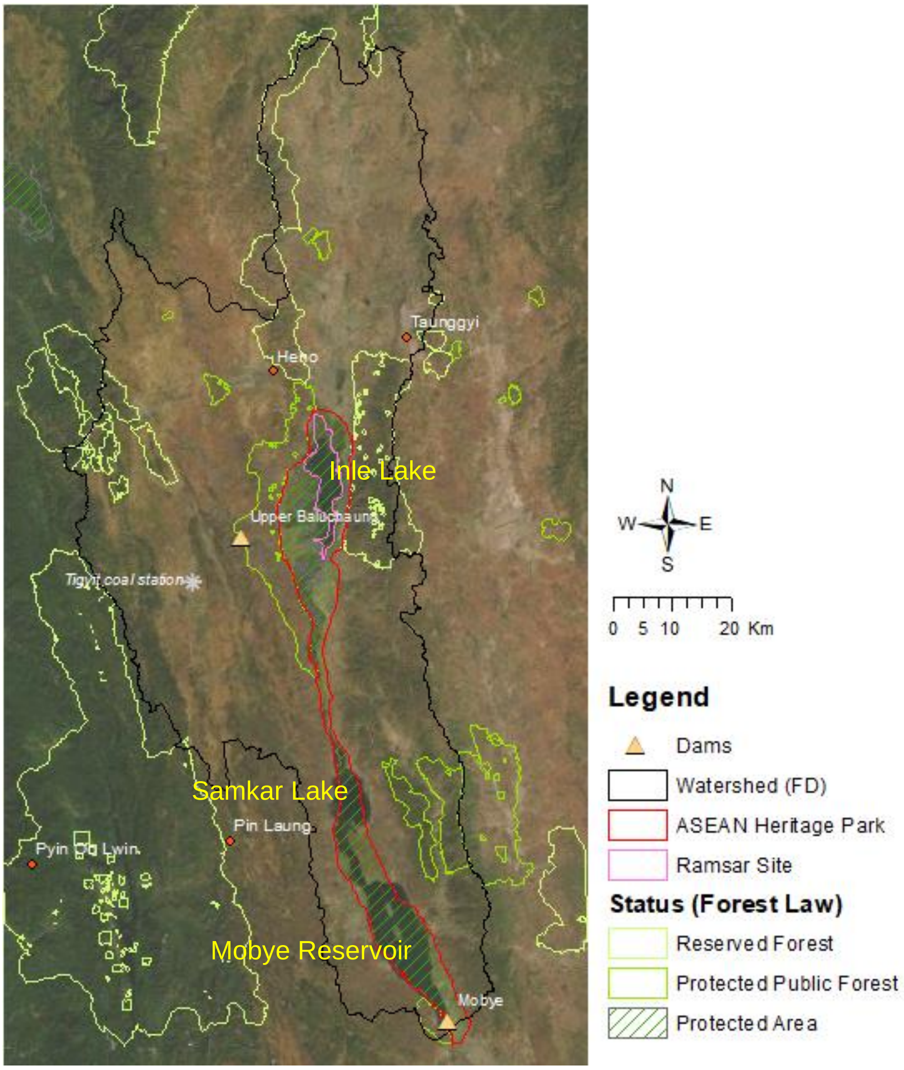

Figure 1. The Inle Lake catchment with various protected area delineations. The watershed boundary depicted was provided by the Forest Department, and is consistent with the watershed used in the 5-year Conservation and Action Plan.

The region features four kinds of agricultural systems (Michalon 2015):

1. The **floating gardens** made of decomposing mats of water hyacinth (an invasive species) and/or other aquatic plants quarried from the Lake-fringe marsh- land using specific tools and techniques. Strips of these are towed to large family farms, covered with mud, and mulched with Lake weeds. This perennial floating substrate is farmed mainly for tomatoes, marketted domestically and in Thailand.
2. The immediate surroundings of the Lake are dedicated to **paddy fields**, whether naturally inundated or irrigated, which yields annually a double crop in most cases;
3. On flat, dry terrain, **rainfed maize**, **sugarcane**, and **potatoes** are produced for export to China;
4. On hillslopes, Pa-O, Danu, and Taungyo farmers formerly practiced swidden agriculture. However, under population pressure and the shift to various **cash crops**, hillslope agriculture has become permanent.

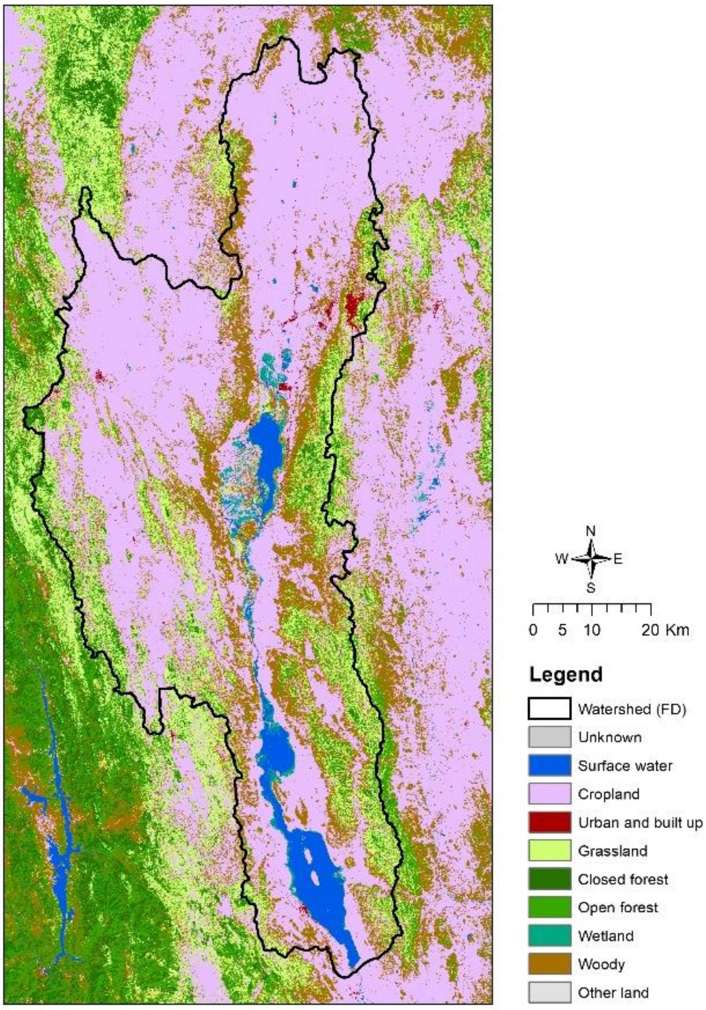

Figure 2. SERVIR-Mekong land use / land cover map for 2015. Forests are subcategorized into ‘closed’ (> 40 % canopy cover) and ‘open’ (10 – 40 % canopy cover), the latter normally degraded. Other woody vegetation (< 10% canopy cover) is classified by SERVIR-Mekong RLCMS as ‘woody’.

2.3 Protected area definitions

Inle Lake and its surroundings are protected under various initiatives, most notably:

- The region comprising Inle Lake, Samkar Lake and Mobye Resrvoir to its south, and their direct surroundings, was established as a Wildlife Sanctuary in 1985 to protect and conserve the rich biodiversity of the wetland ecosystem. As a critical staging ground for migratory birds, the site was listed as an Important Bird and Biodiversity Area (IBA) in 2004 by BirdLife International. It became an ASEAN Heritage Park in 2003. The same area delineation is protected as a Protected Area (PA) under the Myanmar Conservation of Biodiversity and Protected Areas Law 2018.
- Inle Lake, its adjacent peatlands and important bird breeding grounds directly to its north, together are included in the definition of the Inle Lake Ramsar site;
- The Inle Lake region was designated Myanmar’s first UNESCO Man And Biosphere (MAB) Reserve in 2015 (Figure 3). The outer boundary of the MAB largely follows the watershed

boundary. Only the lake itself is designated as a core zone, and the extent of the buffer zone largely follows Nyaung Shwe township borders[1];

- Parts of forest around the watershed are under different levels of protection, either as Protected Public Forest (PPF) or Reserved Forest (RF).

2.4 Ecosystem services

Several frameworks for Ecosystem Services (ES) analyses have been developed. Annex 1 provides a brief overview and a description of the conceptual framework applied in this study.

Services provided by Inle Lake itself are often discussed in an isolated manner, without considering the watershed as an integrated system. As this assignment focuses on ES mapping of the entire watershed, literature sources were reviewed that categorize ES of the Inle Lake watershed with respect to the main categories outlined in the previous section.

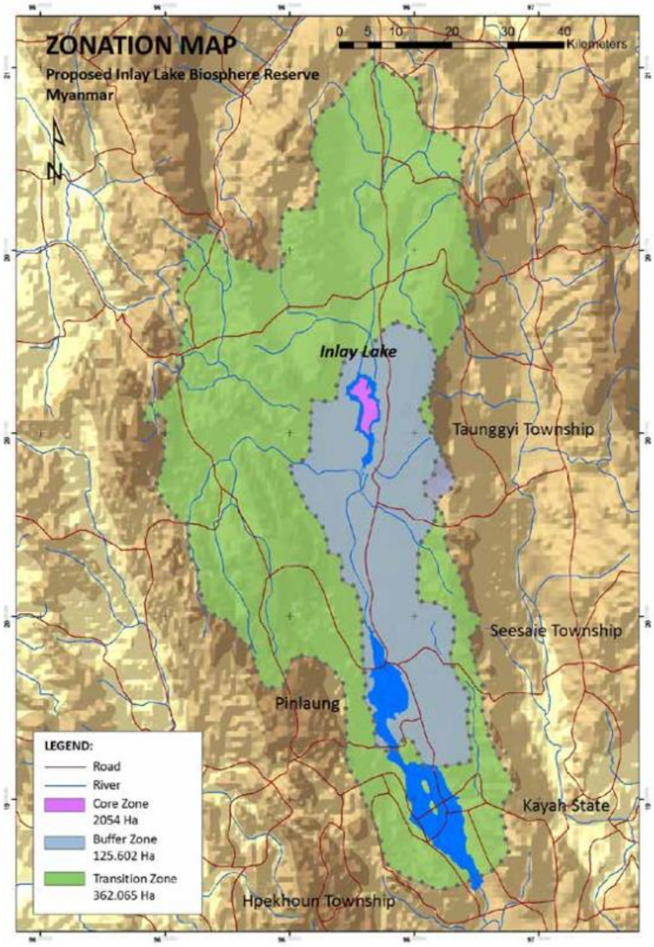

Figure 3. Map of Inle Lake Biosphere Reserve as defined by UNESCO[2].

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[1] UNESCO definitions: **Core zone:** securely protected sites for conserving biological diversity, monitoring minimally disturbed ecosystems, and undertaking non-destructive research and other low-impact uses. In addition to its conservation function, the core area contributes to a range of ecosystem services. **Buffer zone**: used for cooperative activities compatible with sound ecological practices, including environmental education, recreation, ecotourism, and applied and basic research. In addition to the buffering function related to the core areas, buffer zones can have their own intrinsic functions for maintaining anthropogenic, biological and cultural diversity. They can also have an important connectivity function in a larger spatial context. **Transition zone:** area with a central function in sustainable development which may contain a variety of agricultural activities, settlements and other uses.

[2] *http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/asia-and-the-pacific/myanmar/Inle-lake/*

ICIMOD (2018) and Karki et al. (2018) focused on the provisioning ES in the four main landscapes of the Inle Lake watershed, comparing satellite-derived observations with survey results on people's perceptions of ESS. Table 1 lists their results for the four categories: Forest, Agro-ecosystem, Seasonal and Perennial water bodies. Especially the variety and importance of ES provided by forest systems is confirmed by Emerton and Aung (2013) and Latt (2013), who discussed these in particular in the context of their economic benefits to communities.

Similarly, many different cultural, regulating, and supporting ES provided by the watershed are identified (e.g., IME (2011), MoECaF (2014b), IID (2012)), which are listed in Table 2. In terms of regulating services, in particular water yield (in relation to lake inflow, drinking water supply, hydropower generation) and erosion reduction were frequently mentioned, often in relation to rapid land use changes threatening the watershed, as outlined in Section 2.2.4. This perception matches the focus ES of Mandle et al. (2017) for Myanmar.

2.5 Key aspects of degradation

Categorizations of key issues and threats to the ecosystem of Inle Lake watershed are available from several sources (IID 2012; MoECaF 2014b, a; UNDP 2015). This section synthesizes the most prominent aspects of degradation of land and water resources in the watershed. Issues concerning socio-political aspects, such as awareness among communities and coordination between government departments, are left out as they are outside the scope of this assignment.

Table 1. Provisioning ecosystem services provided by the Inle Lake watershed (Karki et al. 2018).

Ecosystem	Forest (17)	Agro-ecosystem (13)	Perennial water bodies (4)	Seasonal water bodies (10)
Provisioning goods and services	Fuel wood Fodder Grazing Timber Poles Medicinal plants Ornamental plants Wild edible vegetables/ mushrooms Fruits Fiber Thatch Bush meat Paddy Cereals Drinking water Water for bathing Water for irrigation	Fuel wood Fodder Grazing Timber/poles Medicinal plants Ornamental plants Wild edible vegetables/ mushrooms Fruits Fiber Thatch Dyes Paddy Cereals	Fish Drinking water Water for bathing Water for irrigation	Ornamental plants Wild edible vegetables Fruits Fish Drinking water Water for bathing Water for irrigation Silt soil Source for seaweed Source for fodder

Table 2. Other ecosystem services provided by the Inle Lake watershed (compiled from various sources: IME (2011), MoECaF (2014b), IID (2012)).

