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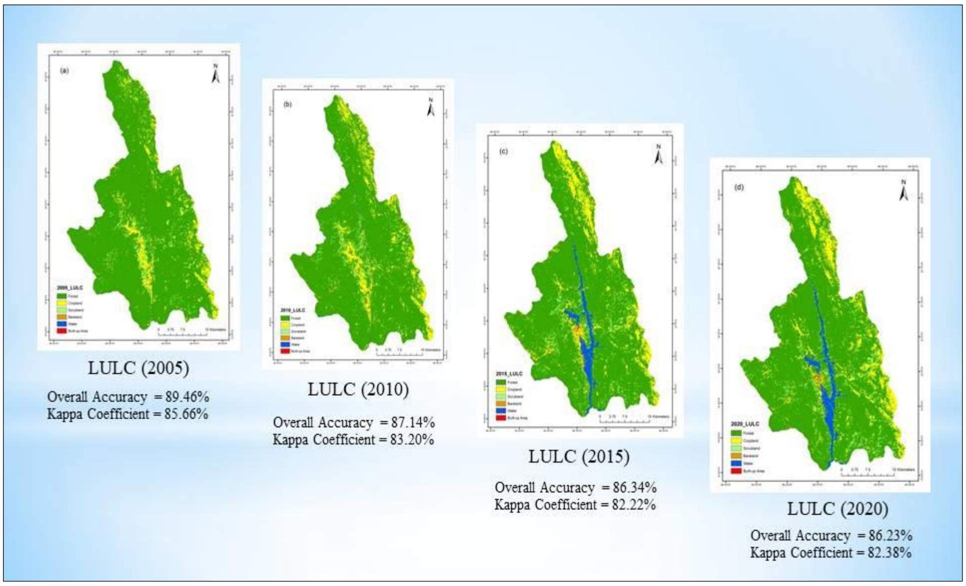
Evaluating Changes of Ecosystem Services regarding to LULC Changes in Paung Laung Reserved Forest, Myanmar



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Evaluating Changes of Ecosystem Services regarding to LULC Changes in Paung Laung Reserved Forest, Myanmar

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Abstract

Ecosystem provides various services for human beings as well as for all living creatures. Nowadays, humans utilize the land in different land forms for their livelihoods, contributing to land use and land cover (LULC) changes. Consequently, LULC dynamics can degrade many ecosystems and have significant impacts on ecosystem services. LULC changes mainly due to deforestation, forest degradation and dam construction have been observed in Paung Laung Reserved Forest. However, estimating ecosystem services changes regarding to LULC changes have not been conducted in the reserved forest. Thus, based on the LULC data for the years of 2005, 2010, 2015 and 2020 using remote sensing techniques and the valuation coefficients for individual LULC classes using the benefit transfer method, evaluating changes of ecosystem services in relation to LULC changes were conducted in Paung Laung Reserved Forest for four different periods. It was significantly observed that there was a continuous decline in forest cover during 2005-2020, but a huge increase in water bodies in 2015 because of the dam. Moreover, there was also a decline in total ecosystem services values (ESV) in 2005-2010 and 2015-2020, and an increase in 2010-2015 due to a large area of water bodies in Paung Laung Reserved Forest, accounting for 917.89 million USD yr^{-1} in 2005, 909.59 million USD yr^{-1} in 2010, 952.68 million USD yr^{-1} in 2015 and 952.07 million USD yr^{-1} in 2020, respectively. The ESV of water-related ecosystem services increased after the dam construction, and food production services also increased because of agricultural expansion. Moreover, the ESV of some ecosystem services provided by forest ecosystem decreased from 2005 to 2020 due to a continuous decline in forest loss. Climate regulation, genetic resources and recreation, which were mainly linked with forest ecosystem and had a continuous loss, were important ecosystem services in the reserved forest, accounting for 77.14% of the total ESV in 2005, 75.50% in 2010, 70.20% in 2015 and 69.94% in 2020, respectively. The study can provide updated scientific data and information of ecosystem services in Paung Laung Reserved Forest, Myanmar, for policymakers, environmentalists, conservationists and land resource managers in the decision-making process of sustainable ecosystem management and forest management.

Keywords: Ecosystem services valuation, Land use and land cover change, Deforestation, Paung Laung, Remote sensing.

ပေါင်းလောင်းကြိုးဝိုင်းအတွင်း မြေအသုံးချမှုပြောင်းလဲခြင်းကြောင့် ဂေဟာစနစ်ဝန်ဆောင်မှု တန်ဖိုးများ ပြောင်းလဲခြင်းအား ဆန်းစစ်လေ့လာခြင်း

နေအောင်၊ ဦးစီးအရာရှိ
သစ်တောဦးစီးဌာန

စာတမ်းအကျဉ်း

ဂေဟာစနစ်သည် လူသားနှင့်သက်ရှိသတ္တဝါများ အားလုံးအတွက် ဂေဟာစနစ် ဝန်ဆောင်မှု အမျိုးမျိုးကို ထောက်ပံ့ပေးလျက် ရှိပါသည်။ ယနေ့ခေတ်တွင် လူသားတို့သည် အသက်ရှင် ရပ်တည်ရေးအတွက် မြေကို နည်းလမ်းအမျိုးမျိုးဖြင့် အသုံးချလျက်ရှိပြီး မြေအသုံးချမှု ပြောင်းလဲခြင်းများစွာ ဖြစ်ပေါ်လျက် ရှိပါသည်။ ဤကဲ့သို့ မြေအသုံးချမှု ပြောင်းလဲခြင်းများသည် ဂေဟာစနစ်များနှင့်၎င်းတို့၏ဝန်ဆောင်မှုများကို ထိခိုက်ပျက်စီးစေပါသည်။ ပေါင်းလောင်း ကြိုးဝိုင်းတွင်လည်း သစ်တောပြုန်းတီးခြင်း၊ သစ်တောအတန်းအစား ကျဆင်းခြင်းနှင့် ဆည်တည်ဆောက်ခြင်းတို့ကြောင့် မြေအသုံးချမှုများစွာ ဖြစ်ပေါ်ပြောင်းလဲလျက်ရှိပါသည်။ သို့သော်လည်း ၎င်းကြိုးဝိုင်းအတွင်း မြေအသုံးချမှု ပြောင်းလဲခြင်းကြောင့် ဂေဟာစနစ် ဝန်ဆောင်မှု တန်ဖိုးများ ပြောင်းလဲသွားခြင်းအား သုတေသနပြု လေ့လာထားခြင်း မရှိသေးပေ။ ထို့ကြောင့် ပေါင်းလောင်းကြိုးဝိုင်းအတွင်း ၂၀၀၅ ၊ ၂၀၁၀၊ ၂၀၁၅ နှင့် ၂၀၂၀ ခုနှစ်များတွင် မြေအသုံးချမှု ပြောင်းလဲကြောင့် ပြောင်းလဲသွားသော ဂေဟာစနစ်ဝန်ဆောင်မှုများအား Remote Sensing နည်းပညာနှင့် ဂေဟာစနစ်အလိုက် သတ်မှတ်ထားသည့် ဂေဟာစနစ် ဝန်ဆောင်မှုတန်ဖိုးများကို အသုံးပြု၍ ဂေဟာစနစ်ဝန်ဆောင်မှုတန်ဖိုးပြောင်းလဲခြင်းအား ဆန်းစစ်လေ့လာခဲ့ပါသည်။ သုတေသနပြုဆောင်ရွက်သည့် အချိန်ကာလအတွင်း သစ်တော ဧရိယာများ စဉ်ဆက်မပြတ် လျော့နည်းလာပြီး ၂၀၁၅ ခုနှစ်တွင် ရေပြင်ဧရိယာပို၍ များပြား လာသည်ကို တွေ့ရှိရပါသည်။ ၂၀၁၀-၂၀၁၅ ခုနှစ်အတွင်း ဆည်တည်ဆောက်မှုကြောင့် ရေပြင်ဧရိယာပိုများလာပြီး ဝန်ဆောင်မှုတန်ဖိုး အနည်းငယ် မြင့်တက်လာခဲ့သော်လည်း ၂၀၀၅-၂၀၁၀ ခုနှစ်နှင့် ၂၀၁၅-၂၀၂၀ ခုနှစ်များအတွင်း ပေါင်းလောင်းကြိုးဝိုင်းမှ ထောက်ပံ့ ပေးသည့် ဂေဟာစနစ်များ၏ ဝန်ဆောင်မှုတန်ဖိုးသည် လျော့ကျသွားကြောင်း တွေ့ရှိရပါသည်။ ဆည်တည်ဆောက်မှုနှင့် စိုက်ပျိုးမြေ ချဲ့ထွင်လာမှုတို့ကြောင့် ရေနှင့်ပတ်သက်သည့် ဝန်ဆောင်မှုနှင့် အစားအစာ ထုတ်လုပ်မှု ဝန်ဆောင်မှုတန်ဖိုးများ ပိုများလာသည်ကို တွေ့ရှိရ ပါသည်။ ထို့ပြင် သစ်တော ပြုန်းတီးမှုနှင့် တောအတန်းအစား ကျဆင်းလာမှုကြောင့် သစ်တော များမှ ထောက်ပံ့ပေးသည့် ဝန်ဆောင်မှုတန်ဖိုးများလည်း တောက်လျှောက် လျော့ကျလာ သည်ကို တွေ့ရှိရပါသည်။ ပေါင်းလောင်းကြိုးဝိုင်းတွင် သစ်တောဂေဟာစနစ်သည် အဓိက ထောက်ပံ့ပေးသည့် ဂေဟာစနစ်တစ်ခု ဖြစ်သောကြောင့် ရာသီဥတု ထိန်းညှိပေးခြင်း၊ မျိုးရိုးဗီဇ အရင်းအမြစ်နှင့် အပန်းဖြေမှု စသည့်ဝန်ဆောင်မှုများသည် သစ်တောဧရိယာများ လျော့နည်းလာမှုကြောင့် လျော့နည်းသွားသည်ကို မြင်တွေ့ရပါသည်။ ဤသုတေသန

တွေ့ရှိချက်များသည် စဉ်ဆက်မပြတ် သစ်တောစီမံအုပ်ချုပ်ရေးနှင့် ဂေဟာစနစ်များ ရေရှည်တည်တံ့စေရေး ဆောင်ရွက်ရာတွင် သဘာဝပတ်ဝန်းကျင်ထိန်းသိမ်းသူများ၊ မြေယာစီမံခန့်ခွဲသူများနှင့် မူဝါဒဆုံးဖြတ်ချမှတ်သူများအတွက် ပေါင်းလောင်းကြိုးဝိုင်း၏ အရေးကြီးသောသတင်းအချက်အလက်များနှင့် ကိန်းဂဏန်းအချက် အလက်များကို ထောက်ပံ့ပေးနိုင်ပါသည်။

Evaluating Changes of Ecosystem Services regarding to LULC Changes in Paung Laung Reserved Forest, Myanmar

1. Introduction

1.1 Background

Ecosystem services are the ecological characteristics, functions, or processes that directly or indirectly contribute to human well-being: the benefits that people derive from functioning ecosystems (Costanza et al., 1997, 2017; Millennium Ecosystem, 2005). These ecosystem services which directly or indirectly affect human beings can be categorized into four main ecosystem services; provisioning, regulating, supporting, and cultural services (Costanza et al., 2017; D. De Groot & Wang, 2010; Millennium Ecosystem, 2005). In 1997, Costanza et al. (Costanza et al., 1997) classified into 17 ecosystem services under four main categories of ecosystem services (Table 1) and developed their valuation coefficients for evaluating changes in ecosystem services values (ESV).

