# Evaluating ecosystem services in primary linkage 1 of the central forest spine in Peninsular Malaysia using InVEST: preliminary results

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The Improving Connectivity of the Central Forest Spine Project (IC-CFS) under the United Nations of Development Programme (UNDP) funded by the Global Environment Facility (GEF) and the Malaysian Government (GOM) is aimed at increasing capacity at the Federal and State level to execute the CFS Master Plan. The study areas involved three linkage sites in Johor, Pahang and Perak. One of the activities require GIS-based ecosystem services valuation tools to be introduced for valuation of ecosystem services in the targeted forest landscapes. The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) tools developed by the Natural Capital Project were chosen to be tested on the selected project sites particularly using 5 models, i.e. Carbon, Water Yield, Habitat Quality, Sediment Delivery Ratio and Recreation. Several of the models were used to determine ecosystem services and trade-offs between current land use pattern and land use options based on conservation scenarios for the study sites. This paper presents the preliminary outputs derived from each model using Primary Linkage 1 in Sungai Yu Pahang as the study site and discuss the potential of these tools in present and future usage in supporting protection and conservation efforts in CFS and other forestry landscapes of Peninsular Malaysia, not only bring benefits to wildlife protection and conservation, but to the surrounding commutes indirectly.

## 1. Introduction

The National Physical Plan identified forest fragmentation as a major threat to the conservation and maintenance of biodiversity and recognizes that conserving forest lands would be integral to optimize the use of land in the country [1]. It also acknowledged the multifunctional role of the forest land to be enhanced through the recognition of the Central Forest Spine programme in creating linkages and corridors to the more isolated reserves. Connecting these fragmented forests is important to secure mutual co-existence and benefit for development and conservation. The Central Forest Spine (CFS) is defined as the backbone of Peninsular Malaysia's Environmentally Sensitive Area (ESA) network, comprises of four major forest complexes (i.e. [i] Banjaran Titiwangsa-Banjaran Bintang-Banjaran Nakawan, [ii] Taman Negara-Banjaran Timur, [iii] South East Pahang, Chini dan Bera Wetlands, and [iv] Endau Rompin Park-Kluang Wildlife Reserves).

The Malaysian Government developed the CFS Master Plan (CFSMP) to re-establish, maintain or restore connectivity within the 37 linkages [2] identified consisting of 17 Primary Linkages (PL) and 20 Secondary Linkages (SL) [3]. The Improving Connectivity in the Central Forest Spine Project (IC-CFS) is a 7 years project (2014-2020) under the UNDP/GEF/GOM initiative to complement the

existing CFS project implemented under the 10th and 11th Malaysian Plan aiming to increase federal and state level capacity in executing the CFSMP through the implementation of sustainable forest landscape management plans in three pilot sites of the proposed linkages. The IC-CFS among other, targets strengthening the Federal and State government's institutional capacity in enhancing CFS connectivity and law enforcement plus setting up sustainable financing mechanisms for CFS conservation to mainstream biodiversity into development plans. Outputs specified in the implementation plan of the IC-CFS project included the introduction of ICT-based ecosystem service valuation tools for valuing ecosystem services in target forest landscapes, with models for determining trade-offs between land use options based on the values of ecosystem services and other land uses [4].
The IC-CFS Project introduced the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST), an open source software tool developed by the Natural Capital Project (NatCap) that models ecosystem services on the basis of biophysical and economic 'production functions' as the potential ICT tool to be tested in the pilot sites. InVEST is designed to help local, regional and national decision-makers incorporate ecosystem services into a range of policy and planning contexts for terrestrial, freshwater and marine ecosystems, including spatial planning, strategic environmental assessments and environmental impact assessments [5]. InVEST models are spatially-explicit, using maps as information sources and producing maps as outputs. InVEST returns results in either biophysical or economic terms.