Cultural	Regulating & supporting
• Ecotourism resources / tourism destinations • Tranquility and serenity • Spiritual / religious significance	• Soil retention • Water supply to hydropower • Groundwater recharge (seasonal / annual water yield) • Lake recharge (seasonal / annual water yield) • Carbon sequestration / mitigation • Habitats for animals • Clean water (regulating nutrients and sediments in the lake by aquatic vegetation) • Climate regulation • Pollination and pest regulation

- **Increased soil erosion and sediment inflow into the lake**
  Soil erosion in the watershed is known to increase due to rapid land use changes. Deforestation associated with agricultural expansion, urbanization, tourism development, fuelwood use, and shifting cultivation is a reality throughout the watershed and has increased sedimentation rates. Sediment deposited at the lake bed is predominantly soil eroded from the hillslopes, rather than biogenic/bacterial magnetite produced within the Lake, confirming that accelerated hillsope erosion has been occurring over the past decades. (Oldfield, 2013, cited in Michalon et al. 2019). Quantitative estimates on soil erosion are present from various studies, with values for upland agriculture typically a factor 10 higher than for lowland agriculture (Htwe et al. 2015a). Total inflow of sediment into the lake is estimated at 268,000 – 277,000 tons/year (Furuichi 2007; MoECaF 2014a). Abandoned floating gardens may also contribute to lake bed sedimentation because the mats release solid matter, although no estimates are available for this phenomenon (Michalon et al. 2019). Apart from affecting the lake itself, erosion-sedimentation processes contribute to the loss of fertile soil and choking of water channels.

- **Decreased water input to the lake**
  A reduction of inflow into the lake has resulted in a net ~1 m fall of water level since 1990 (Michalon et al. 2019). As rainfall has not decreased over this period, this decline is attributed to changes in karstic groundwater circulation and/or increases in human water abstraction. The latter is caused by increased water use for irrigation, rapid development of tourism, and population growth in Nyaung Shwe, which have caused water tables to decline (Michalon et al. 2019). Furthermore, upstream land use changes have most likely altered seasonal dynamics of water inflow into the lake, although no gauging data are available to quantify this. The impact of the new Upper Baluchaung dam on Indein River, planned to be commissioned in 2020, on water inflow patterns remains to be seen.

- **Water quality issues**
  Intensified development and human activity over recent decades have negatively impacted water quality. In addition to sediments discussed above, industrial residues are being disposed into Inle Lake from sugarcane factories and breweries located at the eastern and western sides of the lake. In addition, uncontrolled disposal of household waste and effluents from weaving industries, tomato cultivation and intensive livestock units occurs (Htwe et al. 2015b). Tigyit coal station, previously notorious for its air and water pollution and subsequent impacts on health and agriculture, has recently been taken into operation again (see Figure 1).[1] Large quantities of pesticide and fertilizer are used across the watershed as well as in floating agriculture. As a result, drinking water safety is insufficient, posing a threat to community health. High nutrient levels in lake water have led to a growth of water hyacinth throughout the lake which is out of control, and blocking waterways (MoECaF 2014b).

- **Climate change**
  In existing literature, it is a striking observation that climate change is not commonly considered when discussing threats to the Inle Lake watershed. However, the Myanmar Climate Change Strategy (2019)[2], which presents the most recent climate change projections for Myanmar, reports that towards 2100 monsoon periods will likely become shorter and more intense. Also, a general increase in temperature will occur, with more extremely hot days and prolonged drought events expected. These changes will impact water availability for agricultural and domestic use, as well as fisheries and biodiversity. In addition, a projected higher frequency of intense rainfall event, may exacerbate soil erosion and lake sedimentation.

[1] https://www.mmtimes.com/business/20010-chinese-firm-to-restart-myanmar-s-only-coal-plant.html
[2] *https://myanmar.un.org/sites/default/files/2019-11/MyanmarClimateChangeStrategy_2019.pdf*

3 Approach to the assignment

3.1 Approach to mapping of Ecosystem Services of Inle Lake watershed

An innovative, integrated ES mapping approach was applied that relies on three main components:

1. **Locally-sourced information** available specifically for the Inle Lake watershed was used as much as possible to inform the location of areas which are particularly important in terms of ES, as well as to provide quantitative information on relevant environmental processes. This information was obtained from bilateral meetings with key stakeholders, literature studies, reports and ongoing projects in the region;
2. **Satellite remote sensing** datasets were used because of their suitability to provide spatial, quantitative information on vegetation conditions and environmental and meteorological processes, and to overcome scarcity of ground data. Remote sensing data were used for stand-alone assessment of certain ES, as well as providing input to an ES simulation model;
3. In particular the supply of regulating ES, such as seasonal regulation of water yield and mitigation of soil erosion, was quantified by adding a **simulation modelling** approach. This component of the approach allows for scenario assessments to quantify benefits of natural systems, by subsequently including and removing them in the model analyses.

During an in-country mission in January 2020, a number of bilateral stakeholder meetings were organized in Yangon, Taunggyi, and around Inle Lake (Figure 4). An overview of all meetings, and the key take-away messages from each meeting, can be found in Annex 2.

3.2 Geospatial information and satellite remote sensing

For spatial assessment of ecosystem services, a variety of environmental data are required. Locally sourced data, such as obtained from field measurement projects and surveys, are important to account for the specific context of the study area. However, as ground data are typically scarce in the Inle Lake Region, alternative sources such as satellite-derived and GIS datasets were explored (Table 3).

Figure 4. Discussions with Dr. Tun Hlaing, Inntha Minister, Ywama village, Inle Lake.

Table 3

Table 3. Overview of datasets used as input to ES mapping and simulation modeling.

Description	Source
Current MAB boundary and zoning (GIS layer)	• Forest Department
Other PA definitions (Ramsar, ASEAN)	• Forest Department • WDPA
Rivers and boundaries of watershed / drainage basins	• WWF Hydrosheds • Catchment delineation based on elevation map
Administrative boundaries and villages	• MIMU
Locations of dams and other major water infrastructure	• IFC Myanmar Dam Database • CGIAR Greater Mekong Database
Road network	• MIMU • Open Street Map
Land use / land cover	• SERVIR Mekong land cover map for 2015
Forest loss 2000 - 2018	• Global Forest Change
Elevation	• SRTM
Precipitation	• DMH data • CHIRPS
Actual evapotranspiration	• MOD16
(Normalized Difference) Vegetation Index	• Sentinel-2, Landsat 8
Net Primary Productivity	• Copernicus (PROBA-V) • MODIS
List of natural springs	• Forest Department
Soil properties	• SoilGrids (ISRIC) • HiHydroSoil (FutureWater)

Satellite remote sensing is a proven technology to map certain ecosystem services, particularly in data-scarce regions (De Araujo Barbosa et al. 2015; Pettorelli et al. 2018; Vargas et al. 2019). By providing spatio-temporal information on variables such as rainfall, vegetation cover, and biomass production, in particular key provisioning ES can be mapped. An example of satellite-derived source data for ES mapping is provided in Figure 5. This is a map of the average Normalized Difference Vegetation Index (NDVI) of the Inle Lake watershed for 2018, which allows for identification of healthy vs degraded / stressed vegetation. As extensive archives of satellite imagery are available, remote sensing can be used to evaluate seasonal and multi-annual trends. Figure 6 shows the monthly Coefficient of Variation (CV) of NDVI, which is a measure of intra-annual dynamics.

3.3 Selected Ecosystem Services for Inle Lake watershed

A set of ecosystem services to be mapped was selected based on (i) relevance to the Inle Lake watershed as determined from stakeholder meetings and literature review, (ii) suitability for quantification, and (iii) data availability. These selected services include the following: provisioning ecosystem services, climate cooling, carbon storage, baseflow contribution, and reduction of sediment export.

3.3.1 Provisioning Ecosystem Services

An integrated indicator of provisioning ES from forest systems, such as fruits, fibre, timber, and medicinal plants, was applied. This indicator was based on the study by Paruelo et al. (2016), who expressed an Ecosystem Services Provisioning Index (ESPI) as follows:

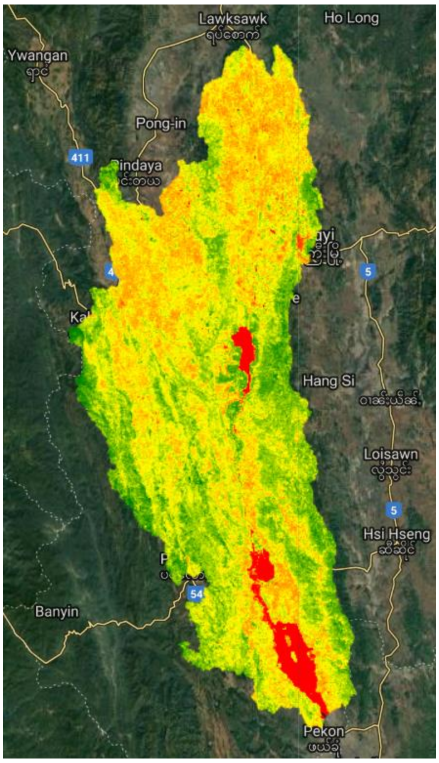

Figure 5. Map of Normalized Difference Vegetation Index (NDVI) based on the Landsat 8 satellite, averaged for the year 2018 and extracted with Google Earth Engine. Green colours show healthy vegetation, yellow to orange areas correspond with degraded forests or barren (crop)lands, red represents open water.

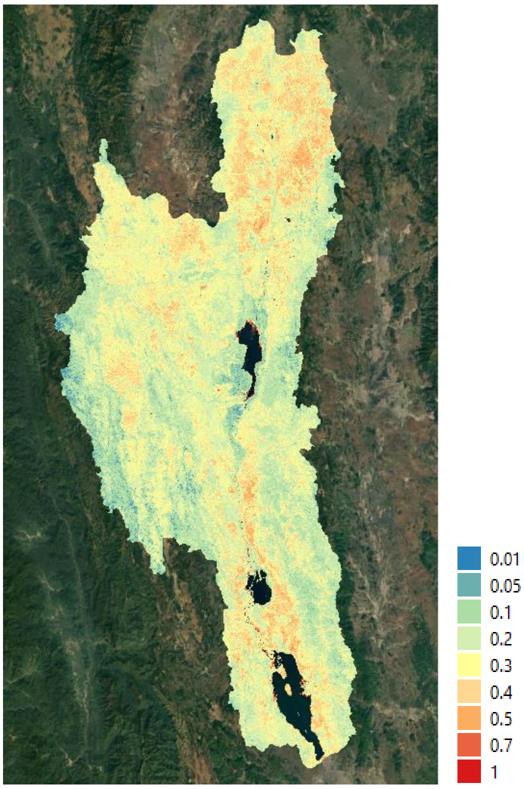

Figure 6. Monthly Coefficient of Variation (CV) of NDVI based on the Landsat 8 satellite, computed for the year 2018 and extracted with Google Earth Engine. Higher values indicate a greater intra-annual variability of vegetation cover. Healthy forests typically show up in blue, while croplands with seasonal cycles are represented in red to yellow.

$$ESPI = NDVI_{mean} * (1 - NDVI_{CV})$$

where $NDVI_{mean}$ is the mean annual Normalized Difference Vegetation Index and $NDVI_{CV}$ is the intra-annual coefficient of variation of monthly NDVI. A high ESPI value thus occurs in case of a high annual mean NDVI and low monthly variability of NDVI, which is often indicative of a healthy forest system. Values should be interpreted with care, however, as high ESPI values may also be computed for plantation forests with multi-annual cycles.

The ESPI was quantified at a high spatial resolution of 30 m from Landsat 8 data using the Google Earth Engine (GEE) platform. The resulting ESPI map is valid for the 2013-2019 period, given Landsat 8 data availability. In addition, a courser (250 m) approach based on the MOD13Q1 product of the MODIS sensor was also applied, to analyse more long-term trends since 2000.

3.3.2 Climate cooling (regulating ES)

This ES is defined as the extent to which a site contributes to reduction of the sensible heat flux, by consuming energy in the process of water consumption. Locally it relates to health and overall quality of living, but on a larger scale it contributes to the generation of precipitation, which provides numerous other benefits. Mapping of the climate cooling ES was based on actual evapotranspiration (ET_{act}) data which are directly available from the 8-daily MOD16A2 product from the MODIS satellite sensor (500 m). Data were processed using GEE to produce an annual average map for 2010 – 2019.

3.3.3 Carbon storage (regulating ES)

An index of carbon storage is determined by the net primary productivity (NPP) of a plant: the amount of carbon dioxide vegetation it takes in during photosynthesis minus the amount of carbon dioxide it releases during respiration. NPP data were obtained from the MODIS MOD17A3 product through GEE and averaged for 2010 – 2019.

3.3.4 Contribution to baseflow (regulating ES)

An important ecosystem service in Inle Lake catchment is the extent to which natural vegetation across the catchment contributes to baseflow, and thus to water availability in the dry season. This is important for maintaining lake levels, groundwater recharge, drinking water access, and hydropower production downstream. Water retention involves complex hydrological processes, both superficial and subterranean, which cannot be observed directly from space. Therefore, the InVEST model (see next section) was applied to quantify this ES, using various satellite-derived and GIS datasets.