Table 1 Types of ecosystem services developed by Costanza et al. (Costanza et al., 1997)

Provisioning Services	**Regulating Services**	**Supporting Services**	**Cultural Services**
Food production	Gas regulation	Erosion Control	Recreation
Raw materials	Climate regulation	Soil formation	Cultural
	Disturbance regulation	Nutrient cycling	
	Water regulation	Pollination	
	Water supply	Biological Control	
	Waste treatment	Habitat/ refugia	
		Genetic resources	

Forest is the most terrestrial ecosystem on the earth, and it provides a variety of ecosystem services (G. Xie et al., 2010). It produces oxygen in photosynthesis and converts carbon dioxide into oxygen and biomass. Forest plays a critical role in the global carbon cycle because it serves as carbon sinks of the terrestrial ecosystem (Vashum & Jayakumar, 2012). Forested watersheds capture and store water, contributing to water supply and purifying water by stabilizing soils and filtering contaminants (Krieger, 2001). In addition to water regulation, the forest provides pollination services and food, timber, water for irrigation, and non-timber forest products (Maass et al., 2005). It also offers several regulating services such as protecting natural disasters (flood, storm, etc.) and reducing the risk of natural disasters (Martin & Watson, 2016). Moreover, forests serve recreational areas, contributing a wide range of benefits to human society and providing rural tourism and economic development (Martin & Watson, 2016).

Land use and land cover (LULC) changes are regarded as one of the main causes of ecosystem services degradation (Rahman & Szabó, 2021). There are many drivers of LULC change. Deforestation and urbanization have often been the primary sources of LULC changes in the past decades (Mea, 2005). In other words, it has often occurred that LULC changes were the most in the forested area than other land covers, except urbanization. According to the global forest resources assessment (2020), forests cover nearly one-third of the total land area of the world, which occupied 4.06 billion ha with 31% of the world's total land area. Among these areas, the most significant proportion of the world's forests (45%) is occurred in the tropical forests, followed by the boreal, temperate and subtropical forests, respectively (FAO, 2020). However, the world's forest area is still decreasing, and it is estimated that the annual rate of deforestation ranges from 10 to 12 million ha in 2010-2015 (FAO, 2020).

The increasing rate of loss of tropical forests in the tropics has a significant impact on ecosystem services and a wide range of ecosystem service loss in the region (Gashaw et al., 2018). On the other hand, forest ecosystems play an essential role in maintaining the Earth's ecological balance (Şen & Güngör, 2018). However, the importance of ecosystem services in forested areas is poorly recognized in developing countries (Bhandari et al., 2018). Regarding LULC changes, evaluating changes in ecosystem services in forests of all parts of the world is essential for ecosystem conservation. For this reason, assessing changes in ecosystem services due to LULC changes has been paid special attention in recent years.

Most studies have emphasized that in most countries with high income, fewer countries with low and lower middle income (Acharya et al., 2019). On the other hand, Myanmar was a developing country with the third-highest rate of deforestation in the world from 2010 to 2015 (FRA, 2015), occurring LULC change in the forest land. Thus, this study was conducted in a reserved forest with high deforestation and in the country with low income to satisfy the information gap. The study's main objective is to evaluate changes in ESV regarding LULC changes over time.

1.2 Significance for studying ecosystem services in Myanmar

Myanmar is one of the countries in Southeast Asia, which has a wide range of forest cover (Naing Tun et al., 2021). Like other Asian countries, Myanmar has been experiencing a significant deforestation and forest degradation rate. The country's forest cover in 2020 was about 42.19% of the total land area, decreasing from 31 million ha in 2010 and 28 million ha in 2020 (FAO, 2020). As a result, Myanmar was the third-highest rate of deforestation in the world during 2010-2015 (FRA, 2015). Although there are many proximate and underlying causes of deforestation and forest degradation in Myanmar, agricultural expansion, legal and illegal logging, fuelwood and charcoal consumption, road construction, mining, and dam construction are significant drivers of forest loss (Naing Tun et al., 2021). In other words, LULC change has significantly occurred in the country, conversion of forests into agricultural land, degraded forest land, built-up area, bareland, and water bodies.

In relation to economic development, human activities and urbanization have been significant pressure on the ecosystems in developing countries (Dugan et al., 2010; Hasan et al., 2020; Lyu et al., 2018; G. Wang et al., 2010). Our new government mainly focuses on economic development contributing to LULC change throughout the country, especially the expansion of agriculture, mining, and urbanization in the reserved forest (RF), protective public forest (PPF), and protected area systems (PAS). As a result, Myanmar was the third-highest annual net loss of forest area in the world during 2010-2020 (FAO, 2020), leading to changes in natural ecosystems and their services.

Environmentalists, conservationists, and land-use planners are worried about LULC changes due to their impacts on the natural ecosystems (Halmy et al., 2015; Tolessa et al., 2017). On the other hand, LULC dynamics is a significant cause of global change and significantly impacts ecosystem processes, biological cycles, and biodiversity (Liping et al., 2018). A systematic assessment of ecosystem services in forested areas has not yet been conducted in Myanmar, and updated information is extremely scarce (Emerton & Aung, 2013). As a result, a well-planned assessment of ecosystem services, especially in forested areas, is essential to fill the research gaps. Generally, a well-planned assessment cannot be achieved without conducting scientific research. Thus, evaluating changes in ecosystem services, especially in forested areas, is urgently needed in Myanmar.

Although very few studies on ecosystem services valuation and assessment have been conducted in Myanmar (Emerton & Aung, 2013; Jarzebski & Gasparatos, 2019; Karki et al., 2018), few studies are based on socioeconomic data and forest cover changes. Many types of researches on LULC dynamics and forest cover changes have been conducted in the country (De Alban et al., 2020; Lim et al., 2017; Naing Tun et al., 2021; P. Sharma et al., 2020; Yang et al., 2019), but the impact of LULC on ecosystem services is nearly lacking at any scale (a local, regional, and national scales). Therefore, this study will evaluate changes in ecosystem services based on LULC changes during four different periods.

1.3 Research Gaps

Although few studies on ecosystem services valuation and assessment (Emerton & Aung, 2013; Jarzebski & Gasparatos, 2019; Karki et al., 2018) have been conducted in Myanmar, few studies are based on socioeconomic data and forest cover changes. Many types of researches on LULC dynamics and forest cover changes have been conducted in the country, but the impact of LULC on ecosystem services is nearly lacking at any scale (a local, regional and national scale). Our study aims to fill the gap by evaluating changes in ecosystem services based on LULC changes during different four periods. This study used remote sensing to determine LULC dynamics and a benefit transfer method with the valuation coefficients developed by Costanza et al. (Costanza et al., 2014) to estimate ESV due to LULC change. The following research gaps were observed from the literature.

(1) The increasing rate of tropical forest loss in the tropics significantly impacts ecosystem services and a wide range of ecosystem service loss in the region (Gashaw et al., 2018). Moreover, studies on the valuation of forest ecosystem services had a significant focus on countries with high income but less on countries with low and lower middle income (Acharya et al., 2019). According to Forest Resources Assessment, 2015, Myanmar has the third-highest rate of deforestation globally, indicating an urgent need to study forest ecosystem service valuation.

(2) LULC changes significantly impact ecosystems (Hansen et al., 2020). The historical changes of LULC highlighted that Southeast Asia, including Myanmar, was the worst among Asia.

(3) It is evident that there are still many areas without any studies on integrating remote sensing into ecosystem service assessment and valuation around the world (De Araujo Barbosa et al., 2015). Myanmar is also a country among these lacking areas. Thus, it is urgently needed in the area because of the high rate of LULC changes.

(4) Currently, Myanmar has very few studies on ecosystem service valuation related to land use changes. The assessment of ESV using remote sensing and benefit transfer method is still lacking in Myanmar.

2. Objectives

2.1 Research objectives

The study's overall objective is to assess changes in ESV in response to LULC changes during four different periods with the help of remote sensing techniques and the benefit transfer method. To achieve the main objective of the study, the specific objectives are as follows:

(1) To estimate LULC changes in the study area over the periods (2005, 2010, 2015 & 2020) using remote sensing techniques to evaluate changes in the value of ecosystem services

(2) To estimate the changes in the value of ecosystem services concerning LULC dynamics using the benefit transfer method

(a) To assess the total value of ecosystem services of each LULC class for each reference year (2005, 2010, 2015 & 2020)

(b) To estimate the value of ecosystem services of each ecosystem function for each reference year (2005, 2010, 2015 & 2020)

1. Materials and Methods

3.1 Study area

The research was conducted in Paung Laung Reserved Forest, located in Pin Laung Township, Southern Shan State, Myanmar. It is also situated between latitudes 19°45'-20°28' N and longitudes 96°22'-96°49' E (Figure 1). It is a watershed area with an elevation ranging from 300-1,700 m above sea level (Kitahara, Sato, & Win, 2019). The precipitation of the study area is generally higher than the eastern parts of the country (Shan State), and minimum and maximum total rainfalls are 2,167 mm and 812 mm, respectively (Mon et al., 2009). The total area of Paung Laung Reserved Forest is over 1700 km^2 and is mostly covered by forests which can be broadly classified as mixed deciduous forests and evergreen forests (Zin, 2005a). Some valuable tree species (e.g., *Xylia xylocarpa*, *Pterocarpus macrocarpus*, *Dalbergia oliveri*, etc.) and some bamboo species (e.g., *Bambusa polymorpha*, *Cephalostachyum pergricile*, etc.) naturally grow in the reserved forest. In 2005, the Upper Paung Laung Dam, located on the Paung Laung River, which runs from north to south in the middle of the study area, was established to generate electricity and irrigate agriculture (Kitahara, Sato, & Win, 2019). Local people are highly dependent on forests for their livelihoods, and the area is essential for local and commercial timber supply, electricity and agriculture. Moreover, the Paung Laung watershed, including the study area, has diverse intrinsic value for the local and national economies and biological diversity conservation (Mon et al., 2009; Swe & Funakawa, 2019; Zin, 2005b). It was noticeably observed that the forest cover and LULC of Paung Laung Reserved forest in Myanmar, the study area, have been significantly changed, especially a significant converting closed forest into open forest and a dramatic changing agricultural land into water bodies from 2011 to 2018 because of the impact of hydropower dam construction (Swe & Funakawa, 2019).

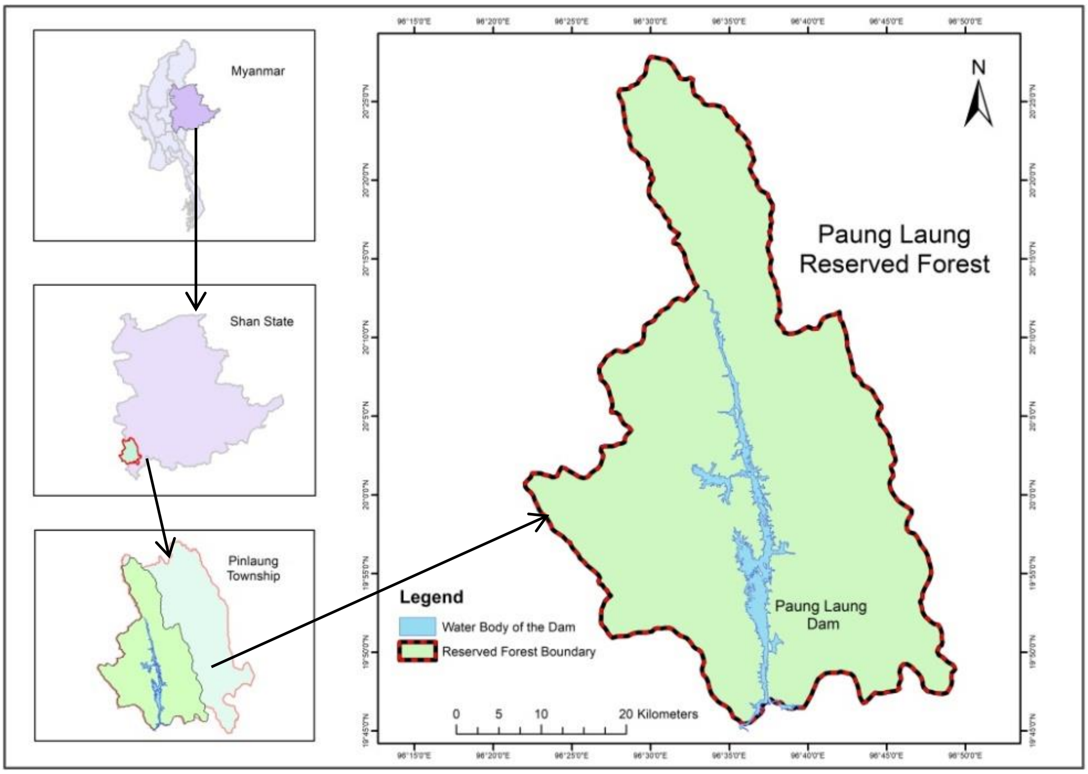


Figure 1 The Paung Laung Reserved Forest: the study area

3.2 Field design and field data collection

The ground-truthing process was conducted in June 2021 to obtain reference data used in the accuracy assessment. Before the field checking, the process of stratification based on land cover categories was conducted to cover all types of land categories in the study area. The study area was divided into six strata (forest, cropland, scrubland, bareland, water and built-up area). The sampling plots were randomly set in each stratum based on the extent of the stratum. The size of a sampling plot was 30 × 30 m, and each sampling plot was equally divided into four subplots to classify land cover (Figure 2). In these subplots, observation was carried out to identify land cover class in the field. In the sampling plots, GPS waypoints using Garmin GPS 62 s were recorded from the position where the observation was investigated. Moreover, field photos were taken for each sampling plot and its relative surroundings. It was observed in the field that more than one type of land cover was mixed at a sampling plot. In that case, the dominant land cover found in the sampling plot was regarded as the land cover of the plot. There is a large military area in the study area. Thus, the sampling plots were inaccessible in some cases due to the restricted area and security reasons. Due to the unstable political situation and the Covid-19 outbreak in Myanmar, only 50 sampling plots for all different LULC types were recorded during the field trip to validate land cover. Moreover, information on the land cover was also collected using in-depth interviews. Interviewing the locals was carried out for local knowledge about historical LULC.