In 2011, WWF and their partners carried out a climate, ecosystem and economic assessment in the Heart of Borneo Initiative (HoB) using several modeling tools, including InVEST [6]. They analyzed annual water supply from three main river basins, map several ecosystem services including erosion control, water yield, and water purification through nutrient retention of the HoB. They found that improved timber management (by Reduced Impact Logging (RIL)) could increase sediment retention in a particular river basin. NatCap and partners devised some planning options with the input of InVEST models that produced higher carbon stocks, reduced sedimentation, cleaner water and greatly enhanced habitat quality, while also providing land for forestry and oil palm production in Sumatra bringing interest to one local corporation to promote comprehensive ecosystem service assessments as a way to direct revenue in forest investments in reducing greenhouse gas emissions [7]. InVEST was also used to evaluate habitat connectivity and assess the target segment of roads that cross the modelled corridor of the RIMBA corridor landscape in Central Sumatra . This study aims to evaluate ecosystem services in target forest landscape. InVEST was used as a tool for valuation. Five models in InVEST, namely as Carbon, Water Yield, Sediment Delivery Ratio (SDR), habitat quality and recreation, were used in this study. The valuation was made for three PL sites, however results and analysis of PL1 site were presented and discussed in this paper.

## 2. Methodology
The study was performed in 3 stages ; (i) spatial and non-spatial data preparation, (ii) data processing using 5 InVEST models of Carbon, Water Yield, Habitat Quality, Sediment Delivery Ratio and Recreation, and (iii) analysis of outputs.

### *2.1 Study Site*

The Primary Linkage 1 (PL1) of the CFS is located in the district of Kuala Lipis, Pahang at 4° 31' 56"N latitude and 101° 59' 31"E longitude (Figure 1**)**. It covers an area of about 4,345 ha comprising parts of the Ulu Jelai and Sg.Yu Forest Reserves in the west and Tanum Forest Reserve in the east where the forests are disconnected by the Kuala Lipis – Gua Musang trunk road and railway as shown in the Figure 1**.** Prior to the CFSMP, this site has been identified as a priority corridor for tigers in the National Tiger Conservation Action Plan (NTCAP) for Malaysia [8]. 3 viaducts were constructed along the road in order to allow wildlife movement. However this study embraced the larger watershed area which encompassed PL1 to enable significance in results especially during the different scenario analysis.

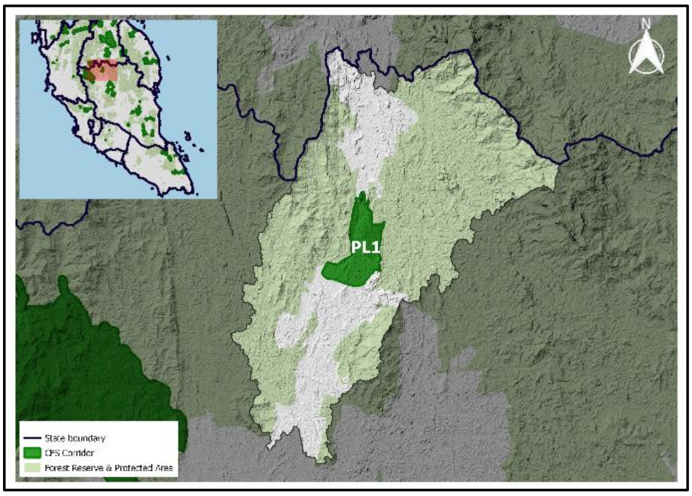


**Figure 1.** Study site (Watershed and PL1)

*2.2 Data preparation*

Data were collected from several sources conferring to the different data input requirements for the 5 InVEST models. Data inserted were prepared according to specified formats. All spatial data were projected to Universal Transverse Mercator (UTM) to suit InVEST's projection. The watershed area limits covering the study site was derived using the Digital Elevation Model (DEM) data generated from the Soil and Water Assessment Tool (SWAT) software. All spatial data used for input for the 5 InVEST models were prepared based on this watershed boundary. However, the DEM data was extended to a 1 kilometer buffer of the watershed boundary to cater for the Sediment and Delivery Ratio (SDR) model processing. In this study, the landuse/landcover (LULC) data was utilized for 4 of the 5 InVEST models. LULC spatial data for the year 2010 (obtained from the Department of Agriculture(DOA)) and Land zoning spatial data for the year 2020 ( provided by the Federal Department of Town and Country Planning (FDTCP)) were applied to portray the present and future landuse scenarios. The Forested area category of the data were further re-classified according to the forest strata of the 5$^{th}$ National Forest Inventory (NFI5). Each strata produced different impacts on the carbon, water yield and SDR results. Unique numbers were assigned to each LULC class and were then converted into raster format using Quantum GIS (QGIS) software.