3.3.5 Reduction of sediment export (regulating ES)

Reduction of sediment export from a certain location is an important ecosystem service, as it can decrease both the inflow of sediment into Inle Lake and the loss of fertile land upstream (see Section 2.5). To address the complexity of this ES, and to allow for scenario analyses, the InVEST model was used to estimate this regulating ES (see next section).

3.4 InVEST modeling approach

3.4.1 Overall description

InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs)[1] is a freely available suite of models for mapping and valuing ES. InVEST enables decision makers to assess quantified tradeoffs associated

[1] https://naturalcapitalproject.stanford.edu/software/invest

with alternative management choices and to identify areas where investment in natural capital can enhance human development and conservation. InVEST is a well-established toolset that is commonly used in similar studies worldwide (Toft et al. 2019), including recent applications in the Myanmar context (Mandle et al. 2017).

In this study, InVEST was applied with the purpose of mapping regulating ES of forest systems related to baseflow contribution and sediment export reduction. The InVEST Seasonal Water Yield (SWY) and Sediment Delivery Ratio (SDR) models were used to quantify these services, respectively. The next sections briefly describe the two models and their application in this study. For a more detailed description of model processes and algorithms, the reader is referred to the extensive InVEST User Guide that is available online[1].

3.4.2 Seasonal Water Yield

The InVEST Seasonal Water Yield (SWY) model aims to provide guidance regarding the contribution of land parcels to the generation of both baseflow and quick flow. The model computes spatial indices that quantify the relative contribution of a pixel to the generation of both baseflow and quick flow. Quick flow (QF) is calculated with a Curve Number-based approach, assuming an exponential distribution of daily precipitation depths on days with rain. The local recharge, or potential contribution to baseflow, of a pixel is computed from the local water balance, where actual evapotranspiration is determined from potential evapotranspiration and a crop factor. The total baseflow is the average of the contributing local recharges (negative or positive) in the catchment, and attribution of baseflow to an individual pixel is based on the relative contribution of that pixel to the local recharge. The baseflow index *B* represents the actual contribution of a pixel to baseflow (i.e., water that reaches the stream). If the pixel contributed to groundwater recharge, then *B* is a function of the amount of flow leaving the pixel and of the relative contribution to recharge of this pixel. For a parcel that is not adjacent to the stream channel, the cumulative baseflow, $B_{sum,i}$, is proportional to the cumulative baseflow leaving the adjacent downgradient parcels minus the cumulative baseflow that was generated on that same downgradient parcel (Figure 7).

The SWY model requires a set of geospatial input data on climate, topography, land cover, and soil, which are listed in Table 3. The model was run using 2015 land cover data and 2010 – 2019 precipitation inputs (CHIRPS). The analysis was performed with a spatial resolution of 90 m, which is equal to the pixel size of the digital elevation model used to determine the hydrological network.

The local baseflow is the key output variable of the SWY model for this analysis. To quantify the contribution of natural vegetation to baseflow, it is required to quantify the impact of losing this vegetation and converting it to agriculture, a conversion which is typical for the Inle Lake Region over the past decades. The SWY model was therefore run using two different land cover maps: one simulation with the original SERVIR-Mekong map for 2015, and one simulation where all forest classes are converted

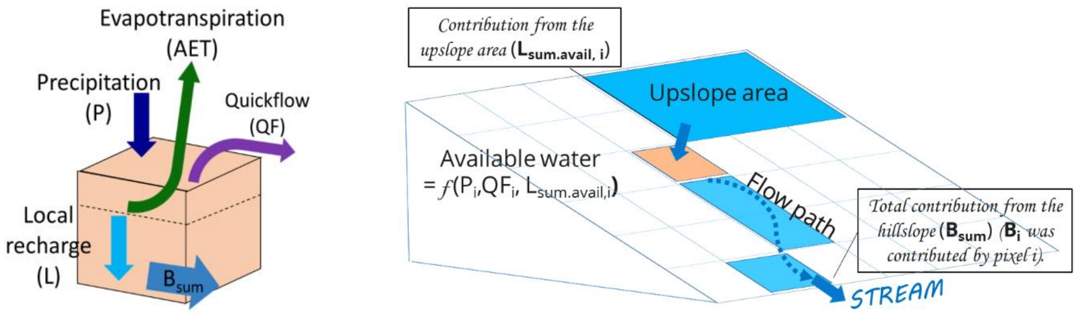

Figure 7. Principles of the InVEST Seasonal Water Yield model (source: InVEST online user guide).

[1] https://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/

to cropland in the land cover map (keeping all other inputs equal). The difference in local baseflow generation is then a measure of the contribution of the ES provided by the natural vegetation.

3.4.3 Sediment Delivery Ratio

The objective of the InVEST Sediment Delivery Ratio (SDR) model is to map overland sediment generation and delivery to the stream. Outputs from the SDR model include the sediment load delivered to the stream at an annual time scale, as well as the amount of sediment eroded in the catchment but retained by vegetation and topographic features.

For each pixel, the model first computes the amount of annual soil loss from that pixel, then computes the sediment delivery ratio (SDR), which is the proportion of soil loss actually reaching the stream. The amount of local annual soil loss from a pixel is given by the Revised Universal Soil Loss Equation (RUSLE)[1]. The model then computes a connectivity index (IC) for each pixel. The connectivity index describes the hydrological linkage between sources of sediment (from the landscape) and sinks (such as streams.). Higher values of IC indicate that source erosion is more likely to make it to a sink (i.e., is more connected), which happens, for example, when there is sparse vegetation or higher slope. Lower values of IC (i.e., lower connectivity) are associated with more vegetated areas and lower slopes. The local soil loss and connectivity index are combined to compute sediment export: the amount of sediment eroded from a pixel that actually reaches the stream.

The RUSLE factors for Inle Lake watershed were quantified based on the equations proposed for Myanmar by Emtehani and Rutten[2]:

- *R* factor: map based on 2010 – 2019 CHIRPS precipitation patterns;
- *K* factor: map based on ISRIC SoilGrids (250 m) soil texture;
- *C* factor: table, per SERVIR-Mekong land cover type and based on average MODIS NDVI.

The ES of interest in this analysis is the reduction of sediment export by natural vegetation. Therefore, similar to the Seasonal Water Yield model application, this ES was expressed by a difference map between the current situation and an "all-agriculture" scenario. The analysis was performed with a spatial resolution of 90 m, which is equal to the pixel size of the digital elevation model used to determine the hydrological network.

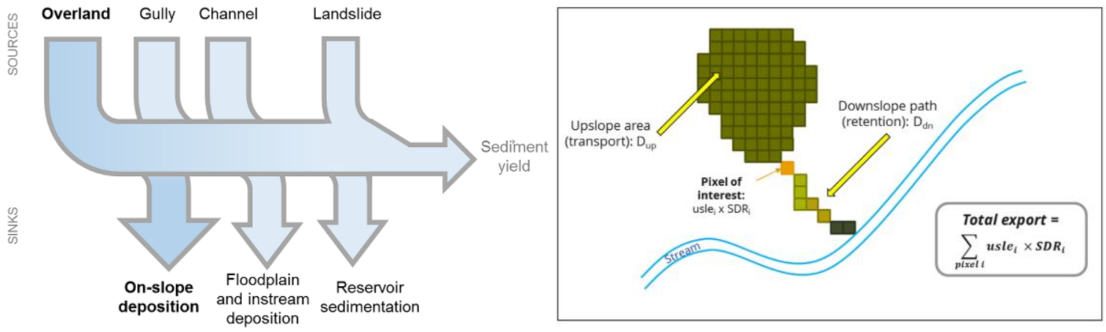

Figure 8. Principles of the InVEST Sediment Delivery Ratio model (source: InVEST online user guide).

[1] An elaborate description is provided in the online user guide: https://invest-userguide.readthedocs.io/en/latest/sdr.html.
[2] https://presentations.copernicus.org/EGU2017/EGU2017-6473_presentation.pdf

3.5 Integration of ecosystem services maps

The approach outlined above yields a set of 5 individual ES maps of Inle Lake watershed, all representative of roughly the same, recent time period. To facilitate use of this information in an updated zoning procedure for developing conservation policies, it holds added value to integrate them into a single ES map of Inle Lake watershed. This requires relative scaling of the individual ES maps as follows:

$(ES_{pixel} – ES_{min}) / (ES_{max} – ES_{min})$

where ES_{pixel} is the ES value of a particular pixel, and ES_{min} and ES_{max} are the overall minimum and maximum values, respectively, occurring in the entire watershed.

The relative ES values were multiplied to arrive at a single ES estimate. This approach leaves room to apply subjective weighting, if a higher importance is attributed to a particular ES. The maps presented in this report were created by attributing equal weighting to provisioning and regulating services; in other words, the ESPI map contributes 50% to the final ES value and the product of the 4 individual regulating ES contributes the other 50%. Since the ESPI map is available at the highest spatial resolution and some correlation with the other ES can be expected, this approach has the added benefit of producing a certain downscaling effect. The integrated ES maps were produced with a pixel size of 90 m.

3.6 Capacity building

As part of the assignment, staff of the line departments participating in the ILMA initiative were trained in ESS mapping. The target group of this training was mostly technical staff with a GIS background. Among others, Forest Department staff, GAD staff, and NWCD staff were trained. It was decided to not wait for formal establishment of the ILMA to organize this training, as the ILMA will not have dedicated staff for implementation. Although originally foreseen as an in-country training, the event was ultimately organized as a 3-day online learning session due to the global COVID-19 pandemic.

A brief description of the training objectives, content, and practicalities, is included in Annex 3. Annex 4 contains an overview of the training participants.

4 Results

4.1 Inle Lake catchment

To evaluate the total drainage area of Inle Lake, Samkar Lake, and Mobye Reservoir, a basin delineation operation was performed in GIS software based on the most recent elevation information available (SRTM Global Elevation Model at 30 m, see Table 3). As these data are more recent and detailed than the elevation data used in earlier basin delineations, the results are somewhat different from the UNESCO MAB outer boundary, as well as from the basin map in the Inle Lake 5-year Plan. The basin area was found to be approximately 10%, or around 500 km^2, larger than mapped in the 5-year Action Plan (see Figure 9 and Figure 10). The difference is likely due to the usage of a different elevation map and differences in methodology and software used.

As an outer boundary of the Inle Lake catchment for this project, despite the difference in basin extent, it was decided to use the UNESCO MAB boundary (Figure 3) as this has been formally authorized by the Shan State government. Although this extent differs somewhat from the updated basin delineation presented above, the impact on ecosystem services maps is not expected to be significant, as the area excluded from the MAB boundary indicated in Figure 10 largely consists of cropland.

4.2 Provisioning Ecosystem Services

A large part of the Inle Lake watershed (in particular roughly the northern half) does not score very high in terms of provisioning ecosystem services (Figure 11). However, patches of high ESPI values can be found in particular close to the watershed boundaries, both on the western and (to a lesser extent) eastern sides. Notable areas with high ESPI are seen in the west of Kalaw sub-catchment, even in areas not formally protected under Forest Law, and more remote parts of Inle Lake East Reserved Forest (R.F.).

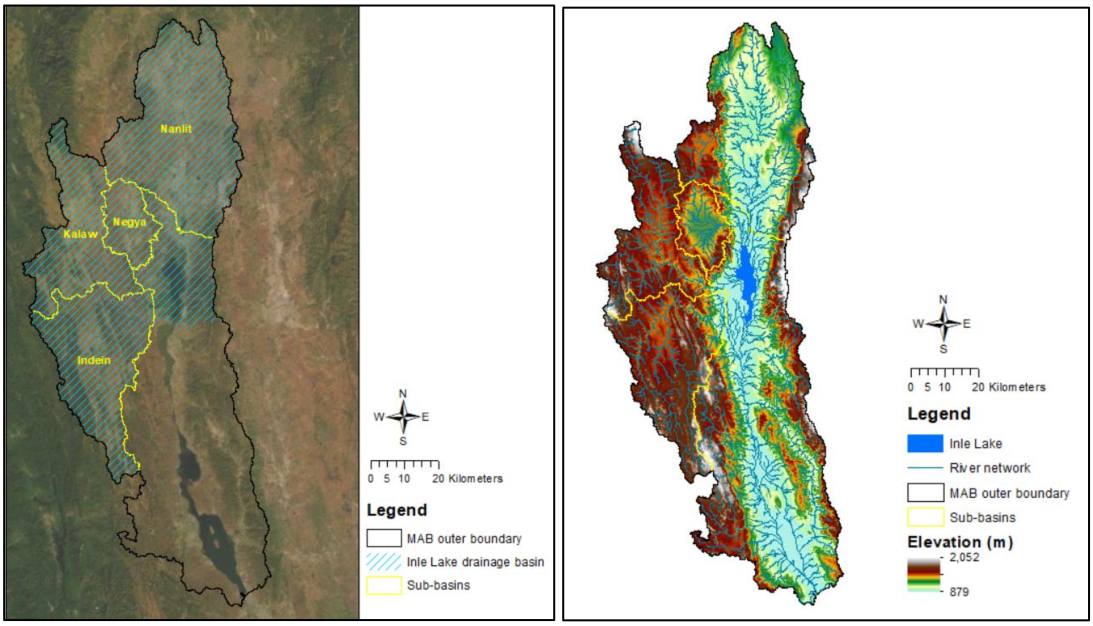

Figure 9. Basin delineation results.