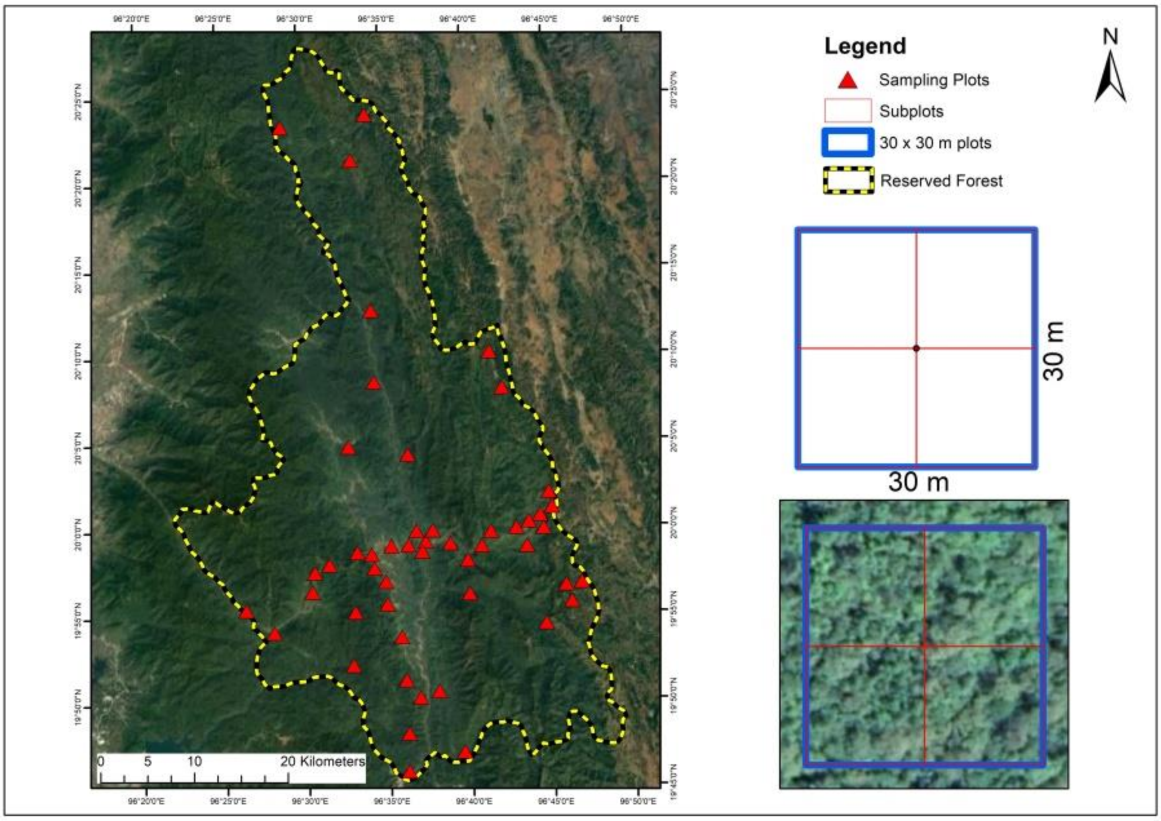


Figure 2 Field sample design to collect field data for land cover validation

3.3 Data acquisition

The research study period was two decades between 2005, 2010, 2015 and 2020. The study area covered two satellite images for each reference year. Thus, a total number of 8 cloud-free Landsat images, including four Thematic Mapper (TM) images from Landsat 5 and four Operational Land Imager (OLI) images from Landsat 8 for the references years (2005, 2010, 2015 and 2020), were collected from the Collection 1 Tier 1 surface reflectance data obtained from the United States of Geological Survey (USGS). These images are atmospherically corrected and have the lowest geo-registration errors. Only the images from January to February were used to detect LULC changes to ensure the tree canopy of deciduous forest and avoid cloud cover (Table 3). The same common spectral bands from Landsat 5 and Landsat 8 were downloaded (Table 2). According to the Landsat data information, the Landsat 5 surface reflectance data are generated using the Landsat Ecosystem Distribution Adaptive Processing System (LEDAPS) algorithm and the Landsat 8 surface reflectance data are generated using the Land Surface Reflectance Code (LaSRC) algorithm. The spatial resolution of all Landsat images was 30 × 30 m, which was projected as UTM Zone 47N, WGS1984.

On the other hand, land cover classification accuracy could be significantly improved by including auxiliary data. For validation and better interpretation of remote sensing, the necessary auxiliary spatial datasets (forest resource assessment and LULC change assessment) and GIS shapefiles (roads, villages and dams) were acquired from the Forest Department, Myanmar. When the image interpretation and classification process is difficult to classify LULC clearly, these auxiliary data were combined with remote sensing data.

3.4 Methods

Changing ESV in Paung Laung Reserved Forest, Myanmar, over the periods were estimated based on LULC changes using the integration of remote sensing with satellite images and benefit transfer method with updated valuation coefficients of Costanza et al. (Costanza et al., 2014).

Table 2 Spectral bands of Landsat TM and OLI used in LULC analysis

Band Name	**Wavelength (micrometers)**	
	Landsat 5 TM	**Landsat 8 OLI**
Blue	0.45-0.52	0.45-0.51
Green	0.52-0.60	0.53-0.59
Red	0.63-0.69	0.64-0.67
Near-Infrared (NIR)	0.77-0.90	0.85-0.89
Shortwave Infrared 1 (SWIR1)	1.55-1.75	1.57-1.65
Shortwave Infrared 2 (SWIR2)	2.08-2.35	2.11-2.29

Table 3 Landsat images used for LULC classification

Year	**Acquisition Dates**	**Sensor**	**Landsat**	**Path/Row**
2005	1st, January to 28th February	TM	Landsat 5	133/046
	1st, January to 28th February	TM	Landsat 5	132/046
2010	1st, January to 28th February	TM	Landsat 5	133/046
	1st, January to 28th February	TM	Landsat 5	132/046
2015	1st, January to 28th February	OLI	Landsat 8	133/046
	1st, January to 28th February	OLI	Landsat 8	132/046
2020	1st, January to 29th February	OLI	Landsat 8	133/046
	1st, January to 29th February	OLI	Landsat 8	132/046

3.4.1 LULC classification

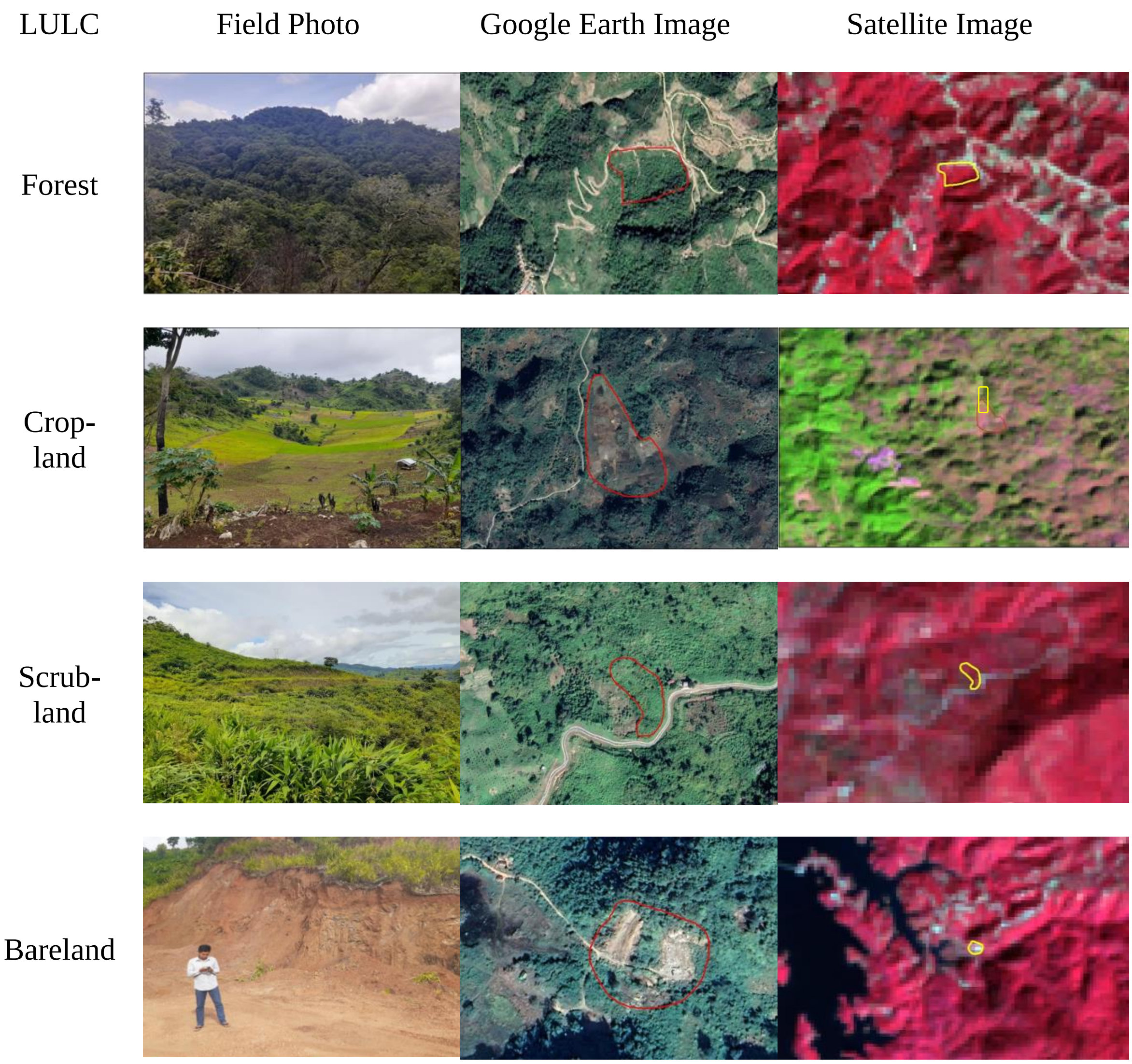
The image classification process was conducted to classify land use classes in the study area using a supervised classification method with a maximum likelihood classification (MLC) algorithm in ENVI 5.3 software. Image classification is the process of assigning the pixels to different classes, and usually, each pixel is treated as an individual unit composed of values in several spectral bands (Pullanikkatil, 2016). The supervised classification method is one of the most frequently used techniques for quantitative remote sensing data analysis. MLC is well-known and most commonly used for parametric classification algorithms (Rai, 2018). Based on a well-known situation of the study area and the local knowledge gained from the locals during the field checking trip, region of Interests (ROIs), as training samples, were created for each land use class in the respective Landsat imageries of the individual study year for the supervised classification. Based on the types of landscape found in the research area, six LULC classes (forest, cropland, scrubland, bareland, water and built-up area (Table 4), were classified using the MLC algorithm. Previous forest inventory data of the study area conducted from the Forest Department, Myanmar and field checking points using GPS were applied for the challenging categories to determine clearly (Boundeth, 2012). Post-classification and manual editing in ArcGIS 10.5 software to conduct majority and minority analysis was applied for better classification and reducing some classification errors.