Carbon pools value containing the estimated values of carbon density (for above-ground, below-ground, soil and dead organic matter) of each landuse class were created based on past studies [9] and were applied in the Carbon model to produce the total carbon estimates of each LULC class. Meanwhile, the Water Yield model required annual precipitation, reference evapotranspiration, average root restricting layer depth and plant available water content maps of the study site.. A biophysical table containing values of maximum root depth and plant evapotranspiration coefficient for vegetated LULC class is also a pre-requisite. Rainfall erosivity and soil erodibility maps of the study site were prepared for the use in the SDR model along with the LULC, DEM and watershed data. Rainfall erosivity values were derived from studies by Morgan (1974) [10] and Roose (1977) [11] while soil erodibility values were obtained from DOA. A biophysical table containing information on cover management factor (C) and support practice factor (P) was also obtained from the same agency. As for the Habitat Quality Model, main threats to big mammals especially tiger and elephant were identified and mapped. The Recreation model only requires the polygon boundary limits of the study site for processing.

*2.3 Data processing*

InVEST version 3.3.3 was used to evaluate the 5 ecosystem services (carbon, water yield, SDR, habitat quality and recreation) of the watershed area of the study site. The Carbon model input spatial data of LULC and carbon stocks in 4 carbon pools to estimate (i) the amount of carbon currently stored in the study site and (ii) the amount of carbon sequestered over a given time period [12]. The monetary value of the Carbon ecosystem service to society is then estimated using data on the market or social value of sequestered carbon, its annual rate of change and a discount rate. The Water Yield model identifies the amount of water yield contributed by each LULC class. The model has 3 evaluation functions i.e. water yield, water consumption and hydropower production that enable estimates of the annual average quantity of hydropower yielded from reservoirs. The 2 latter functions were not tested during this study.

The SDR model maps the overland sediment generation and its delivery to the stream. This model basically used the Universal Soil Loss Equation (USLE) [11] where the total amount of sediment exported to the stream are estimated. The Habitat Quality model was used to produce habitat quality maps that show the most suitable to the least suitable areas for tiger and elephant presence within the watershed. Modeling habitat quality alongside ecosystem services enables users to compare spatial patterns and identify areas where conservation will most benefit natural systems and protect threatened species [13]. The Recreation model uses geocoded photograph database extracted from Flickr.com website to map popular spots of attraction within the area of interest based on the frequency of photographs taken and published by visitors at particular spots. Future scenario analysis using 2020 LULC zoning data from FDTCP was done to see the impacts to the 4 ecosystem services (excluding recreation) by assessing changes of LULC compared to the present scenario (2010).

## 3. Results & Discussions

*3.1 Landuse Change*

PL1 covers about 0.04% of the total area of the watershed area of 109,963 ha delineated from the DEM data for the 5 InVEST model outputs generation. The watershed area of PL1 has 20 LULC classes.The forest class was reclassified (through overlay analysis with the NFI5 data) into 8 forest strata. The forest covers about 83% of the watershed area in 2010 and will decrease to about 80.5% in 2020 as shown in Figure 2**.** The 2.5% deforestation within the watershed is expected to occur through oil palm plantation conversion, which will also affect about 225 ha (5%) of PL1. However, the loss in forest land may be compensated by maintaining and enhancing the quality of the remaining forest (forest reserves and non-forest reserves) through appropriate silvicultural treatment and protection.