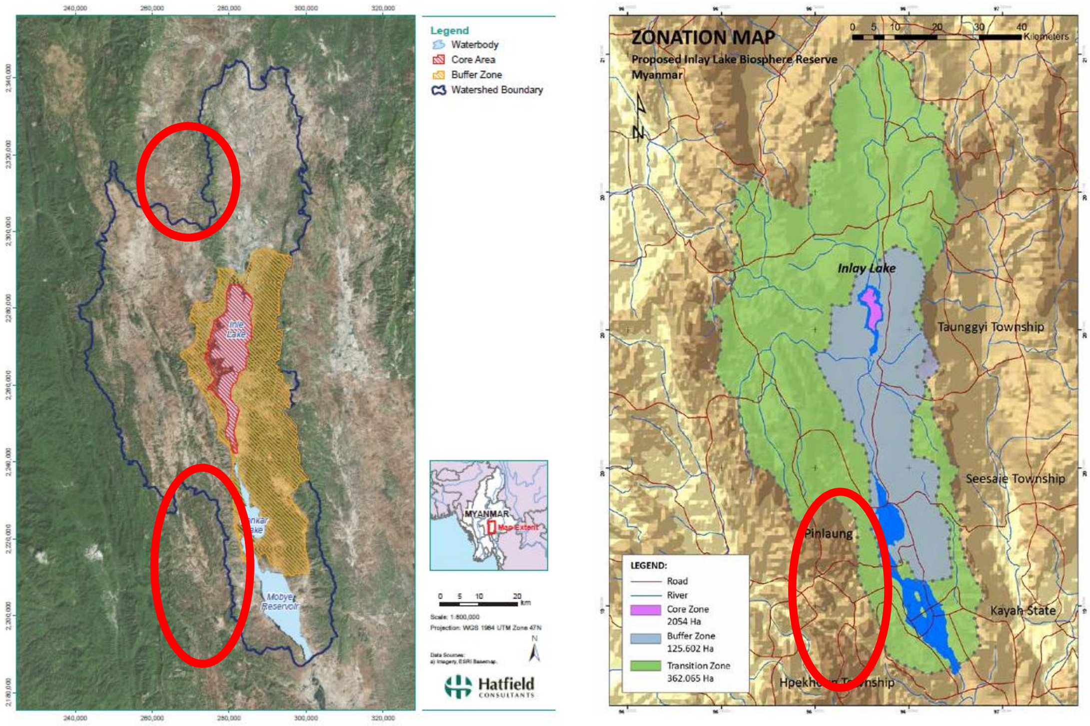

Figure 10. Previous Inle Lake drainage basin delineations: 5-year action plan (left) and UNESCO MAB (right). Main differences with the updated basin delineation are indicated in red. These are mainly comprised of cropland area, and are therefore not expected to significantly impact the identification of ES hotspots.

As explained in Section 3.3.1, an additional analysis based on MODIS data was performed to map the trend in provisioning ES from 2000. Figure 12 shows the results of this analysis based on two consecutive 5-year periods: 2006-2010 and 2011-2015. Although initial visual inspection does not seem to indicate a clear overall trend within the watershed, a closer comparison to results for 2011-2015 shows that red (negative) patches are generally found in areas with high ESPI values. In other words, the strongest declines in ESPI values are observed in areas where natural vegetation is/was still present in 2015, with high provisioning ES estimates. This indicates that the sites identified as delivering high provisional ES are already impacted by degradation, and can be expected to be affected further if no action is taken towards improving their conservation.

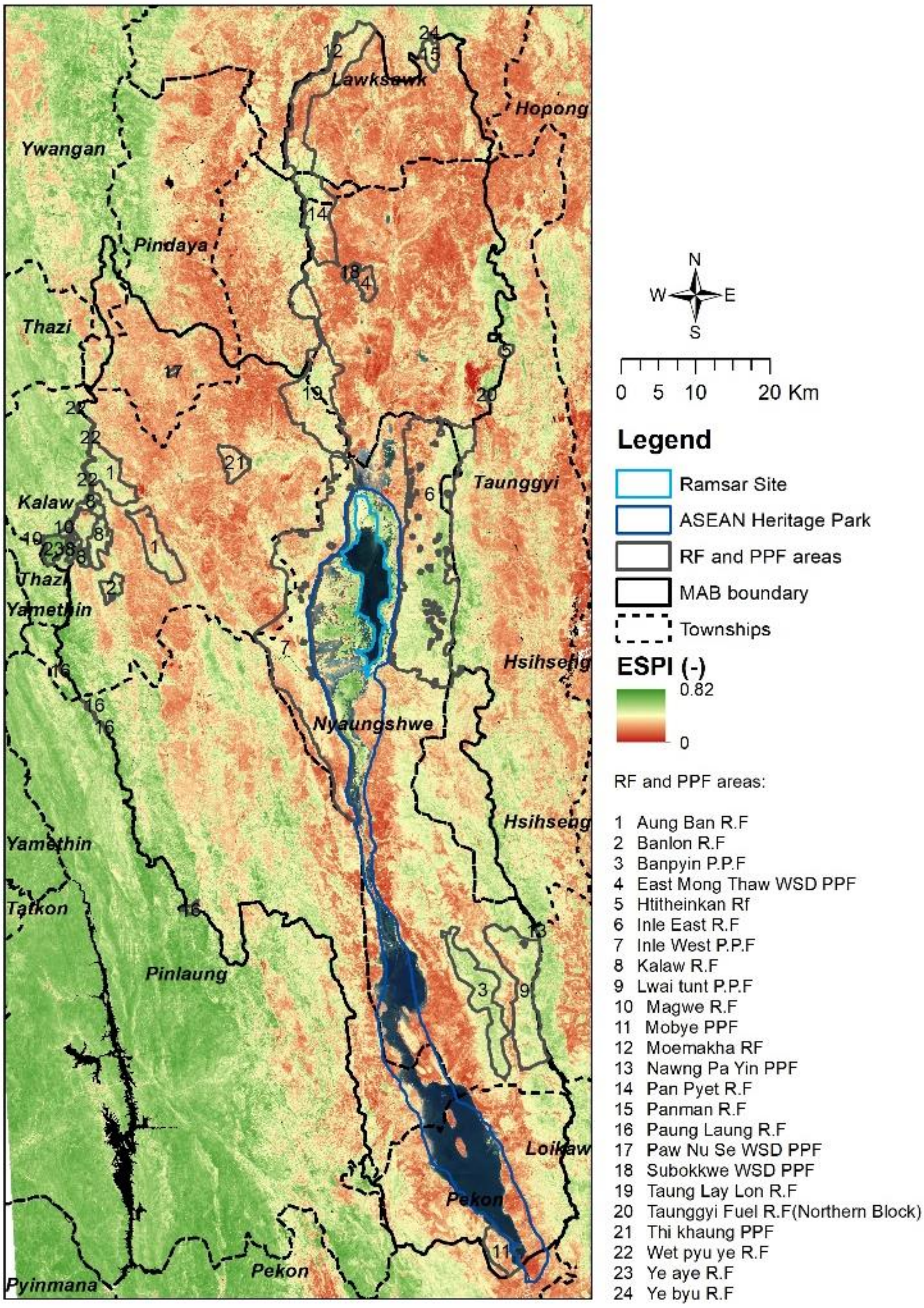

Figure 11. Ecosystem Services Provisioning Index (ESPI) of Inle Lake watershed, based on 2013-2019.

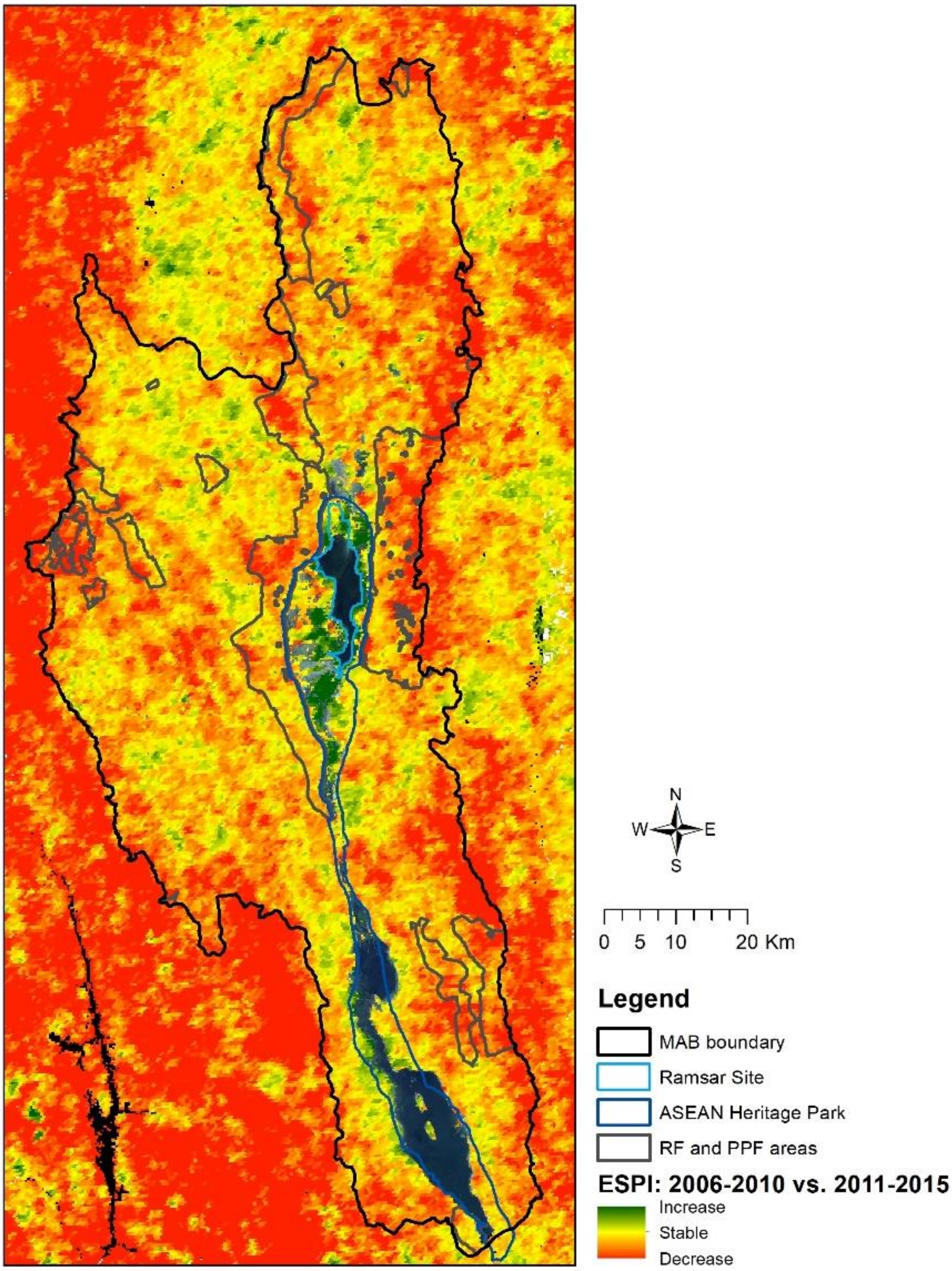

Figure 12. Trend in Ecosystem Services Provisioning Index (ESPI) of Inle Lake watershed, indicating change in 2011-2015 with respect to 2006-2010.

4.3 Regulating Ecosystem Services

Figure 13 shows annual average ET_{act} (climate cooling) across Inle Lake catchment, from 2010 to 2019. Comparing with results in Figure 2 shows a clear correlation between high climate cooling values and land cover types that provide a green vegetation cover throughout the year, such as forests and grassland. Continuous stretches of cropland, such as in the northwest of the watershed, heat up the most, in particular during times of the year when they remain fallow. The data also show that ET_{act} in the large area of primary forest found in Pinlaung, directly southwest from the watershed, is significantly higher than the values obtained for Inle Lake watershed. This demonstrates the substantial climate cooling impacts that can be achieved from healthy forest.