Accuracy assessment is the results obtained from remote sensing data and is necessary to know its quality (Rimal et al., 2018; Shrestha et al., 2019). It is an essential process in classifying LULC. It is accepted that stratified random points were adopted to validate the classification accuracy of land cover data in Google Earth (Rimal et al., 2018; Shrestha et al., 2019). In this study, 300 stratified random points per land use class were generated to assess the accuracy based on visual interpretation. The minimum linear distance was 100 meters between two sampling points for accuracy assessment. In some cases, less than 300 points were adopted for some classes based on the class area. After creating sampling points, Google Earth was used for assessing the accuracy of classified LULC. Google Earth is a powerful tool for the accuracy assessment of LULC, resulting in reasonable accuracy with low cost (Tilahun & Teferie, 2015). The previous studies in Myanmar were used Google Earth for the accuracy assessment and validation of classification (Htun, 2009; Htwe, 2015; Y.-C.Wang, 2018; Yang et al., 2019). Apart from Google Earth imagery, forest cover map, LULC maps, forest inventory data from Myanmar Forest Department, ground-checking points, field photos and interviews with the locals were used as other reference data because the local knowledge of the study area played a critical role in the process of accuracy assessment as well as image classification. Kappa Coefficient is generally used in assessing classification accuracy (Das & Das, 2019; Foody et al., 1992). The Kappa Coefficient value is from 0 to 1, where 0 indicates the least accuracy between the actual situation in the field and the classification results, and over 0.85 represents strong accuracy (Monserud, 1992). The Kappa Coefficient and the overall accuracy will be derived and assessed for each period.

Figure 3 Interviewing the locals for local knowledge of LULC

Table 4 Description of classified LULC classes for the research area

LULC Types	Description
Forest	Land with dense tree canopy density and mixed deciduous forest
Cropland	Land for crop cultivation including farms, fields, etc.
Scrubland	Land with bush, shrub, grass cover and degraded forest land
Bareland	Land with no any vegetation
Water	Land with water bodies including lakes, streams, rivers, etc.
Built-up Area	Urban and rural areas, including villages, build-up, etc.



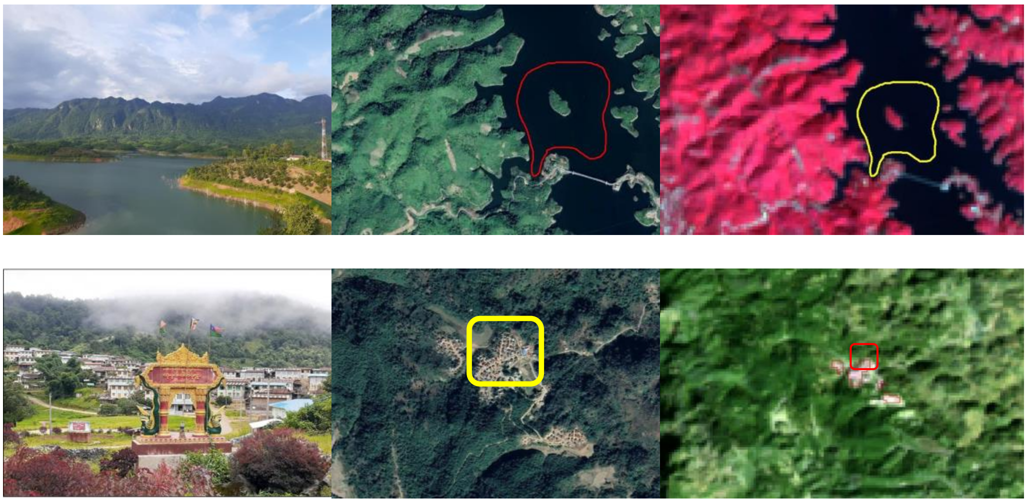


Figure 4 Selection of ROIs for LULC classification

3.4.2 Assigning ecosystem services values

There are different methods with different advantages and disadvantages for estimating ESV (R. S. De Groot et al., 2002; Farber et al., 2006; Koetse et al., 2015; R. Sharma et al., 2019). Various valuation coefficients of ecosystem services were proposed and adopted at the global and regional scales (Costanza et al., 1997, 2014; D. De Groot & Wang, 2010; G. D. Xie et al., 2003). Regarding estimating the economic value of ecosystem services, previous studies have used the global value coefficients directly or indirectly (Camacho-Valdez et al., 2014; Gashaw et al., 2018; Kindu et al., 2016b; Sannigrahi et al., 2018; Seidl & Moraes, 2000; Tianhong et al., 2010; Zhao et al., 2004). In this study, the benefit transfer method, which was cost-effective (Colombo et al., 2007; R. Sharma et al., 2019), was used to estimate the values of ecosystem services dealing with LULC dynamics. It is a procedure in which the existing estimated values of ecosystem services in a location can be borrowed and applied to estimate ESV in a similar location, especially in the lack of site-specific valuation data (King et al., 2000; Plummer, 2009; Richardson et al., 2015). In the study, LULC was used as a proxy for ESV estimation. Each LULC class from the study was compared with the representative ecosystems from Costanza et al. (Costanza et al., 2014) (Table 5). All 17 ecosystem services specified by Costanza et al. (Costanza et al., 2014) were used in this study to estimate the ecosystem services of the study area. The valuation coefficients developed by Costanza et al. (Costanza et al., 2014) were used in the study because Costanza et al. (Costanza et al., 2014) developed a systematic and comprehensive set of valuation coefficients for a quick assessment of multiple ecosystem services. Previous studies have been conducted using the equivalent ecosystem type of Costanza et al. (Costanza et al., 1997) and (Arowolo et al., 2018; Bian & Lu, 2013; Costanza et al., 2014; Estoque & Murayama, 2013; R. Sharma et al., 2019).

Table 5 LULC classes of the study, equivalent ecosystem types of Costanza et al. (Costanza et al., 2014) and Total ESVs

LULC Classes	**Equivalent Ecosystem Types**	**Total Ecosystem Services Values (USD ha^{-1} yr^{-1})**
Forest	Tropical Forest	5381
Cropland	Cropland	5568
Scrubland	-	0

Bareland	-	0
Water	Lakes/Rivers	12512
Built-up Area	Urban	6661

Table 6. ESV coefficients (USD ha^{-1} yr^{-1}) of equivalent ecosystem types of Costanza et al. (Costanza et al., 2014) for the LULC classes of the study

Ecosystem Functions	Forest	Cropland	Scrubland	Bareland	Water	Built-up Area
Food production	200	2323	0	0	106	0
Raw materials	84	219	0	0	0	0
Gas regulation	12	0	0	0	0	0
Climate regulation	2044	411	0	0	0	905
Disturbance regulation	66	0	0	0	0	0
Water regulation	8	0	0	0	7514	16
Water supply	27	400	0	0	1808	0
Waste treatment	120	397	0	0	918	0
Erosion Control	337	107	0	0	0	0
Ecosystem Functions	**Forest**	**Cropland**	**Scrubland**	**Bareland**	**Water**	**Built-up Area**
Soil formation	14	532	0	0	0	0
Nutrient cycling	3	0	0	0	0	0
Pollination	30	22	0	0	0	0
Biological Control	11	33	0	0	0	0
Habitat/ refugia	39	0	0	0	0	0
Genetic resources	1517	1042	0	0	0	0
Cultural						
Recreation	867	82	0	0	2166	5740
Cultural	2	0	0	0	0	0
Total ESV	5381	5568	0	0	12512	6661

3.4.3. Calculating ecosystem services values

In the calculation of ESV, the six LULC types in Paung Laung Reserved Forest were compared with 16 biomes identified by Costanza et al. (Costanza et al., 2014) (Table 6) and the nearest equivalent biome was used as a surrogate. For example, the tropical forest was used as a proxy for forests in this study.

For the estimation of the total ESV of the study area, firstly, the ESV of each LULC class in a reference year was estimated using the equation (1) (Table 7), which was used in previous studies (Arowolo et al., 2018; Kreuter et al., 2001; Jinchang Li et al., 2010; Rai et al., 2018; S. Wang et al., 2014). Then, all the estimated values of ecosystem services of

LULC classes were summed to obtain the total ESV of Paung Laung Reserved Forest in the reference year.

The ESV of 17 individual ecosystem services for each reference were computed using the coefficients adopted by Costanza et al. (Costanza et al., 2014) (Table 6), and the equation (2) (Table 7), which was also applied in other studies (Arowolo et al., 2018; Kreuter et al., 2001a; Jinchang Li et al., 2010; S. Wang et al., 2014).

The equation (3) (Table 7) was used to detect the changes of ESV across different periods, including between different two periods (i.e. ESV change from 2005 to 2010, etc.). This equation was applied in many previous studies (Arowolo et al., 2018; Kindu et al., 2016b; Kreuter et al., 2001a; Jinchang Li et al., 2010; S. Wang et al., 2014).

Table 7 Equations for estimation of ESV change

Equations	Description
Equation (1)	$ESV_t = \sum(A_{kt} \times VC_k)$ where ESV_t is the estimated total ESV at time t, A_{kt} is the area (ha) of LULC class k at time t and VC_k is the valuation coefficient of ecosystem service (USD $ha^{-1}yr^{-1}$) of LULC class k.
Equation (2)	$ESV_{ft} = \sum(A_{kt} \times VC_{fk})$ where; ESV_{ft} is the estimated ESV of each ecosystem function f at time t, A_{kt} is the area (ha) of LULC class k at time t and VC_{fk} is the valuation coefficient of ecosystem service (USD ha^{-1} yr^{-1}) of each ecosystem function f for each LULC class k.
Equation (3)	$ESV_c = \frac{ESV_{t_2} - ESV_{t_1}}{ESV_{t_1}} \times 100\%$ where; ESV_c is the changes of ESV between two periods, t_1 and t_2, $ESVt_1$ and $ESVt_2$ are the estimated total values of ecosystem services at the starting, t_1 and ending, t_2 periods.

In brief, there are two main parts in the methodology to evaluate changes of ecosystem services based on LULC changes (Figure 5). An assessment of LULC changes, the first part of the methodology, was conducted for four different periods. Firstly, the required data were obtained by downloading the satellite imagery (Landsat Collection 1 Tier 1 Surface Reflectance) from the USGS website and collecting existing LULC and forest cover, necessary GIS shapefiles, forest inventory data with coordinate points from Myanmar Forest Department. Then, regions of interest (ROIs) were selected to process and classify the images using a supervised maximum likelihood classifier. In image classification, the auxiliary data obtained from Forest Department were used when it was challenging to choose ROIs. Next, majority and minority analysis to reduce classification errors and manual editing in ArcMap were done post-classification for better classification. After that, stratified random points per land use class generated from Google Earth and ground-truth points were applied to validate the classification accuracy based on visual interpretation. Moreover, some auxiliary data (forest cover, LULC data and forest inventory data from Forest Department) were also used to assess the accuracy. Furthermore, local knowledge, field photos and ground-checking knowledge gained from the field trip were also applied to improve the accuracy. The main purpose of the second part of the methodology is to assign valuation coefficients by using the benefit transfer method based on the coefficients of Costanza et al. (Costanza et al., 2014). Then, based on the LULC change data and the valuation coefficients, changes in ESV were estimated for four different periods.