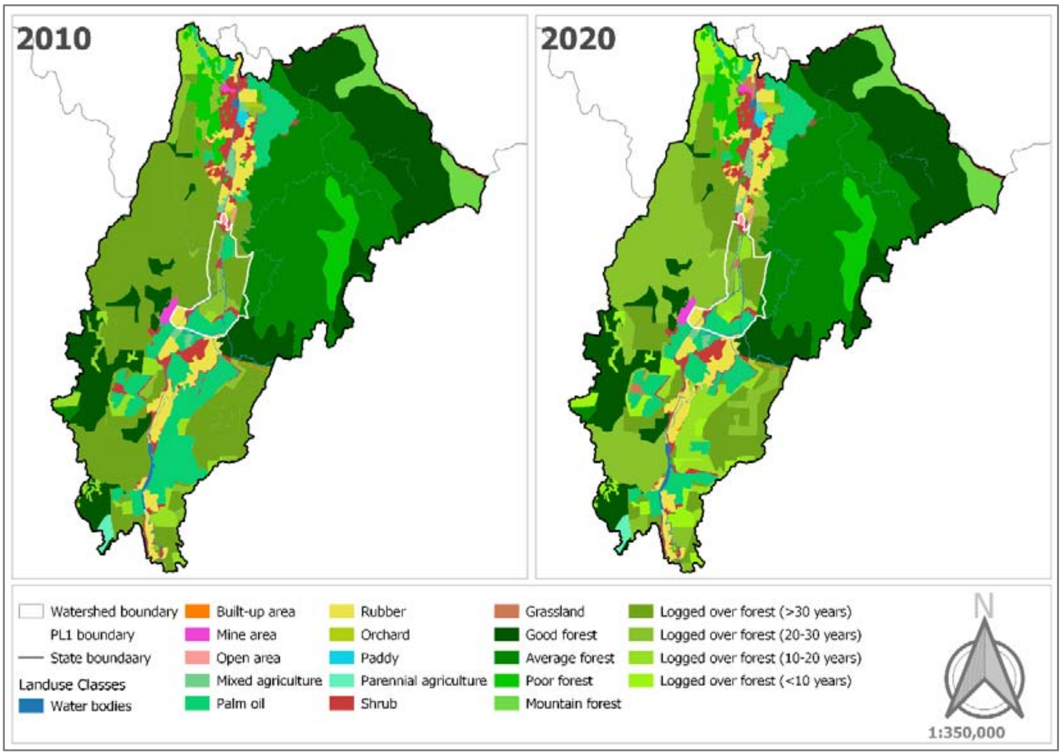


**Figure 2.** PL1 landuse in year 2010 versus 2020

*3.2 Carbon Change*
At watershed level of PL1 (see Figure 3), a total of about 32,608,628 Mg of carbon is potentially stocked in 2010. If the planned l LULC zoning is realized in 2020, the total carbon stored will increase by only about 38,737 Mg(0.001%) to 32,647,365 Mg. In contrast, the total carbon in PL1 is expected to slightly decrease from 1,078,042 Mg to 1,050,823 Mg ( 0.025%) as the stocking capacity of the standing forest at different stratum of growth is still insufficient to compensate the 5% conversion of forest to oil palm plantation in 2020. The carbon sequestration role of forest in reducing emission that contributes to climate change is recognized by Malaysia [14]. However, the carbon trading process is still in the early stages of implementation with steps taken gradually to harmonize state and Federal policies on forest, carbon and climate change; aligning forest carbon inventories accounting, intensify capacity building and acquire the appropriate funding [15].