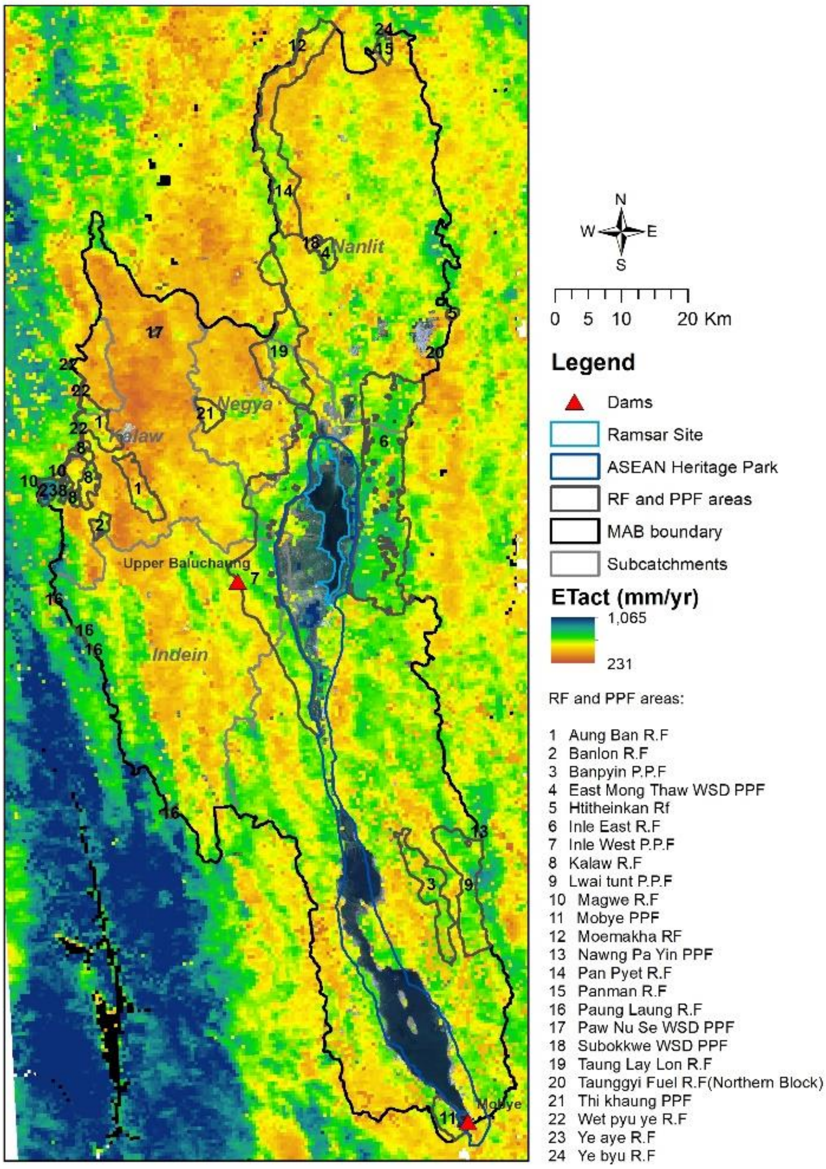

Figure 13. Climate cooling (actual evapotranspiration) in Inle Lake watershed, based on annual averages for 2010 – 2019.

The carbon storage map (Figure 14) largely shows a similar spatial pattern as the climate cooling map, as both processes are closely related. Overall, more carbon was stored in the east of the watershed than in the West, with relatively high values in Inle East R.F. and directly south from this Reserved Forest. Evaluating this ES holds great value for assessments of (changes in) carbon stock, such as might be accomplished under the REDD+ initiative.

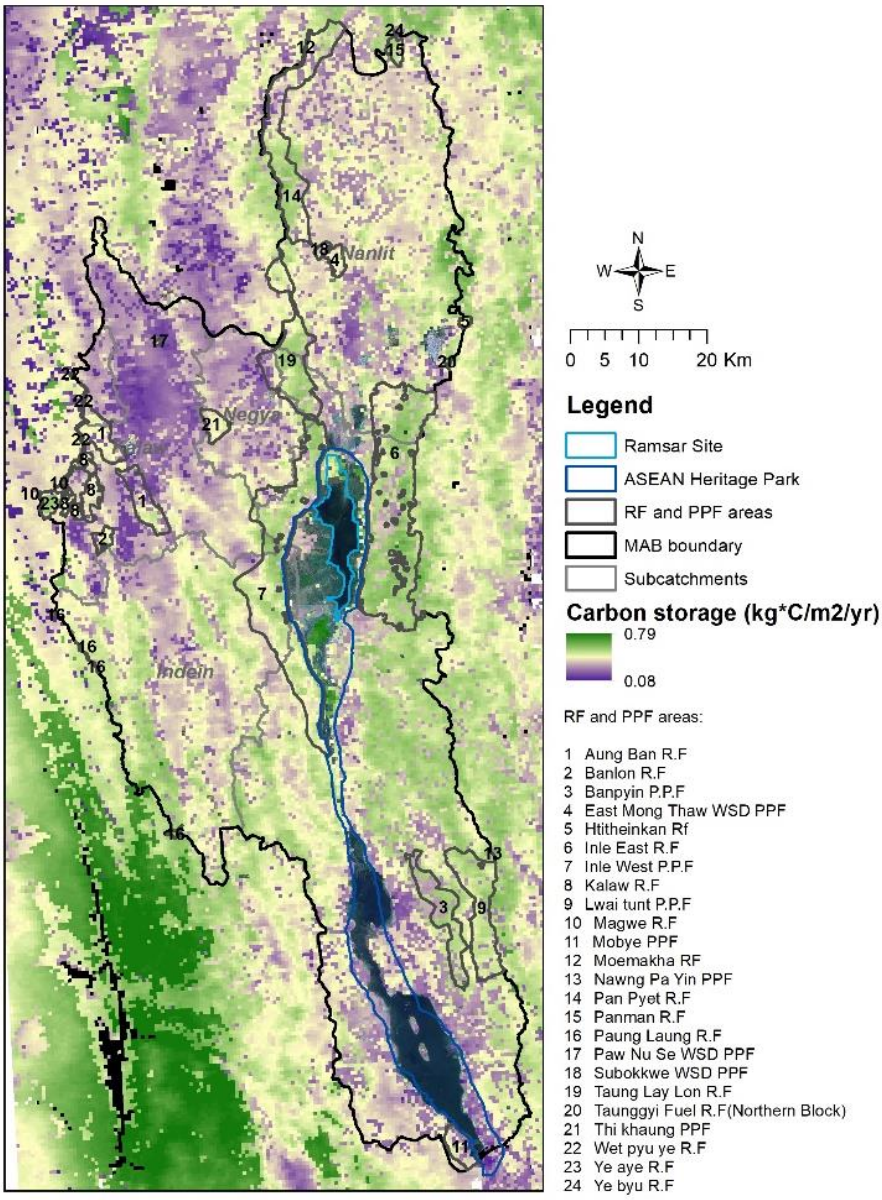

Figure 14. Carbon storage (based on Net Primary Productivity) in Inle Lake watershed, based on annual averages for 2010 – 2019.

Figure 15 shows the annual average baseflow contribution of natural vegetation in Inle Lake watershed over the 2010 – 2019 period. Here, natural vegetation is defined as land cover under one of the following classes in the 2015 SERVIR-Mekong map (Figure 2): closed forest, open forest, woody, or grassland. Figure 15 therefore only has values for these land cover classes. Interestingly, values can vary substantially even within a particular land cover class, depending on soil characteristics, slope, and (over larger areas) climate. The contribution to baseflow of natural vegetation can amount to over 100 mm/yr, to locally over 150 mm/yr.

Possibly the most interesting observation in Figure 15 can be made in the large stretch of forest southwest of the watershed, where the presence of forest actually reduces baseflow generation. This aligns with a growing understanding of the fact that, under certain conditions, reforestation can actually impact water supply in a negative manner.[1] For many geographical locations, forest types and climate conditions, annual water yields are reduced as a result of reforestation, due to enhanced access to soil water and transpiration of the vegetation (Duan and Cai 2018; Senent-Aparicio et al. 2018) Especially in tropical climates, depending on tree species used, soil water content is effectively restored to natural conditions by reforestation and associated deep rooting systems (Liu et al. 2021). It should be noted that increased landscape transpiration after reforestation also drives enhanced atmospheric moisture recycling, leading to increased precipitation either locally or elsewhere in the "precipitationshed" (Keys et al. 2014).

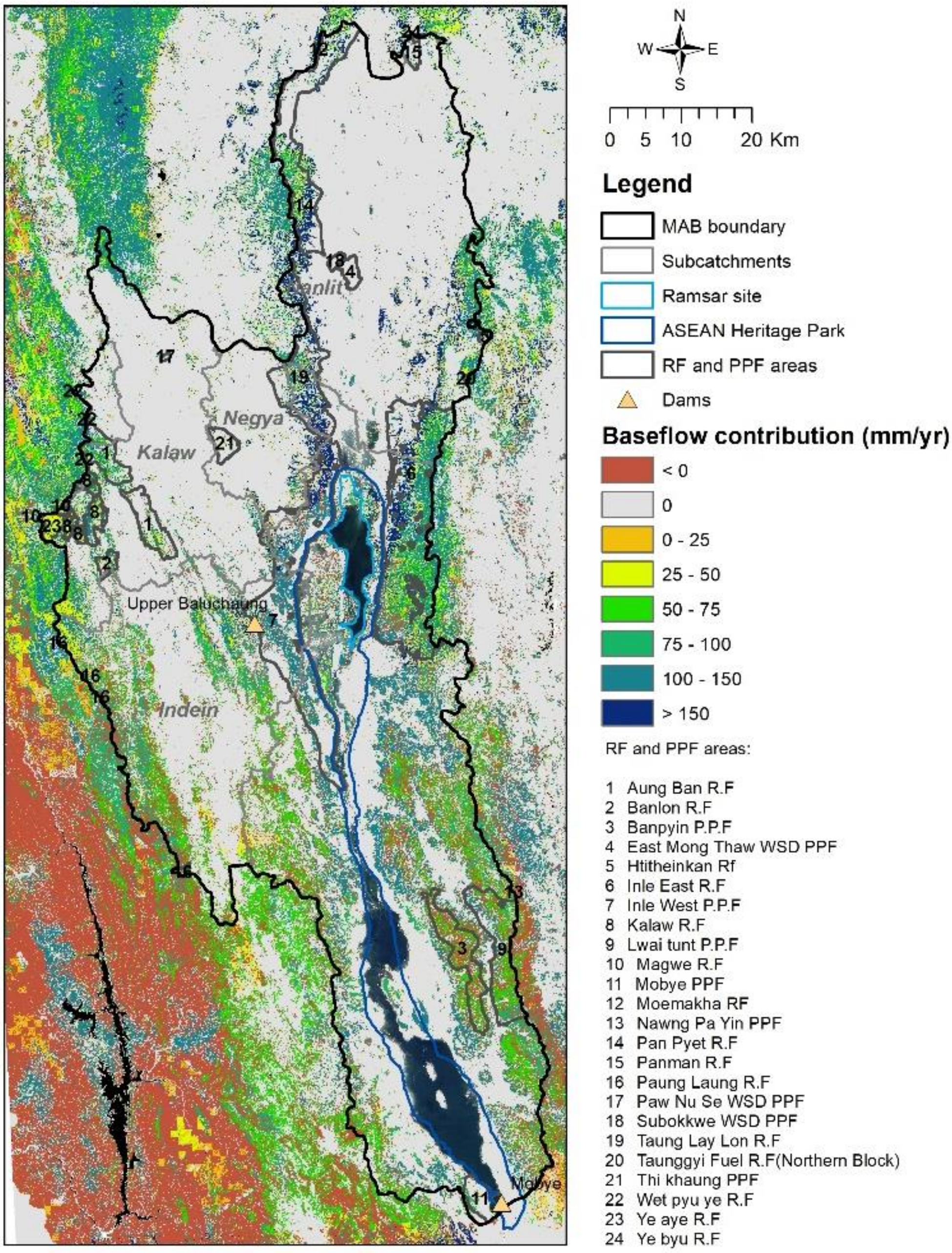

Figure 15. Baseflow contribution of natural vegetation in Inle Lake watershed, based on annual averages for 2010 – 2019.

[1] e.g. https://sdg.iisd.org/commentary/guest-articles/afforestation-increases-water-supply-but-only-with-these-considerations/

Slope is one of the key factors determining the reduction of sediment export by natural vegetation in Inle Lake watershed, as can be seen in Figure 16. Spatial variability of this ES is relatively high, with highest values occurring locally on the steep hillslopes in the east of the watershed, particularly in Inle East R.F., along the mountain range in the northeast, and in Lwai Tunt P.P.F. It should be noted that this map should be especially interpreted in terms of its relative spatial patterns, as the InVEST SDR module documentation prescribes not to use absolute values in an uncalibrated context (as is the case for this application).

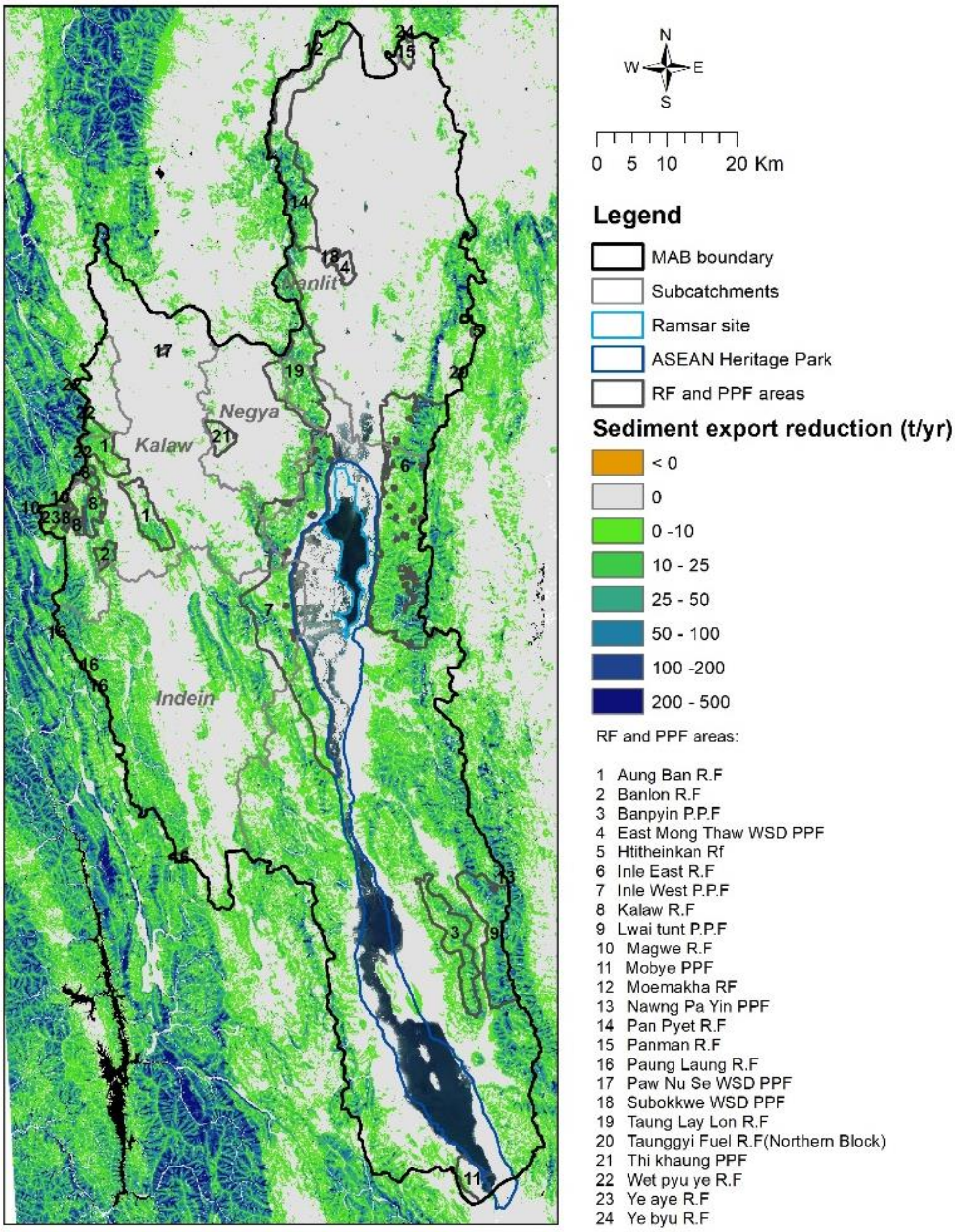

Figure 16. Reduction of sediment export by natural vegetation in Inle Lake watershed, based on annual averages for 2010 – 2019.