4. Results

4.1 Land use and land cover dynamics between 2005-2020

The overall accuracy of classification products for different reference years was acceptable (Anderson, 1976), accounting for 89.46% in 2005, 87.14% in 2010, 86.34% in 2015 and 86.23% in 2020, respectively (Table 8), (Table 9), (Table 10) and (Table 11). Moreover, the corresponding Kappa Coefficients during the study periods were all greater than 0.81 for different study years, accounting for 0.86 (85.66%) in 2005, 0.83 (83.20%) in 2010, 0.82 (82.82%) in 2015 and 0.82 (82.38%) in 2020, respectively (Table 8), (Table 9), (Table 10) and (Table 11).

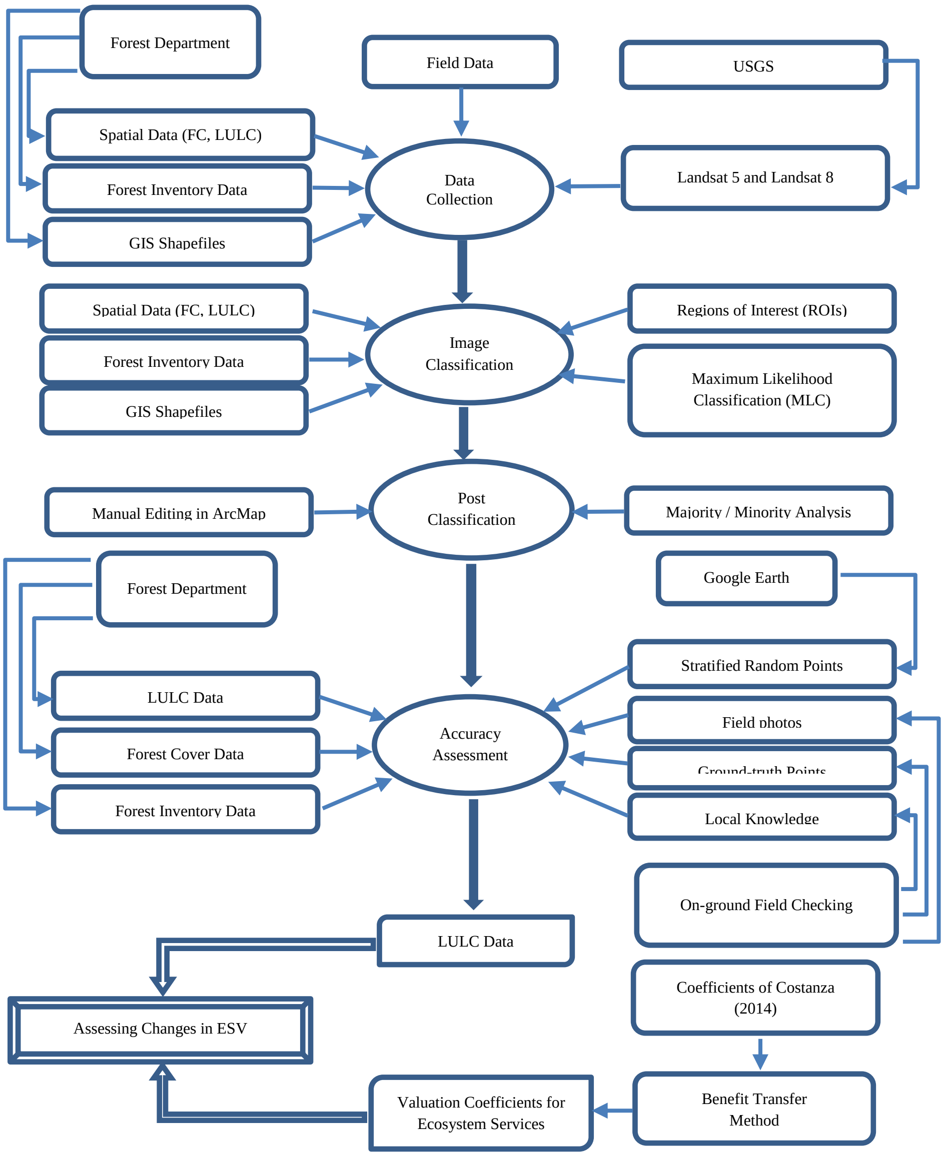


Figure 5. Methodological framework to access ESV change due to LULC change

In other words, there was an almost perfect agreement between the classified data and the reference data for all periods.

Based on the magnitude of LULC types, the dominant LULC type was forest (Figure 6), occupying about 89.57% of the study area in 2005, 85.60% in 2010, 81.25% in 2015, and 80.71% in 2020, respectively (Table 12 and Figure 7). As a result, it was observed that the forest showed a continuous downward trend during the study periods (Figure 7). On the other hand, there was an upward trend in cropland from 2005 to 2020, accounting for 7.74%, 11.03%, 11.28% and 11.68% of the total area, respectively (Table 12 and Figure 7). Furthermore, scrubland, water and built-up area in the reserved forest also experienced the same during the reference years. However, bareland occupied the least proportion in the study area, increasing 0.03% of the whole study area in 2005, 0.22% in 2010 and 0.26% in 2015, but decreasing 0.07% in 2020 (Table 12).

There was a difference in the net changes for each land cover type during the study period. During the first study period (2005-2010), cropland (5688.99 ha) occupied the highest net gain of area changes, followed by scrubland (713.79 ha), bareland (321.12 ha), water (129.06 ha) and built-up area (10.71 ha) (Table 8). On the other hand, water (6369.03 ha) was the largest proportion among different types of land class during the second period (2010-2015), followed by scrubland (512.55 ha), cropland (430.65 ha), built-up area (123.48 ha) and bareland (66.15 ha). Further, cropland (668.23 ha) occupied the highest gain in the last research period (2015-2020), followed by scrubland (485.55 ha), water (94.23 ha) and built-up area (0.18 ha), while a noticeable loss of area changes was occurred in bareland (323.37 ha). Noticeably, a continuous net loss of area changes was experienced in the forest (6862.32 ha, 7504.65 ha and 939.69 ha in the first, second and last periods) throughout the reference years (Table 8 and Figure 7). During the whole research period (2005-2020), the highest net gain of area changes was observed in the cropland (6807.87ha) in the study area, followed by water (6592.32 ha), scrubland (1711.89 ha), built-up area (134.37 ha) and bareland (63.90 ha), while there was a significant loss in the forest (15306.66 ha) (Table 12).

There were different rates of changes of LULC types during the research periods (Table 12). During the whole reference years (2005-2020), cropland, scrubland, bareland, water and built-up area increased rate of changes, while forest land class showed a decreasing rate of changes. The increasing rate of changes was observed in cropland, scrubland, water, and built-up area in 2005-2010, 2010-2015 and 2015-2020. Although bareland showed the annual rates of increase in the first and second study periods (106.35% in 2005-2010 and 3.47% in 2010-2015), it decreased in the last periods (14.45% in 2015-2020). Significantly, forests occupied the continuous downward trend in the rate of changes, accounting for 0.89% in 2005-2010, 1.02% in 2010-2015 and 0.13% in 2015-2020, respectively. Noticeably, water bodies increased at the fastest rate (257.19%) in 2010-2015 because the Paung Laung Hydropower dam was constructed during this period.

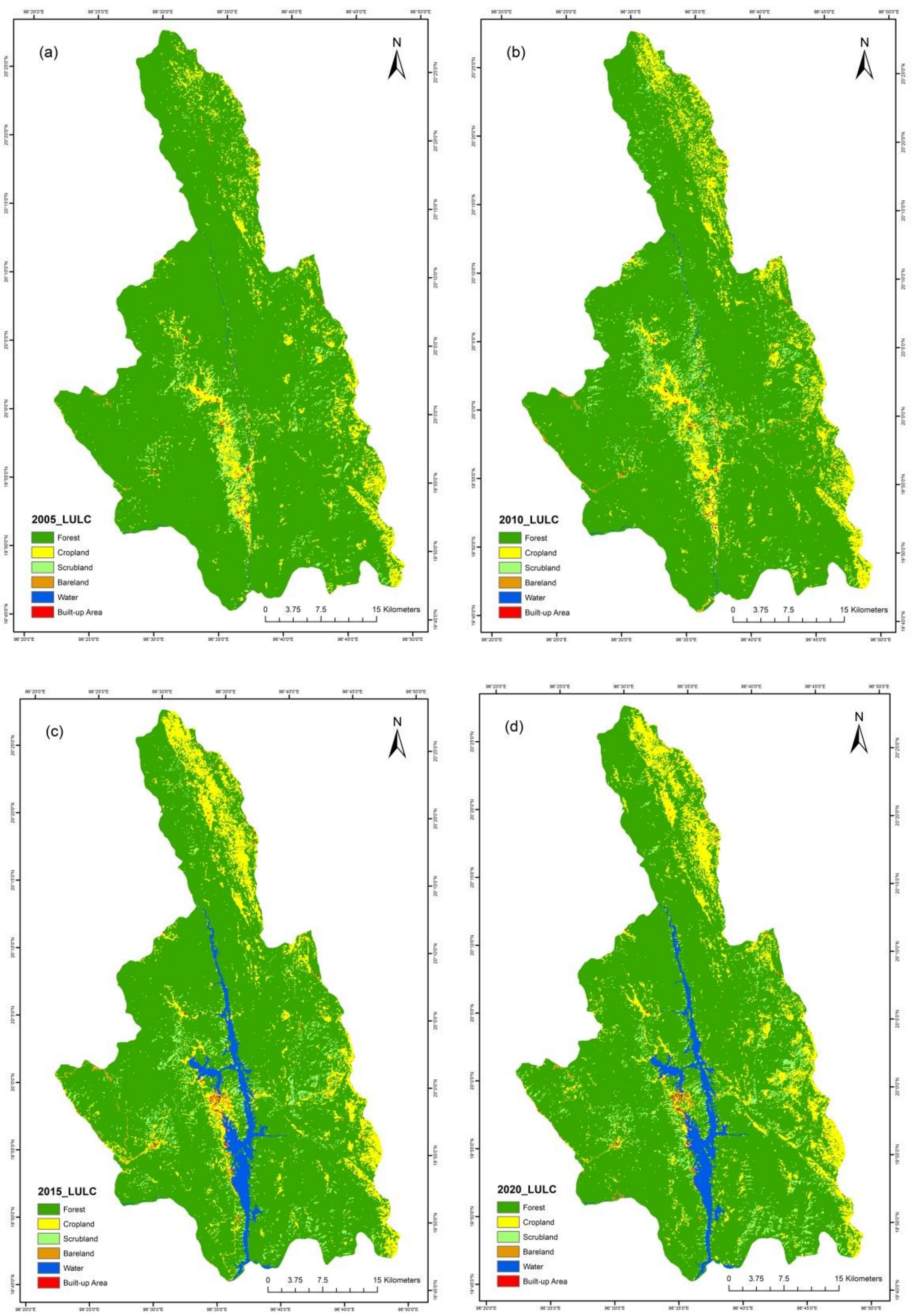


Figure 6 Spatial distribution of LULC in Paung Laung Reserved Forest in (a) 2005, (b) 2010 (c) 2015 and (d) 2020

Table 8 Accuracy assessment of LULC of Paung Laung Reserved Forest in 2005

	Forest	Cropland	Scrubland	Bareland	Water	Built-up Area	Row total

Forest	277	1	22	0	0	0	300
Cropland	24	259	16	1	0	0	300
Scrubland	35	0	265	0	0	0	300
Bareland	1	0	0	11	0	0	12
Water	4	0	2	0	61	0	67
Built-up Area	2	0	0	0	0	44	46
Column total	343	260	305	12	61	44	1025

Overall Accuracy = 89.46% Kappa Coefficient = 85.66%

Producer's Accuracy (omission error)				User's Accuracy (commission error)			
Forest	= 80.76%	19.24%	omission error	Forest	= 92.33%	7.67%	commission error
Cropland	= 99.62%	0.38%	omission error	Cropland	= 86.33%	13.67%	commission error
Scrubland	= 86.89%	13.11%	omission error	Scrubland	= 88.33%	11.67%	commission error
Bareland	= 91.67%	8.33%	omission error	Bareland	= 91.67%	8.33%	commission error
Water	= 100%	0%	omission error	Water	= 91.04%	8.96%	commission error
Built-up Area	= 100%	0%	omission error	Built-up Area	= 95.65%	4.35%	commission error