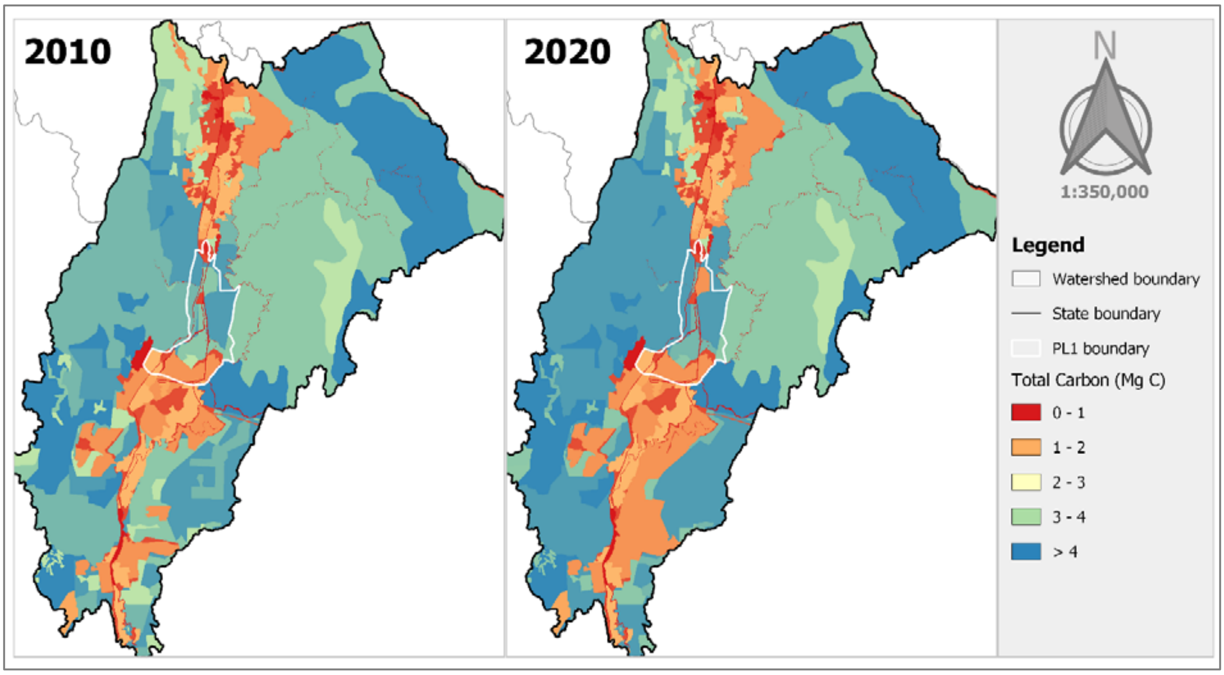


**Figure 3**. Carbon maps of PL1 site for year 2010 and 2020

*3.3 Water yield and SDR changes*
The ecosystem services evaluation in relation to water yield and SDR from the watershed area are projected to exhibit positive increment in 2020. Water yield volume is expected to gain by about 259,166 $m^3$ from 2,197,426,518 $m^3$ in 2010 to 2,197,685,685 $m^3$ in 2020 at the watershed level (see Figure 4). The water yield volume is also expected to increase by 718,814 $m^3$ from 869,165,812 $m^3$ in 2010 to 869,783,996 $m^3$ in the PL1 corridor after 10 years. The planned LULC zoning of 2020 of the watershed will reduce the sediment exported to the stream by 35% from 340,669 Mg to 220,557 Mg (see Figure 5). However, only about 3.9% reduction of sediment exported to the stream is estimated in the PL1 corridor due to the conversion of a portion of the forest to oil palm plantation. The total sediment exported to the stream for year 2010 and 2020 for PL1 is about 8,428 Mg and 8,100 Mg respectively. The sediment retention capability is enhanced over time when the trees matured and the soil are stabilized after the conversion activity ceased.