4.4 Integrated Ecosystem Services Assessment

4.4.1 Integrated Ecosystem Services mapping

The procedure described in Section 3.5 was applied to come to a single, integrated ES map of Inle Lake watershed (Figure 17). This can be considered an important base layer for any development of conservation policies and, in particular, when proposing additional or upgraded conservation zones. Continuous stretches of high ES (green colour) can be considered appropriate for intensified nature conservation.measures and enforcement. Interestingly, several Reserved Forests and Protected Public Forests can no longer be considered as providing major benefits from ES. At the same time, some parts of the watershed (e.g., in the west and northeast) do provide notable ES, but have no current protected status. Based on this map, in particular Ye Aye R.F., some patches south from Ye Aye, and the eastern section of Inle East RF could be considered suitable candidates for designation of a higher protection status, such as inclusion in the MAB core zone, based on the selected ES.

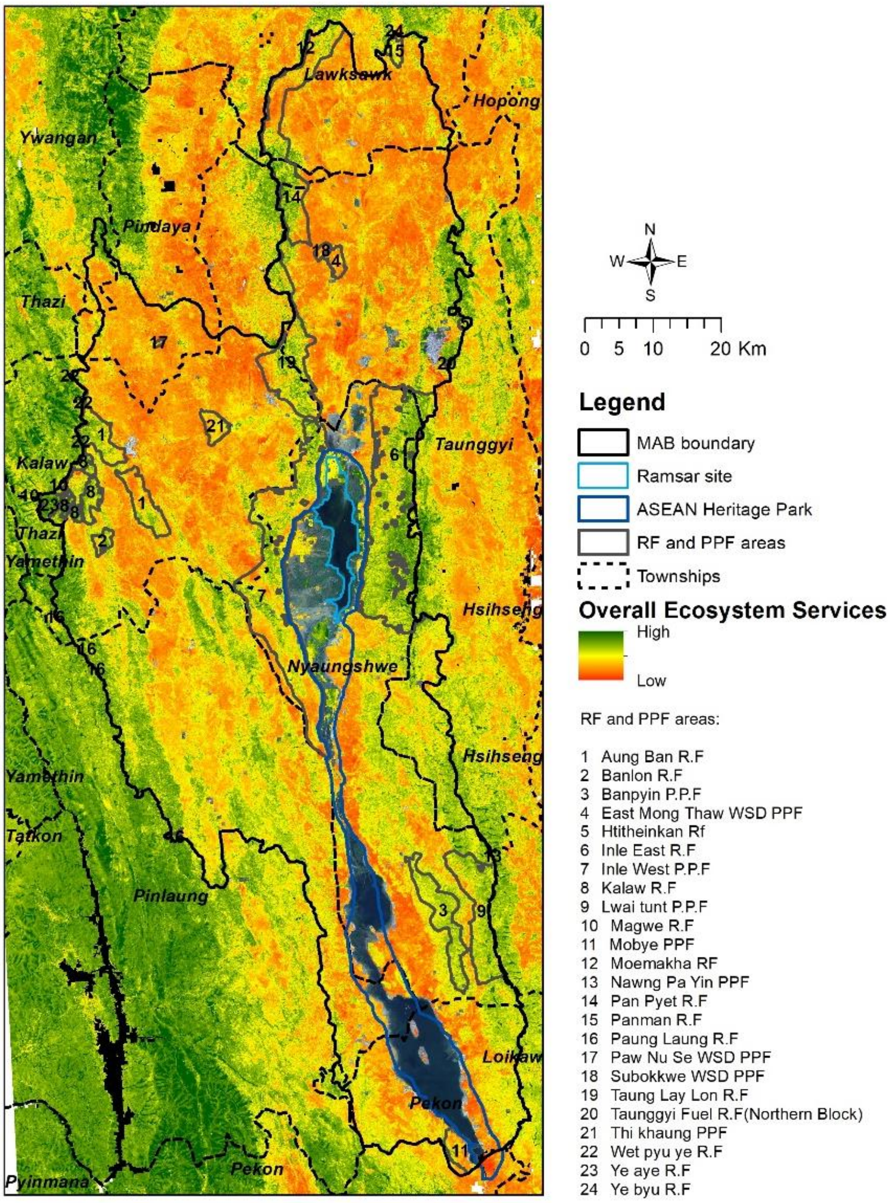

Figure 17. Overall selected Ecosystem Services (ESPI, baseflow contribution, climate cooling, carbon storage, sediment yield reduction) map of Inle Lake watershed.

The integrated ES map, as well as all individual ES data and the main intermediate products, have been delivered in GIS format to UNDP Myanmar for incorporation in the ILMA web platform that is currently being developed.

4.4.2 Hotspot selection

Table 4 lists the average individual ES values for each of the 24 areas that hold a special status under Forest Law. The purpose of this table is to rank the protected areas according to the ES they provide to the local population. For this reason, additional information is provided in the table: the number of villages nearby, the surface area within the MAB, and the relative portion of the area located in the watershed.

Two areas that are identified as particularly important in this assessment are Yen Aye R.F. (Figure 18) and Inle East R.F (Figure 19). Provisioning ES are the highest in Yen Aye R.F., and although small, this area in the far west seems to still hold the healthiest forest in the watershed. This is confirmed by the high-resolution Sentinel-2 (10 m) satellite image composite presented in Figure 18. In Inle East R.F., on the other hand, spatial variability in ES provision is quite significant. Where the northwest of the R.F. no longer provides any significant ES, its eastern section is still quite important. Particularly sediment export reduction values are high (Figure 19). Combined with the high surface area over which these values occur, as well as its proximity to the lake, it is plausible that this is a key area in mitigating sediment inflow to the lake (and thus, lake siltation and further reduction of lake levels).

Table 4. Overview of average ES values and other relevant properties of each area with a certain protection status under Forest Law. Darker green colours indicate higher ES values.

Name	Area within MAB (ha)	% of total RF/PPF area within MAB	No. of villages nearby (<2km)	Provisioning ES (ESPI, -)	Regulating ecosystem services				Overall			
					Sediment export reduction (tonnes/ha/yr)	Dry season flow contribution (mm)	Climate cooling (ET in mm/yr)	Carbon storage (kg*C/m2)	Overall ES (scaled, average)	Overall ES (scaled, aggregated for area)	Rank (area-averaged)	Rank (total ES)
Aung Ban R.F	4995	100%	33	0.46	9.8	39.2	459	0.40	0.31	0.07	15	7
Banlon R.F	614	100%	18	0.50	13.7	38.3	489	0.42	0.33	0.01	12	12
Banpyin P.P.F	4460	100%	9	0.54	20.7	5.0	520	0.45	0.36	0.08	8	6
East Mong Thaw WSD PPF	766	100%	1	0.34	0.1	1.3	526	0.43	0.23	0.01	21	14
Htitheinkan Rf	213	67%	2	0.47	3.3	63.0	480	0.47	0.34	0.00	10	18
Inle East R.F	20973	82%	90	0.48	27.2	79.1	587	0.49	0.37	0.37	7	1
Inle West P.P.F	19723	100%	146	0.43	15.8	45.5	549	0.48	0.32	0.30	14	2
Kalaw R.F	2356	88%	25	0.55	24.2	62.1	518	0.42	0.38	0.04	5	8
Lwai tunt P.P.F	6336	93%	10	0.50	40.7	29.1	554	0.47	0.36	0.11	9	5
Magwe R.F	265	3%	0	0.56	14.8	53.2	512	0.41	0.37	0.00	6	16
Mobye PPF	1687	83%	3	0.40	1.7	12.4	526	0.39	0.26	0.02	20	9
Moemakha RF	149	24%	0	0.44	0.4	7.4	484	0.46	0.29	0.00	18	20
Pan Pyet R.F	9146	92%	13	0.43	19.1	48.3	468	0.45	0.31	0.14	16	3
Panman R.F	635	87%	0	0.47	1.3	22.2	524	0.50	0.32	0.01	13	13
Paung Laung R.F	233	0%	6	0.63	10.0	9.8	656	0.51	0.41	0.00	3	17
Paw Nu Se WSD PPF	96	100%	3	0.37	0.2	5.4	364	0.32	0.23	0.00	22	22
Subokkwe WSD PPF	285	100%	0	0.32	0.0	0.0	461	0.40	0.22	0.00	23	19
Taung Lay Lon R.F	7497	65%	9	0.45	16.5	68.5	504	0.47	0.34	0.12	11	4
Taunggyi Fuel R.F(Northern B	65	7%	0	0.64	5.6	95.9	627	0.52	0.45	0.00	1	21
Thi khaung PPF	1090	100%	9	0.41	1.1	10.3	472	0.43	0.27	0.01	19	11
Wet pyu ye R.F	282	4%	3	0.58	13.0	68.9	544	0.44	0.39	0.01	4	15
Ye aye R.F	795	99%	0	0.68	19.0	51.6	742	0.49	0.44	0.02	2	10
Ye byu R.F	16	1%	0	0.48	0.0	0.0	412	0.37	0.30	0.00	17	23

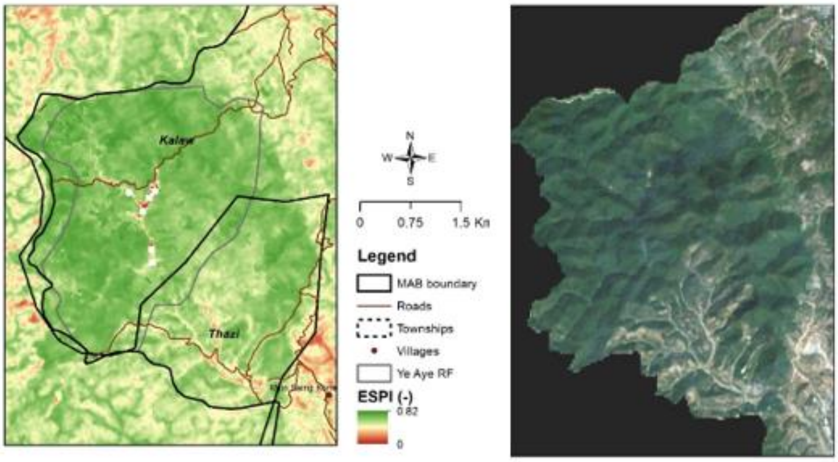

Figure 18. ESPI map of Ye Aye R.F (left) and a 2019 Sentinel-2 composite of the same area (right).