Table 9 Accuracy assessment of LULC of Paung Laung Reserved Forest in 2010

	Forest	Cropland	Scrubland	Bareland	Water	Built-up Area	Row total
Forest	268	5	27	0	0	0	300
Cropland	24	262	10	3	0	1	300
Scrubland	45	0	255	0	0	0	300
Bareland	7	1	3	60	0	3	74
Water	8	4	0	0	78	0	90
Built-up Area	0	1	0	1	0	46	48
Column total	352	273	295	64	78	50	1112

Overall Accuracy = 87.14% Kappa Coefficient = 83.20%

Producer's Accuracy (omission error)				User's Accuracy (commission error)			
Forest	= 76.14%	23.86%	omission error	Forest	= 89.33%	10.67%	commission error
Cropland	= 95.97%	4.03%	omission error	Cropland	= 87.33%	12.67%	commission error
Scrubland	= 86.44%	13.56%	omission error	Scrubland	= 85.00%	15.00%	commission error
Bareland	= 93.75%	6.25%	omission error	Bareland	= 81.08%	18.92%	commission error
Water	= 100%	0%	omission error	Water	= 86.67%	13.33%	commission error
Built-up Area	= 92%	8%	omission error	Built-up Area	= 95.83%	4.17%	commission error

Table 10. Accuracy assessment of LULC of Paung Laung Reserved Forest in 2015

	Forest	Cropland	Scrubland	Bareland	Water	Built-up	Row total

						Area	
Forest	269	1	30	0	0	0	300
Cropland	30	239	28	0	0	3	300
Scrubland	64	0	236	0	0	0	300
Bareland	6	5	6	64	1	2	84
Water	5	2	0	0	293	0	300
Built-up Area	1	0	0	0	1	68	70
Column total	375	247	300	64	295	73	1354

Overall Accuracy = 86.34% Kappa Coefficient = 82.82%

Producer's Accuracy (omission error)				User's Accuracy (commission error)			
Forest	= 71.73%	28.27%	omission error	Forest	= 89.67%	10.33%	commission error
Cropland	= 96.76%	3.24%	omission error	Cropland	= 79.67%	20.33%	commission error
Scrubland	= 78.67%	21.33%	omission error	Scrubland	= 78.67%	21.33%	commission error
Bareland	= 100%	0%	omission error	Bareland	= 76.19%	23.81%	commission error
Water	= 99.32%	0.68%	omission error	Water	= 97.67%	2.33%	commission error
Built-up Area	= 93.15%	6.85%	omission error	Built-up Area	= 97.14%	2.86%	commission error

Table 11. Accuracy assessment of LULC of Paung Laung Reserved Forest in 2020

	Forest	Cropland	Scrubland	Bareland	Water	Built-up Area	Row total
Forest	265	2	31	0	2	0	300
Cropland	28	234	31	3	0	4	300
Scrubland	47	5	246	1	1	0	300
Bareland	2	0	1	19	1	0	23
Water	6	2	5	0	287	0	300
Built-up Area	2	0	2	1	1	64	70
Column total	350	243	316	24	292	68	1293

Overall Accuracy = 86.23% Kappa Coefficient = 82.38%

Producer's Accuracy (omission error)				User's Accuracy (commission error)			
Forest	= 75.71%	24.29%	omission error	Forest	= 88.33%	11.67%	commission error
Cropland	= 96.30%	3.70%	omission error	Cropland	= 78%	22%	commission error
Scrubland	= 77.85%	22.15%	omission error	Scrubland	= 82%	18%	commission error
Bareland	= 79.17%	20.83%	omission error	Bareland	= 82.61%	17.39%	commission error
Water	= 98.29%	1.71%	omission error	Water	= 95.67%	4.33%	commission error
Built-up Area	= 94.12%	5.88%	omission error	Built-up Area	= 91.43%	8.57%	commission error

Table 12. LULC changes in Paung Laung Reserved Forest from 2005 to 2020

	LULC Types	Forest	Cropland	Scrubland	Bareland	Water	Built-up Area
Area (ha)	2005	154708.92	13364.91	3974.49	60.39	366.21	250.02
	2010	147846.60	19053.90	4688.28	381.51	495.27	260.73
	2015	140341.95	19484.55	5200.83	447.66	6864.30	384.21
	2020	139402.26	20172.78	5686.38	124.29	6958.53	384.39
Propor-tion (%)	2005	89.57	7.74	2.30	0.03	0.21	0.14
	2010	85.60	11.03	2.71	0.22	0.29	0.15
	2015	81.25	11.28	3.01	0.26	3.97	0.22
	2020	80.71	11.68	3.29	0.07	4.03	0.22
Area Changes (ha)	2005-2010	-6862.32	5688.99	713.79	321.12	129.06	10.71
	2010-2015	-7504.65	430.65	512.55	66.15	6369.03	123.48
	2015-2020	-939.69	688.23	485.55	-323.37	94.23	0.18
Changes (%)	2005-2010	-4.44	42.57	17.96	531.74	35.24	4.28
	2010-2015	-5.08	2.26	10.93	17.34	1285.97	47.36
	2015-2020	-0.67	3.53	9.34	-72.24	1.37	0.05

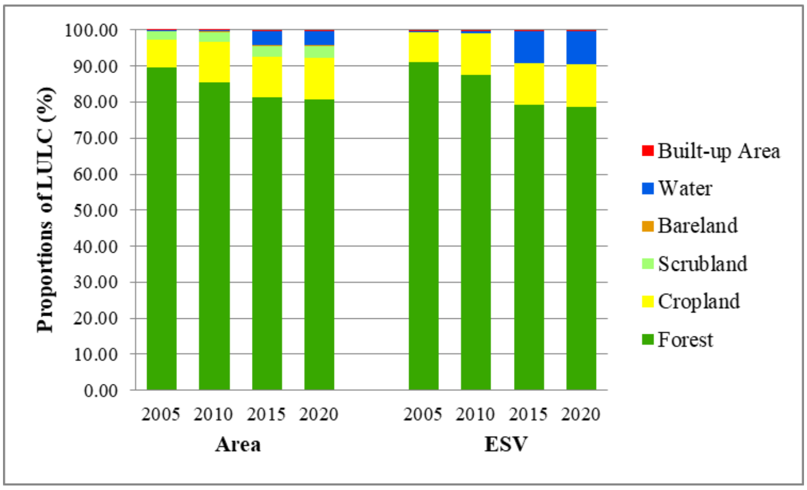


Figure 7. Changes of area and ESV of LULC in Paung Laung Reserved Forest from 2005 to 2020

4.2 Changes in total ecosystem services values

The ESV for each land use category and the total values for the reference years were estimated based on the ESV coefficients of Costanza et al. (Costanza et al., 2014). The total estimated ESV for the research area accounted for about 913.15 million USD yr^{-1} in 2005, 909.59 million USD yr^{-1} in 2010, 952.12 million USD yr^{-1} in 2015 and 952.07 million USD yr^{-1} in 2020 (Table 13 and Figure 10). The different types of LULC of the study area provided different ESV in the reference years. As the forest was the major land cover in Paung Laung Reserved Forest (Figure 6), it occupied about 832.49 million USD yr^{-1} in 2005 (Table 13), which was 91.17 % of the total ESV in the research area. In the same period, cropland was the second-largest portion of the reserved forest, accounting for about 74.42 million USD yr^{-1} (8.15%), followed by water (4.58 million USD yr^{-1}), and built-up area (1.67 million USD yr^{-1}), respectively (Figure 6 and Table 13). In 2010, forest, cropland, water, and built-up area estimated about 795.56 million USD yr^{-1} (87.46%), 106.09 million USD yr^{-1} (11.66%), 6.20 million USD yr^{-1} (0.68%) and 1.74 million USD yr-1 (0.19%) of the total values of the research area (Figure 7 and Table 13). Moreover, the highest ESV in 2015 was contributed by forest (755.18 million USD yr^{-1}), followed by cropland (108.49 million USD yr^{-1}), water (85.89 million USD yr^{-1}) and built-up area (2.56 million USD yr^{-1}), respectively (Figure 12 and Table 13). In the last study period (2020), the forest also contributed the most ESV among the land types, resulting in 750.12 million USD yr^{-1} (78.79%) of the total values of the study landscape (Figure 12 and Table 13). In the same period, the ESV of cropland and water were also large, contributing 112.32 million USD yr^{-1} (11.80%) and 87.07 million USD yr^{-1} (9.14%), respectively. However, built-up area contributed the least ESV in 2020, occupying 2.56 million USD yr^{-1} (0.27%) of the total values of the study area (Figure 12 and Table 13).

From 2005 to 2010, the ESV from cropland ecosystems, water and built-up area in Paung Laung Reserved Forest increased by 41.36%, from 80.66 million USD yr^{-1} in 2005 to 114.03 million USD yr^{-1} in 2010 (Table 13). The ESV change in cropland accounted for the largest part (94.95%) of the total ESV gain from these ecosystems, followed by water (4.84%) and built-up area (0.21%) of the total gain, respectively. On the other hand, the ESV of forest in the study area during this period decreased by 4.44% from 832.49 million USD yr^{-1} to 795.56 million USD yr^{-1}. Overall, the total ESV in Paung Laung Reserved forest from 2005 to 2010 decreased by 3.56 million USD yr^{-1} (Table 13 and Figure 10). From 2010-2015, the highest ESV gain was from water (79.69 million USD yr^{-1}), followed by cropland (2.40 million USD yr^{-1}) and built-up area (0.82 million USD yr^{-1}), respectively, while there was ESV loss in the forest (40.38 million USD yr^{-1}) (Figure 11). Overall, the total ESV during 2010-2015 increased by 42.53 million USD yr^{-1} (Table 13 and Figure 10) because the water area significantly increased in 2015 due to dam construction in the study area (Figure 6). The total ESV changes in the study landscape was a net loss of about 0.04 million USD yr^{-1} in the last study period (2015-2020). There was a significant ESV loss in the forest (5.06 million USD yr^{-1}) in the same period. In contrast, the ESV changes in cropland, water and built-up area showed an increase, accounting for about 3.83 million USD yr^{-1} (3.35%), 1.18 million USD yr^{-1} (1.37%) and 0.001 million USD yr^{-1} (0.05%), respectively.