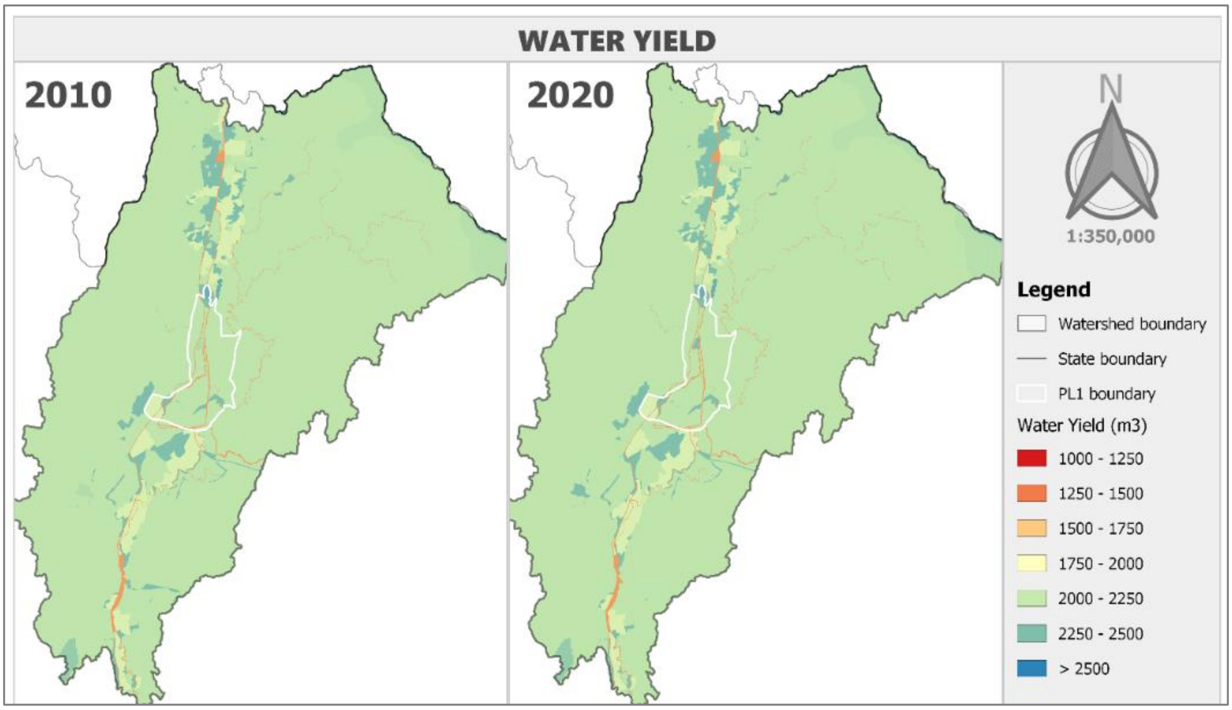


**Figure 4.** Water yield maps of PL1 site for year 2010 and 2020

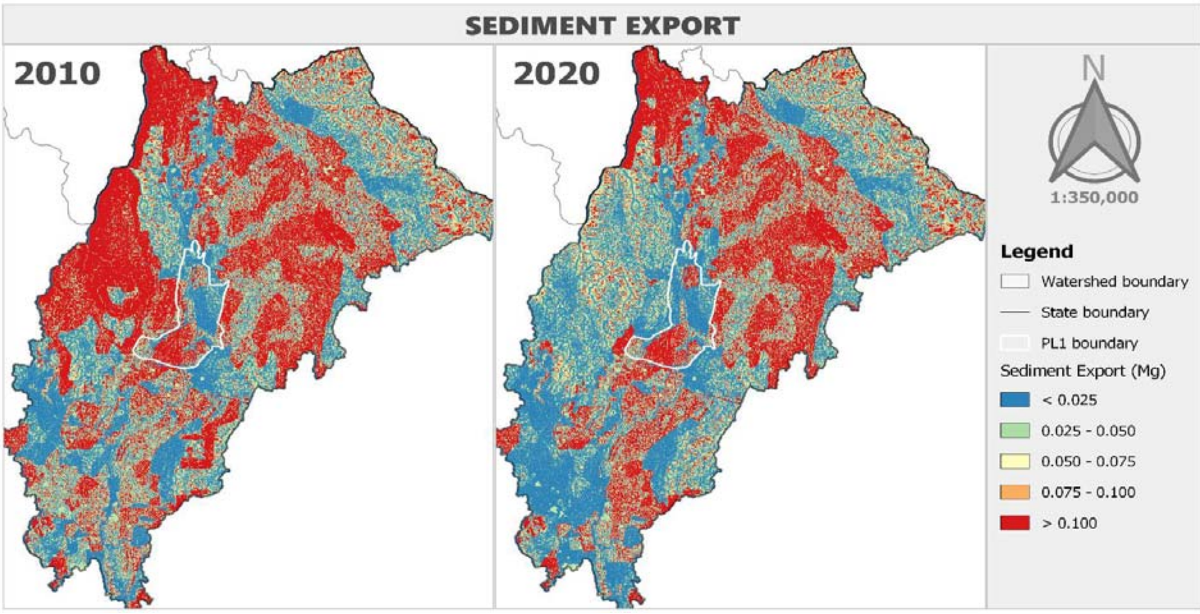


**Figure 5**. Sediment export maps of PL1 site for year 2010 and 2020

*3.4 Habitat quality change*

The habitat quality index at the watershed level averaged favorably at 0.90 for the year 2010. However the index is expected to decline in year 2020 by 0.01 to 0.89. As for the PL1 corridor, the average habitat quality index was 0.80 in year 2010 and is expected to decrease to 0.76 in the year 2020 obviously due to the intended forest to oil palm plantation conversion as displayed in Figure 6.

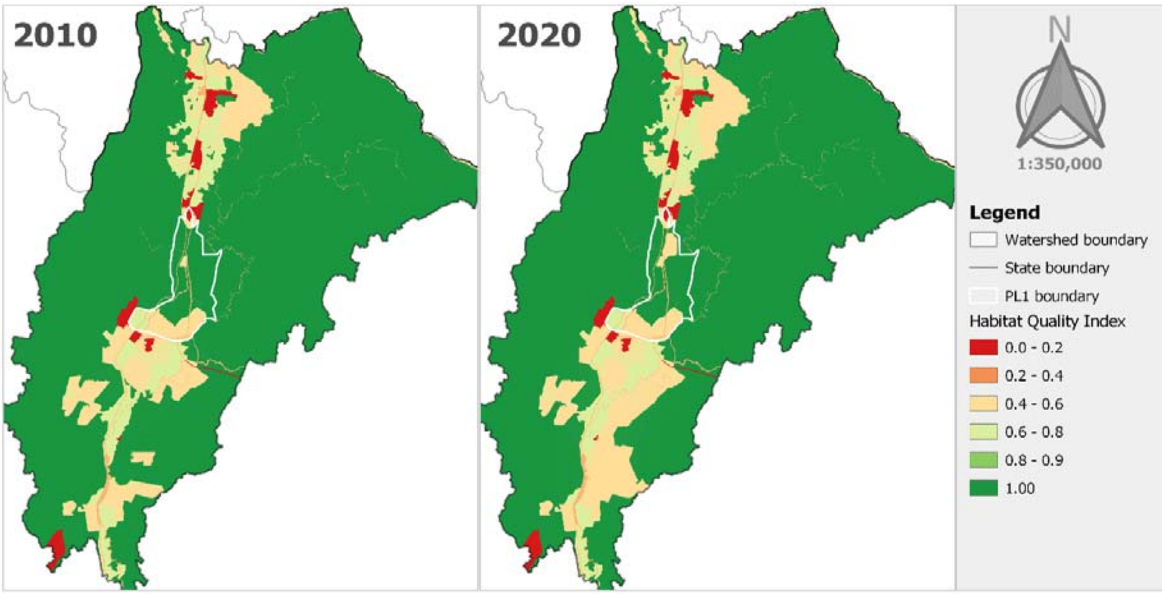


**Figure 6.** Habitat quality index maps of PL1 site for year 2010 and 2020

*3.5 Recreation potential*

The watershed area includes the existing Sungai Yu Recreation Forest within the Sungai Yu Forest Reserve. However the InVEST recreation model predicts the spread of person-days of recreation, based on the locations of natural habitats and other features that factor into people's decisions about where to recreate based on geotagged photographs posted to the Flickr website between 2005 to 2014. The frequency of photos taken per day at popular spots in PL1 enable relevant local authorities to utilize the information to identify the best spot to develop for recreational purposes. The different spots produced in Figure 7 based on the frequency of photographs taken displayed a scattered distribution pattern with the Sungai Yu Recreation Forest included as one of the popular spot (right hand side of Figure 7). The accuracy of the information can be enhanced through use of actual records of visitor entry from FDPM and through inclusion of geocoded photographs from other social media sources such as Instagram and Facebook.