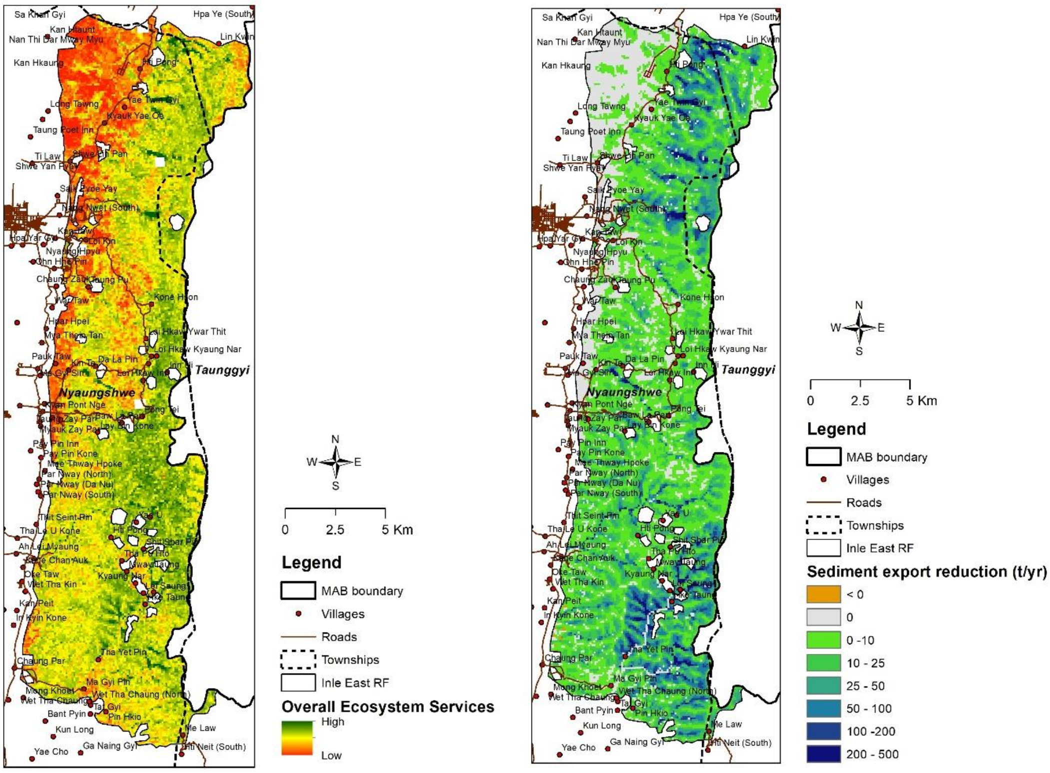

Figure 19. Overall selected Ecosystem Services map (left) and sediment export reduction (right) of Inle East R.F.

5 Conclusions and recommendations

This report presents the ecosystem services maps for the Inle Lake watershed based on the MAB boundary, regarding five selected key ES: provisioning ES (through the integrated indicator ESPI), climate cooling, carbon storage, baseflow contribution, and sediment export reduction. The maps clearly show that, although the Inle Lake watershed has suffered a significant loss of ES over the years, there are still important areas to preserve that would safeguard local benefits from these services, as well as downstream benefits to the lake and its dwellers.

As is typical for ES assessments, the results presented in this report are guided by the selection and definition of indices that are considered relevant in the context of Inle Lake watershed. The applied methodology integrates various techniques, including satellite remote sensing and simulation modelling. Both tools come with a certain degree of uncertainty and inaccuracies, which particularly manifest themselves in the absolute values estimated for biophysical processes such as carbon sequestration and baseflow generation. However, the greatest added value of applying these technologies lies in their capability of identifying spatial patterns and temporal dynamics, which is crucial for the purposes of identifying ES hotspots and informing zonation for conservation strategies.

Digital versions of the maps will be available through the ILMA knowledge and data-sharing platform, currently under development. Arguably, even more important than the maps themselves, this assignment has yielded an innovative methodology that incorporates already available satellite-derived data, GIS information, and locally-sourced data. This integrated methodology was developed with the objective in mind that any data coming available in the future (e.g., land cover) could be easily integrated. The methodology described in this report was conveyed to technical staff of the line departments involved in ILMA, to ensure that future updates of the ES maps by ILMA staff will be possible.

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Annex 1: Ecosystem Services: conceptual framework

The description of the conceptual framework provided in this section is based on the white paper prepared by Simons et al. (2017).

Ecosystems provide a wide range of benefits to humans, but these ecosystem services (ES) are rarely accounted for in any proactive way by decision makers. More typically, ecosystem benefits are ignored until it is too late, at which point expensive and reactive interventions are required to address the loss of ecosystem benefits. Different frameworks based on the general concept of ecosystem services to humans were developed over the past two decades, aiming to mainstream the proactive consideration of ecosystem benefits in planning and policy decisions.

Application of ES frameworks is most fundamentally about the quantification of tradeoffs. When ecosystems are affected by economic development, the benefits that the ecosystem once provided may be compromised or eliminated. Some such services, such as the regulation of water flows, can be replaced via engineered solutions but the cost of this replacement can be significant. In contrast, many cultural services such as the aesthetic or spiritual value of nature are often irreplaceable. Quantification of these opportunity costs can be compared to the economic benefits of the development, allowing for a more holistic view of costs and benefits. ES frameworks are used not only to look at the loss in services from development, but also at the gain in services achieved through effective ecosystem restoration and its impact on people's livelihoods.

One of the most common systems of categorization is from the Millennium Assessment[1]. It splits up all ecosystem services into four overarching functional categories (Figure). After the Millennium Assessment, one of the most significant attempts at categorizing ecosystem services came out the Economic of Ecosystems and Biodiversity (TEEB) project, which proposed a variant on the MA framework. This variant keeps two of four primary categories, slightly alters the cultural category and replaces the Supporting Services category with “Habitat Services”. TEEB’s strong focus on habitat and biodiversity is based on the contention that these two things underpin almost all other services. The Ecosystem Services and Resilience Framework (ESR) of the CGIAR Research Program on Water, Land and Ecosystems builds on the TEEB concept, and emphasizes the interplay between agricultural systems and ecosystems (CGIAR Research Program on Water Land and Ecosystems, 2014). In this concept of integrated agricultural landscapes, communities are supported by stocks and flows of ecosystem services that they are able to manage at different scales, to ultimately improve human well-being and alleviate poverty.

[1] https://www.millenniumassessment.org/en/index.html

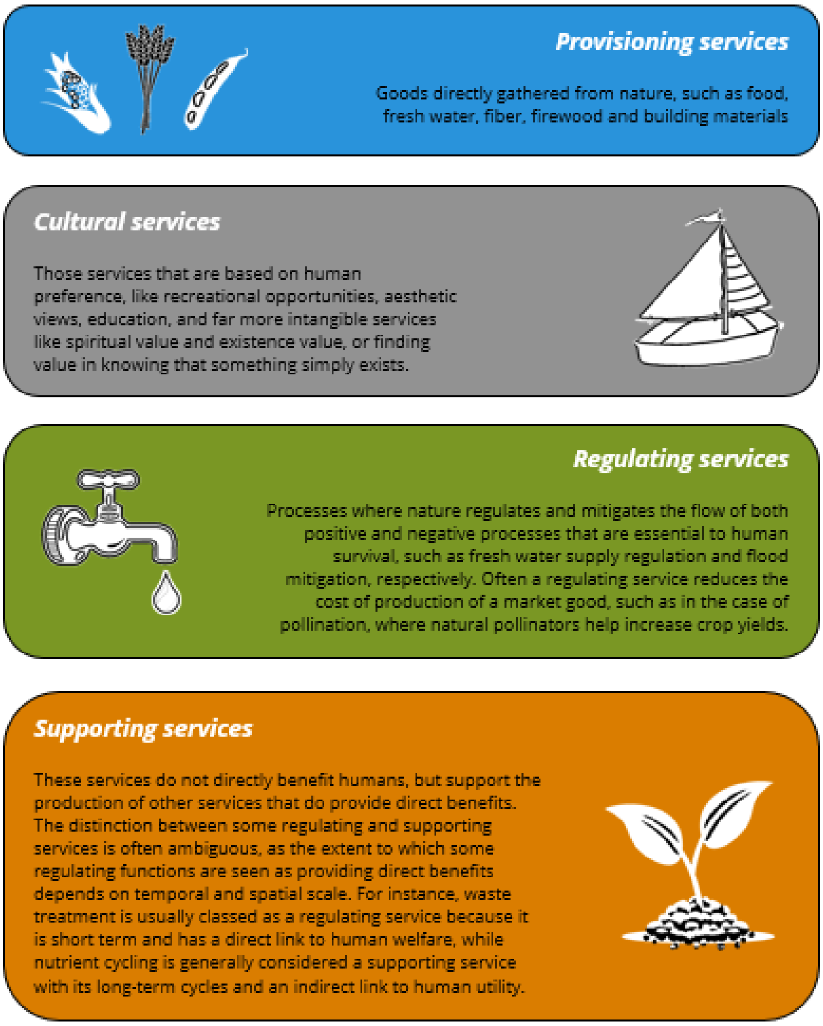

Figure A 1. The most common categorization of Ecosystem Services into four categories.

Some types of ES are impossible to value or quantify. For instance, spiritual, religious, educational, or bequest values (feeling of value associated with providing for future generations) are of great importance for ecosystems across the world, but they do not lend themselves to quantification in most circumstances (Figure). Nor do non-use values, such as existence or option value, which is the value that people ascribe to a place for its mere existence, or for the fact that it may be useful at some time in the future. Even habitat value is not generally considered quantifiable as it is not a service that is directly consumed by human beneficiaries, but rather supports the creation of other services that humans consume.

Nonetheless, many other services—particularly those that involve the need to engineer replacements—can be quantified and even monetized. Many services that involve water fall under this category: water supply regulation, nutrient and sediment regulation, waste assimilation, flood regulation, and carbon sequestration can all be quantified by using state-of-the-art tools. A value can subsequently be ascribed to them when there are human beneficiaries downstream. All of these services depend on healthy upstream ecosystems and we can evaluate the extent to which land change will compromise the flow of these services which, in turn, will require expenditures to engineer replacements to maintain a certain level of well-being among downstream beneficiaries.

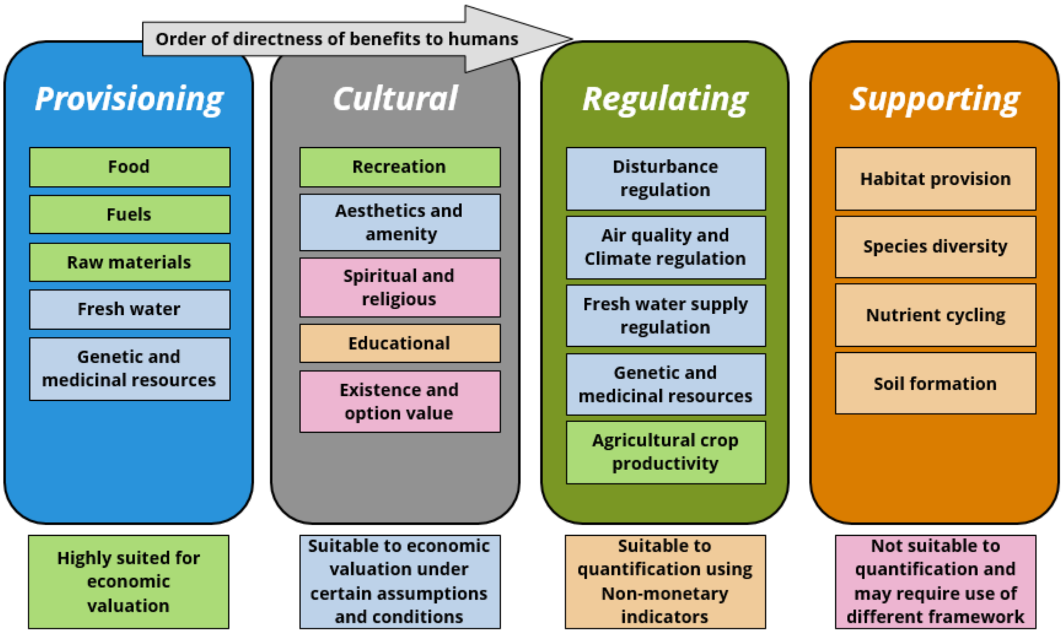

Figure A 2. Ecosystem service classification system, color-coded by suitability for quantification.

Annex 2: Inception mission report

Itinerary

From Jan 20 to 24, a mission to Myanmar was organized, with visits to stakeholders in Yangon, Taunggyi, and Nyaung Shwe. Table A.1 provides an overview of the various meetings that were conducted during this week.

Table A 1. Mission itinerary

Date	Location	Attendants
Jan-20	Myanmar Information Management Unit (MIMU), Yangon	• Catherine Lefebvre (GIS Specialist, MIMU)
Jan-21	Residence of Dr. Tun Hlaing, Ywama village	• Dr. Tun Hlaing (Inntha Minister)
	Forest Department, State level office, Taunggyi	• U Khin Maung Win (Director, State Forest Department, Shan State) • U Kyi Min (Assistant Director, Watershed Division of FD) • U Aung Myo Khaing (Assistant Director, District FD, Taung Gyi District) • U M Khaw Sao (Assistant Director, State FD, Shan State) • U Zam Suan Khai (Staff Officer, Township FD, Nyaung Shwe)
	Residence of Mr. U Khin Maung Win	• U Khin Maung Win, MP for Nyaung Shwe Township in Shan State parliament
Jan-22	General Administrative Department (GAD), District office, Taunggyi	• U Thet Naing Oo (Deputy Director, District General Administration Department, Taung Gyi District), • U Aung Myo Khaing (Assistant Director, District Forest Department, Taung Gyi District) and • U Zaw Khin (Staff Officer, District GAD, Taung Gyi District)
	Inle Lake PA Warden office, Nyaung Shwe	• U Sain Tun (Park Warden, National Wildlife Conservation Department)
	Forest Department, Nyaung Shwe Township office	• U Zam Suan Khai (Staff Officer, Township FD, Nyaung Shwe)
Jan-24	OneMap Myanmar office, Yangon	• Khun San Aung, Remote Sensing Officer, SERVIR-Mekong
	Netherlands Embassy, Yangon	• Johan Heymans (Water delegate) • Aung Myint Oo (Water resources officer) • Vera Hollander

Key findings

Below bullet points list the main findings of each of the meetings, in particular those related to data collection and ecosystem services of the Inle Lake Region. This section is not intended to provide comprehensive minutes of the meetings, but rather points out the key conclusions which complement the literature review (Chapter 2) and inform follow-up steps on the data collection, MAB boundary demarcation and ecosystem services mapping approaches.