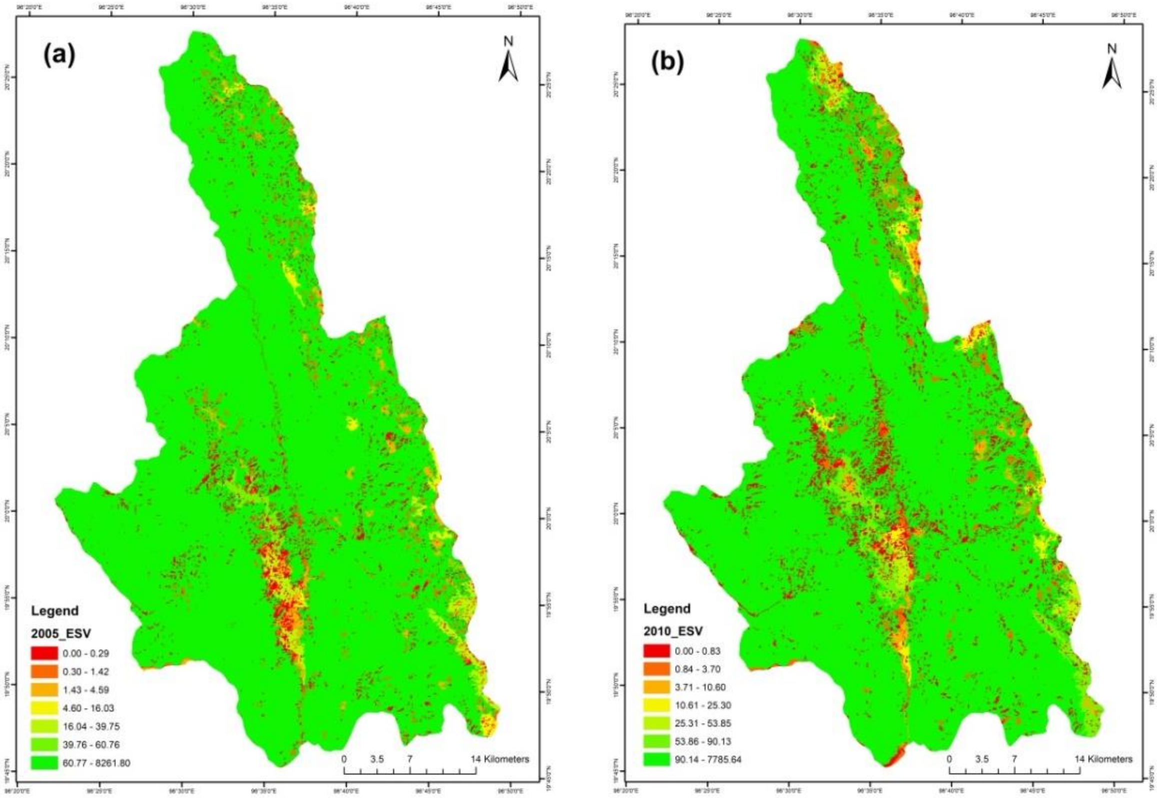


Figure 8 Spatial distribution of ESV (10^5 \$) in Paung Laung Reserved Forest in (a) 2005 and (b) 2010

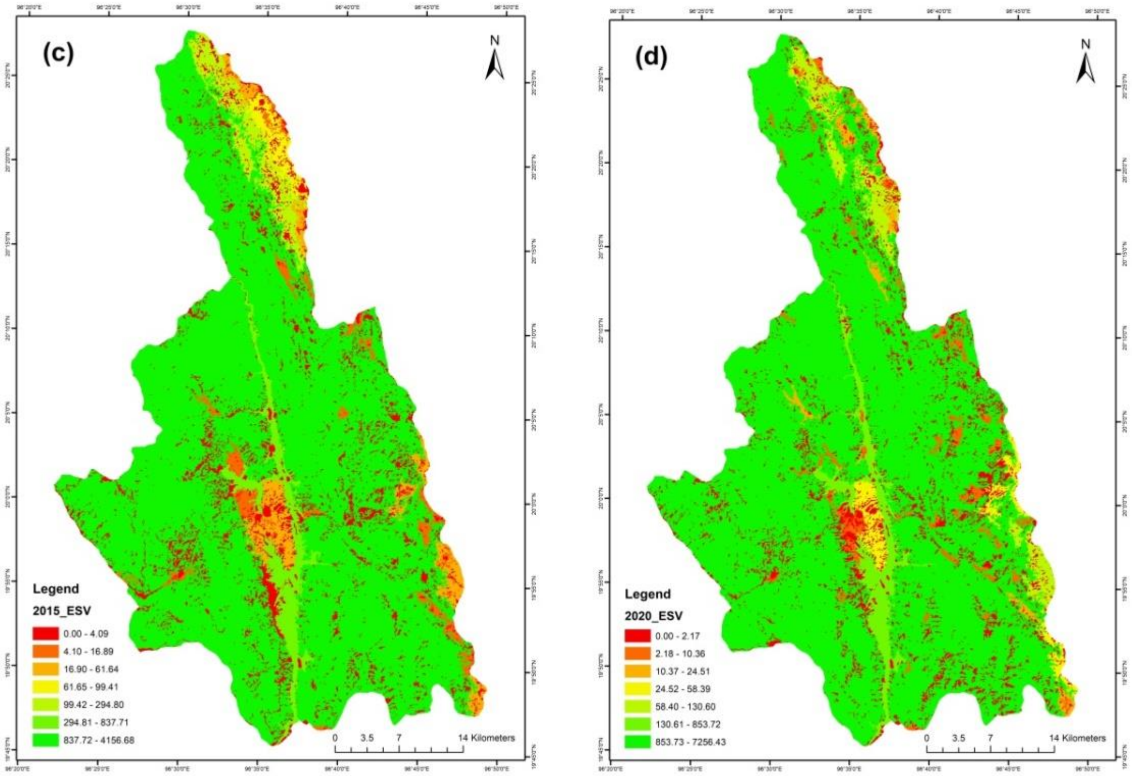


Figure 9 Spatial distribution of ESV (10^5 \$) in Paung Laung Reserved Forest in ((c) 2015 and (d) 2020

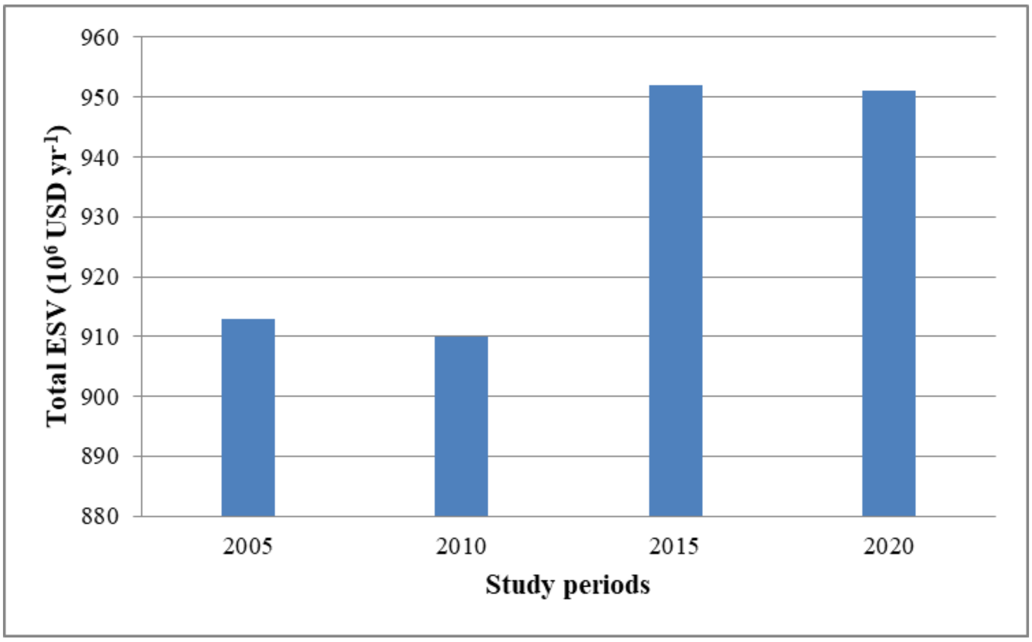


Figure 10 Changes in total ESV for different reference years in Paung Laung Reserved Forest

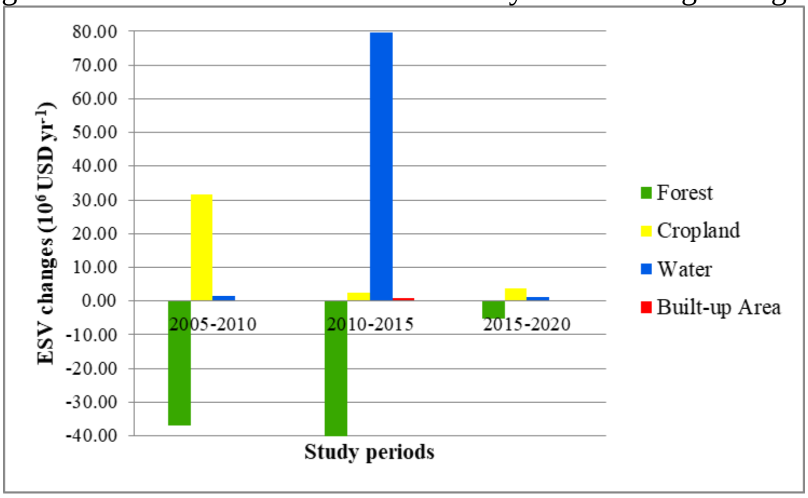


Figure 11 Changes in ESV of LULC between two study periods in Paung Laung Reserved Forest

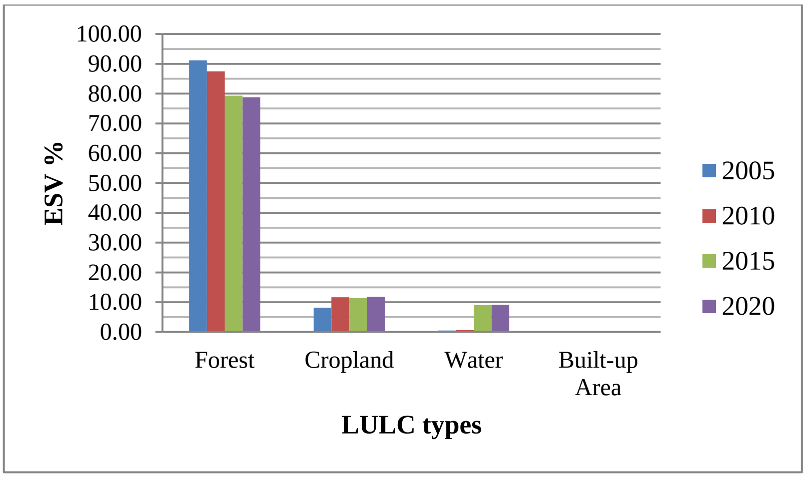


Figure 12. ESV (%) for different LULC types in Paung Laung Reserved Forest from 2005 to 2020

Table 13. Estimated ESV for different LULC types and the changes in the reference years in Paung Laung Reserved Forest from 2005 to 2020

	LULC Types	Forest	Cropland	Water	Built-up Area	Total
ESV (10^6 USD yr^{-1})	2005	832.49	74.42	4.58	1.67	913.15
	2010	795.56	106.09	6.20	1.74	909.59
	2015	755.18	108.49	85.89	2.56	952.12
	2020	750.12	112.32	87.07	2.56	952.07
ESV (%)	2005	91.17	8.15	0.50	0.18	100.00
	2010	87.46	11.66	0.68	0.19	100.00
	2015	79.32	11.39	9.02	0.27	100.00
	2020	78.79	11.80	9.14	0.27	100.00
ESV Changes (10^6 USD yr^{-1})	2005-2010	-36.93	31.68	1.61	0.07	-3.56
	2010-2015	-40.38	2.40	79.69	0.82	42.53
	2015-2020	-5.06	3.83	1.18	0.001	-0.04
ESV Changes (%)	2005-2010	-4.44	42.57	35.24	4.28	77.66
	2010-2015	-5.08	2.26	1285.97	47.36	1330.51
	2015-2020	-0.67	3.53	1.37	0.05	4.28

4.3 Changes in values of ecosystem service functions

Based on the coefficients of 17 ecosystem service functions developed by Costanza et al. (Costanza et al., 2014), the ESV for all ecosystem service functions in Paung Laung Reserved Forest were estimated for the study periods of 2005, 2010, 2015 and 2020 (Table 14). There was a decreased trend during the study periods (2005 and 2010) before dam construction and during 2015-2020 after dam construction in the study area. It accounted for 917.89 million USD yr^{-1} in 2005, 909.59 million USD yr^{-1} in 2010, 952.68 million USD yr^{-1} in 2015, and 952.07 million USD yr^{-1} in 2020, respectively (Figure 10). In comparing the situations before and after the dam, however, the total ESV of all ecosystem functions significantly and dramatically increased from 909.59 million USD yr^{-1} in 2010 to 952.68 million USD yr^{-1} in 2015 (Table 14 and Figure 10). In four different reference years, the most important ecosystem functions in Paung Lung Reserved Forest were climate regulation, genetic resources and recreation, which contributed to 35.07%, 27.09%, and 14.98% of the total ESV of different ecosystem functions in 2005; 34.11%, 26.84% and 14.55% of the total ESV in 2010; 30.99%, 24.48% and 14.73% in 2015; and 30.84%, 24.42% and 14.68% in 2020, respectively (Table 14 and Figure 13).