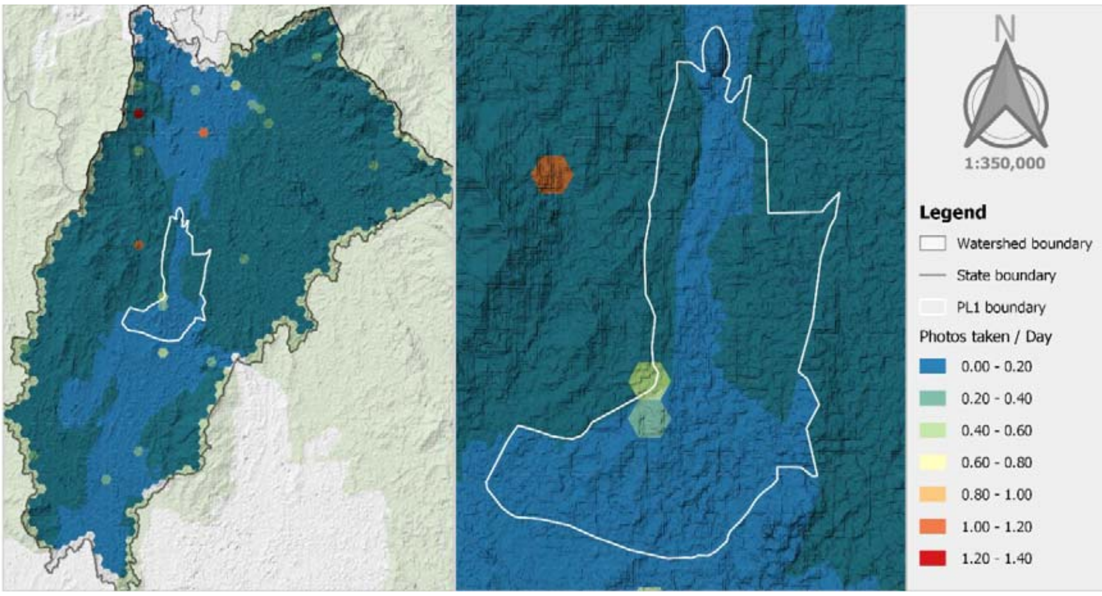


**Figure 7.** Recreation map of PL1 site

Using InVEST models as tool to evaluate ecosystem services in forest (including the Central Forest Spine linkages) which comprises areas planned for non-forest use conversion, will enable decision makers to analyze and re-assess their earlier choice, to go for those that provide the most optimum benefits in the long term. InVEST models of carbon, water yield, SDR and habitat quality provide relevant platforms to perform 'business as usual' scenario versus scientific and multi-stakeholder consultation planned scenario for comparison analysis in a better map visualization manner. LULC data can be further categorized into finer classes through implementing large scale mapping where classes such as oil palm plantation are classified according to age or quality with different values given permitting improved accuracy of the results.

The monetary pricing of the ecosystem services may be added up to the outputs to show the real economic value of the services such as in the case of the about 7.5 ha of Bukit Sungai Puteh Forest Reserve conversion to the Sungai Besi-Ulu Kelang Elevated Highway (SUKE) valuing 22 ecosystem services at RM19.2 million per hectare[16] but using the Economics of Ecosystems and Biodiversity (TEEB) method. InVEST models have high potential for application towards ecosystem services evaluation as it is practical where the map outputs make stakeholders and decision makers easier to visualize and understand the necessity and benefits of forest conservation and protection for the whole landscape and will encourage the pursuant for the development of payment for ecosystem services in the near future. The models can be perfected through future trial and application in other forest areas planned for development and customization through collaboration with NatCap to suit local needs.

## 4. Conclusion

The valuation of ecosystem services at PL1 has been done in this study. Four InVEST's models, which are carbon, water yield, SDR and habitat quality, have been used to evaluate the services by comparing current and future land uses. Total carbon was decreases based on the scenario tested in this study. However, water yield and sedimen export were improved and the average habitat quality index is decrease from 0.8 to 0.76. Recreation model was used to identify for ecotourism purpose. This study has shown that ecosystem services can be estimated and InVEST can be one of the tool to achieve it. Further study need to be done especially on the accuracy and reliability of the results by comparing with in situ data.

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