Myanmar Information Management Unit (MIMU)

- MIMU data on administrative borders and road network were already collected for the assignment. MIMU does not have any unpublished datasets on other input data (e.g. land use, soil);
- SERVIR-Mekong is mentioned as the key source for up to date land use / land cover data;
- DMH and/or DWIR are mentioned as sources of hydrological data. After the meeting, the DMH gauging station network of Myanmar was checked, but no stations in the Inle Lake watershed exist;
- Soil data may be obtained from the Myanmar Earthquake / Engineering Society;
- In general it is difficult for MIMU to get data from line departments, as their core activity is to publish these data. It may be easier for the project team to obtain information as the mandate is different;
- MIMU points out to be interested in publishing any (geo)data that is created by the project.

Ethnic Affairs (21 Jan)

- The minister indicates that, due [mainly] to family planning, population in the Inntha community has stabilized. Expansion of floating gardens is no longer allowed, and diversification of income and jobs is a focus area;
- Previously, Inntha would go to the forests in the watershed to cut down trees for firewood, but this is no longer the case;
- Shifting cultivation is regarded as the main source of deforestation, but this is not practiced by lake dwellers;
- The minister provides a comprehensive overview of issues threatening the lake, which is consistent with those outlined in Section 2.2.4;
- Next to provisioning and regular services, upland forests are of spiritual significance to the Inntha and are valued for their esthetic qualities;
- Many natural springs should be protected;
- Infrastructural renovations (roads) and other hardware purchases related to conservation practices are currently financed by the Inle Lake entrance fee charged to tourists.
- Reforestation with fast-growing species and clearing the water of water hyacinth should be key management activities to restore ecosystem health.

Forest Department (state level)

- Peatlands adjacent to the lake are key to include in the core zone;
- For all GIS data, reference is made to the GIS division at FD in Nay Pyi Taw;
- A key conclusion is that final decisions on boundary demarcation, zoning and ecosystem services selection will need to be made during a follow-up workshop, with the relevant people present who can make these decisions.

Nyaung Shwe township MP

- A list of natural springs with coordinates exists, which is part of a new law recently approved by Shan State government.

General Administrative Department (GAD), district level

- GAD is trained by One Map Myanmar on sharing of GIS data;
- Socio-economic data are collected annually for each township, and available in hardcopy. Can be made available to the project but should go through an official request;

- GAD does not have a dedicated GIS department. For geodata, reference is made to FD and DALMS;
- Due to its unique position in the Myanmar government structure, GAD can coordinate information requests with other line agencies;
- Population growth and encroaching by local communities is mentioned as a key issue. Demarcation on the ground of dedicated areas for nature conservation is regarded as a necessary next step;
- GAD suggests to inform the State government on this assignment.

Forest department Nyaung Shwe township

- The ongoing Integrated Watershed Management for the Inle Lake project (JICA)1 is collecting field data on hillslope erosion as well as siltation of the lake. Lake water samples were recently sent to Japan for evaluation. Monthly sediment inflow (and discharge?) data are collected for the four main streams contributing to Inle Lake;
- For information about a new 5-year conservation and management plan, reference is made to the NWCD headquarters;
- The following suggestions are made for consideration in the PA zonation:
    - The breeding grounds of 15 endemic species;
    - Remaining patches of forest in upstream areas are crucial;
    - Peatlands should be part of the core zone.
    - In preparation for the workshop, it will be key to develop concrete proposals regarding boundary demarcation and zonation, to obtain feedback;
    - District level FD should be consulted for the list of natural springs.

PA Park Warden (NWCD)

- The following suggestions were made with regards to MAB zonation:
    - The Ramsar extent should be considered as the core zone, as it includes not only the lake but also the valuable adjacent peatlands, birds nesting sites and fish breeding grounds. Including the full PA as core zone may in practice not be feasible, due to the large number of villages;
    - The Southern two lakes, although limited in terms of fisheries, contain islands that are important sites for migratory waterbirds;
    - An important patch of forest bird habitat exists southeast of Pway Hla Ywar Ma (northwest of the watershed)
    - The lake to the west of this forest is important salamander habitat
- For the natural springs list, reference is made to the FD (district / state level?). Springs are especially present at the western side of the lake, and their water yield is declining due to forest degradation;
- It is recommended to maintain the outer UNESCO MAB boundary, as this was proposed by Forest Department and approved by the Shan State government;
- Ongoing activities related to PA management are e.g. ESS, socio-economic and fish surveys, are executed in parallel to the current assignment so no results are available yet;
- Overall, the Park Warden points out the importance of having one clear MAB map with zone demarcations for implementing conservation and management activities.

[1] https://www.facebook.com/jica.myanmar.fdsnr.iliwm/

SERVIR-Mekong

- SERVIR-Mekong provides technical support to OneMap Myanmar. OMM aims to facilitate data sharing by government departments. Its portal is ready but no data are available yet, first technical training of govt depts is needed, as well as awareness raising on the importance of data sharing;
- Two regional land use/land cover (LULC) maps are available from their portal1. The main difference is in the grassland extent – currently unclear what FD wants as definition, either normal grassland (for buffalo, cow) or very tall grassland. Version 1 looks the most realistic.
- Next to the Mekong regional product, also a national Myanmar product is developed. SERVIR-Mekong is collaborating with FD on this. Contact person at FD: Dr. Mya Su Mon
- Current national land cover version (11 classes) is draft version. Classes are fixed and approved by FD, but further input / field data to validate map is still needed for approval. Validation workshop with FD to be organized around April, then official version can be released. Khun is confident that there will be no delay.
- “Primary forest” data available through the SERVIR portal is defined as status in 2000, so not really representative of primary forest. To be updated for 1985 info this year, Khun will check if it is already possible to share a draft version;
- The SERVIR approach allows for annual updates, but these are sensitive due to inconsistencies with annual land cover statistics from different depts;
- Current official data used by FD is 2015 Landsat-based data, used for reporting to FAO, but not publicly shared. These data are also not flexible like SERVIR data to make annual maps, and only have the 4 FRA classes. General comparison between SERVIR and official 2015 data: total area is similar but patterns are somewhat different;
- SERVIR uses same forest definitions as FD: closed forest >40% cc, open forest >10% cc, tree height > 5m.
- SERVIR-Mekong is interested to collaborate on the ILMA geodatabase. Khun indicates the possibility of providing training at a later stage.

[1] Details on their mapping approach are described in Potapov et al. (2019).

Annex 3: Training Description

The below text was shared with all participants along with the letter of invitation.

Training on Ecosystem Services Mapping in Inle Lake, Myanmar: 23--25 November, 2020

Authors: Gijs Simons (FutureWater) and Aung Thu Moe

Background

Background

The Inle Lake in Myanmar is renowned for a number of traditional cultural and livelihood practices, which have made it one of the main attractions for Myanmar's booming tourism industry. The lake is, however, is suffering environmental degradation due to the combined effects of unsustainable resource use, increasing population pressures, climate variability and rapid tourism development.

UNDP Myanmar with the funding support from Government of Norway, is implementing a 2-year project on Strengthening the Inle Lake Management Authority to Improve Development and Conservation. The project's main aim is to support the implementation of the Inle Lake Conservation 5-Year Action Plan (2015/16 to 2019/2020) by establishing and strengthening the Inle Lake Management Authority (ILMA), to coordinate, manage and develop the Inle Lake effectively. This will require strong leadership and coordinated efforts of all stakeholders involved – government, non-governmental organizations and local communities. As such, it is vital to strengthen the governance of Inle Lake to rally private, civil and government actors at various levels and defines various roles. It is also equally important to develop local capacities to collect and monitor the information of the lake's ecosystem and establish a baseline and central database to measure, assess and use data to support the roles of the stakeholders.

One of the objectives of the on-going project is to support the capacity building of the key government staff on ecosystem services mapping.

Training objectives and modalities

After the training, the participants should:

- Understand the importance of ecosystem services mapping, and the underlying concepts;
- Be proficient in mapping ecosystem services based on various satellite-derived products, GIS data, and the Sediment Delivery Ratio and Water Yield modules of InVEST;
- Be able to use GIS software to interpret the resulting maps and use them to delineate geographic zones to be used in policy-making.

To comply with limitations in place due to the Covid-19 global pandemic, a remote training will be organized. The training will be implemented using Zoom software and can be accessed through the following link: **https://zoom.us/j/7824420449**. This can be used from your browser or by installing the dedicated desktop app. The training will consist of plenary sessions and presentations organized via Zoom, and independent hands-on working on the exercises in the training tutorial.

Training schedule

All times listed below are in Myanmar Time.

Table A 2. Training schedule

Day	Time	Topic
23-Nov	1:30 PM	Opening
	1:45 PM	Introduction of participants and trainer
	2:00 PM	Presentation: Introduction to Ecosystem Services & ES mapping of Inle Lake
	3:00 PM	Break
	3:15 PM	Exploring datasets in QGIS
	3:30 PM	Introduction to tutorial
	3:45 PM	Working on first exercises
	4:30 PM	Discussion of first exercises
24-Nov	9:00 AM	Independent working on exercises from tutorial
	1:30 PM	Discussion of exercises
	2:00 PM	Presentation: Introduction to InVEST model
	2:30 PM	Demonstration of InVESTt model
	3:00 PM	Break
	3:15 PM	Working on exercises
	4:30 PM	Discussion of exercises
25-Nov	9:00 AM	Independent working on exercises from tutorial
	1:30 PM	Presentation: Integrating new data and MAB zonation processes
	2:15 PM	Working on exercises
	3:00 PM	Break
	3:15 PM	Discussion of exercises and demonstration of any open / difficult issues
	4:30 PM	Evaluation and closing

Requirements from participants

- All participants should have a background in GIS and at least a basic understanding of environmental analyses;
- Working internet connection sufficient for video calls;
- Personal laptop / PC with InVEST and QGIS installed. Installation files for QGIS (if not already on your pc) and InVEST software can be downloaded from the Software folder in the training Dropbox: **https://tinyurl.com/y4ks2f4v**;
- **All data in the Data folder on Dropbox need to be downloaded to your PC**!

Annex 4: Overview of participants

Table A 3. List of participants.

No.	Name	Organization	Location
1	Daw Kaung Su Theim,	GAD	Nyaung Shwe
2	U Hlaing Aye Win	FD	Taung gyi
3	U Khun Ai Yee	FD	Hsihseng
4	U Kyaw Lin Htet	ECD	Shan
5	U Min Thiha Aung	ECD	Shan
6	U Myo Thant Zin	FD	Naung Shwe
7	U Nyi Nyi Htet	GAD	Naung Shwe
8	U San Win	FD	Pekon
9	U Soe Lwin Moe	FD	Kalaw
10	U Soe Naing Aye	NWCD	Nyaung Shwe
11	U Thein Than Oo	FD	Nyaung Shwe
12	U Yar Zar Lay Naung	NWCD	Nyaung Shwe
13	U Zaw Naing Win	DALM	Nyaung Shwe
14	U Tun Oo	Irrigation	Nyaung Shwe

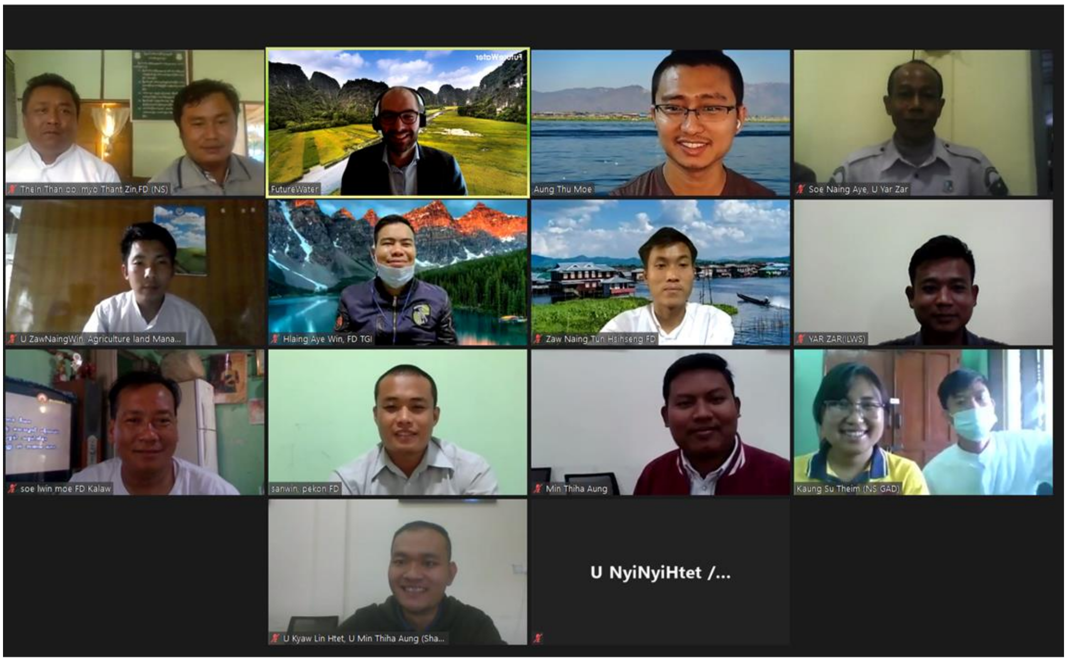

Figure A 3. Group photo taken at closure of the training.