The total ESV of all ecosystem service functions dramatically reduced during the first study period of 2005-2010. However, there was a significant increase in ESV of food production, raw materials, water regulation, water supply, waste treatment, soil formation, and biological control, which increased by 10.66%, 4.20%, 22.91%, 22.81%, 6.42%, 31.59% and 5.24%, respectively (Figure 14). On the other hand, the ESV of gas regulation, disturbance regulation, nutrient cycling, habitat/regufia, and cultural services (4.44%) decreased more significantly than other ecosystem functions, followed by recreation (3.74%), climate regulation (3.63%), erosion control (3.18%), genetic resources (1.80%) and pollination (1.64%), respectively. The highest and lowest rates of change of ESV among 17 ecosystem service functions were 31.59% and (1.64%) from soil formation and pollination services during 2005-2010 (Figure 14).

In the second study period (2010-2015), there was a significant increase of 43.09 million USD yr^{-1} from the ESV of all ecosystem functions. The ESV of some ecosystem service functions in the reserved forest increased remarkably (e.g., water regulation, water supply, waste treatment, etc.), while that of some ecosystem functions decreased more obviously (e.g., gas regulation, nutrient cycling, etc.) (Figure 14). However, there was a significant ESV gain from water regulation (966.34%) and water supply (88.54%). Of 17 different functions, the lowest rate of change in the values of ecosystem services was from food production, which contributed to 0.24% during the same period (Table 14).

In the last study period (2015-2020), the total ESV change for all ecosystem functions showed a slight reduction by decreasing from 952.68 million USD yr^{-1} in 2015 to 952.07 million USD yr^{-1} in 2020 (Table 14 and Figure 10). Among 17 ecosystem service functions, the ESV from six ecosystem functions increased (e.g., food production, water regulation, soil formation, etc.), but there was an ESV decrease in other ecosystem services (e.g., gas regulation, climate regulation, etc.). Pollination service function (4.06%) decreased more rapidly than any other ecosystem function. In contrast, the ESV of soil formation services increased more quickly than other ecosystem functions from 2015 to 2020 (Figure 16).

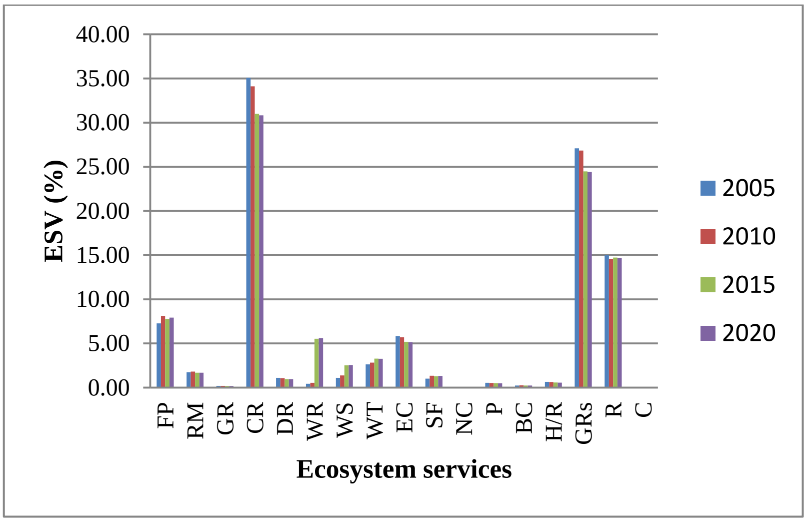


Figure 13. ESV (%) of each ecosystem services in Paung Laung Reserved Forest from 2005 to 2010

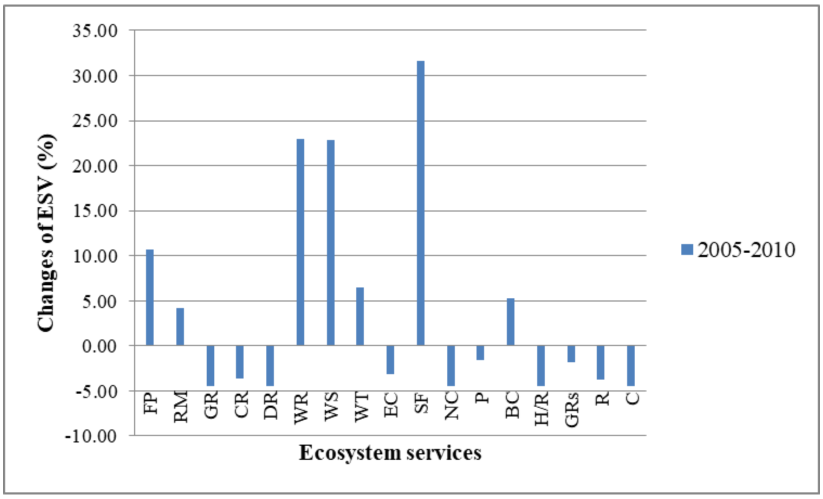


Figure 14. Changes of ESV (%) of each ecosystem services in Paung Laung RF from 2005 to 2010

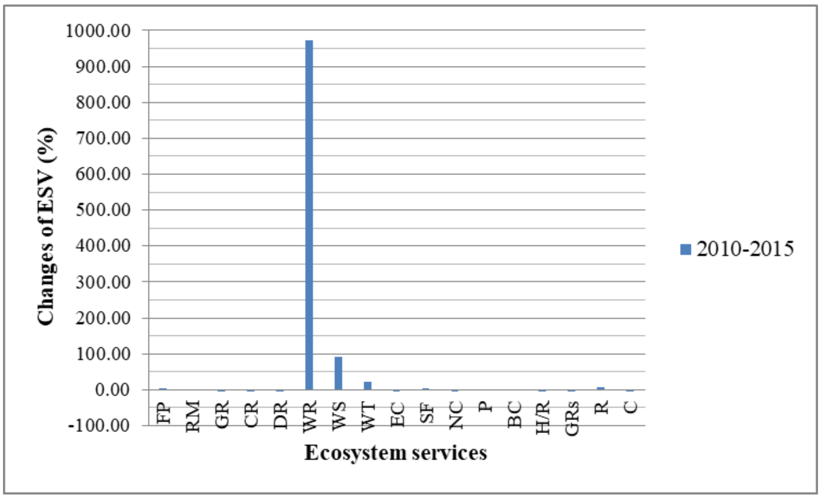


Figure 15. Changes of ESV (%) of each ecosystem services in Paung Laung RF from 2010 to 2015

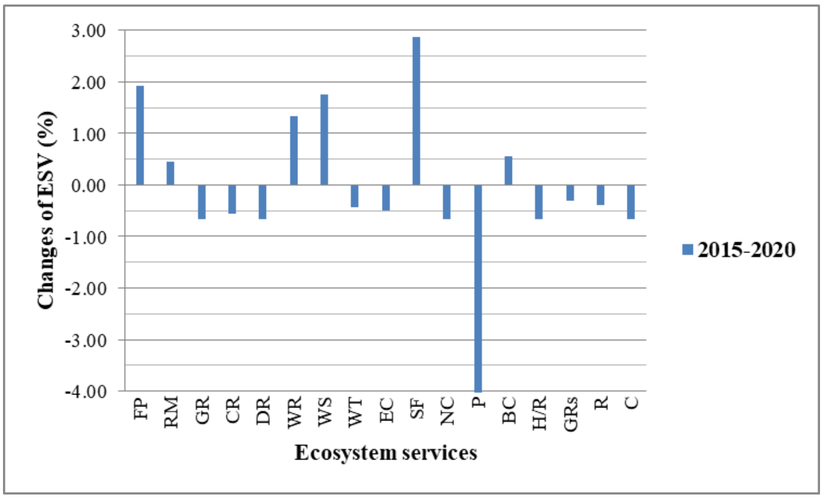


Figure 16. Changes of ESV (%) of each ecosystem services in Paung Laung RF from 2015 to 2020

Table 14. Estimated ESV for different ecosystem service types and the changes in the reference years in Paung Laung Reserved Forest from 2005 to 2020

Ecosystem Services	ESV of ecosystem services types (10^6 USD yr^{-1})				ESV Changes (10^6 USD yr^{-1})			ESV Changes (%)		
	2005	2010	2015	2020	2005 - 2010	2010 - 2015	2015 - 2020	2005 - 2010	2010-2015	2015 - 2020
Provisioning										
FP	66.76	73.88	74.06	75.48	7.12	0.17	1.42	10.66	0.24	1.92
RM	15.92	16.59	16.06	16.13	0.67	-0.54	0.07	4.20	-3.23	0.45
Regulating										
GR	1.86	1.77	1.68	1.67	-0.08	-0.09	-0.01	-4.44	-5.08	-0.67
CR	321.94	310.27	295.21	293.58	-11.68	-15.05	-1.64	-3.63	-4.85	-0.55
DR	10.21	9.76	9.26	9.20	-0.45	-0.50	-0.06	-4.44	-5.08	-0.67

WR	3.99	4.91	52.71	53.41	0.92	47.80	0.70	22.91	973.82	1.33
WS	10.19	12.51	23.99	24.41	2.32	11.48	0.42	22.81	91.81	1.75
WT	24.21	25.76	31.26	31.12	1.55	5.50	-0.14	6.42	21.36	-0.44
Supporting										
EC	53.57	51.86	49.38	49.14	-1.70	-2.48	-0.24	-3.18	-4.79	-0.49
SF	9.28	12.21	12.33	12.68	2.93	0.12	0.35	31.59	1.02	2.86
NC	0.46	0.44	0.42	0.42	-0.02	-0.02	0.00	-4.44	-5.08	-0.67
P	4.94	4.85	4.82	4.63	-0.08	-0.03	-0.20	-1.64	-0.68	-4.06
BC	2.14	2.26	2.19	2.20	0.11	-0.07	0.01	5.24	-3.03	0.57
H/R	6.03	5.77	5.47	5.44	-0.27	-0.29	-0.04	-4.44	-5.08	-0.67
GRs	248.62	244.14	233.20	232.49	-4.48	-10.94	-0.71	-1.80	-4.48	-0.30
Cultural										
R	137.46	132.31	140.35	139.79	-5.14	8.03	-0.55	-3.74	6.07	-0.39
C	0.31	0.30	0.28	0.28	-0.01	-0.02	0.00	-4.44	-5.08	-0.67
Total ESV	917.89	909.59	952.68	952.07	-8.30	43.09	-0.61	67.68	1047.87	-0.71

FP = Food Production; RM = Raw Materials; GR = Gas Regulation; CR = Climate Regulation; DR = Disturbance Regulation; WR = Water Regulation; WS = Water Supply; WT = Waste Treatment; EC = Erosion Control; SF = Soil Formation; NC = Nutrient Cycling; P = Pollination; BC = Biological Control; H/R = Habitat/ Refugia; GRs = Genetic Resources; R = Recreation; C = Cultural.

5. Discussion

5.1 ESV changes regarding to LULC changes

LULC dynamics are a significant driver of global change and impact ecosystem processes, biodiversity cycles and biodiversity (Liping et al., 2018). Myanmar was the country with the third-highest rate of deforestation in the world between 2010 and 2015 (FRA, 2015). Forests were converted into other land types due to agricultural expansion, illegal logging, infrastructure development, etc. The research area has also undergone significant LULC changes during the study periods. LULC changes have been observed in Paung Laung Reserved Forest mainly due to deforestation, forest degradation, agricultural expansion and dam construction.

Different drivers caused LULC dynamics in Paung Laung Reserved Forest. It was significantly observed that forests were mainly converted into other LULC types in the study area. Due to the gradually increasing population of forest dwellers (Local Administrative Offices), encroachment in the forest lands was gradually increasing (Myint, 2002). Closed forests were converted into open forests and cultivated land due to the increased population in the study area (Mon et al., 2009). Consequently, the population growth contributed to increasing pressure on food and agricultural land in Paung Laung Reserved Forest.

On the other hand, agricultural expansion was a major driver of deforestation in Myanmar [17,18]. In the hilly region of Myanmar, including Shan State, shifting cultivation was one of the significant causes of deforestation (Aung et al., 2018). Shifting cultivation, which caused to change from forest to cropland and scrubland, was a traditional framing system in Myanmar, including the study area conducted by indigenous ethnic groups (Mon et al., 2009; Myint, 2002; Zin, 2005b). It was still considered a main driver of deforestation in the mountainous regions of Myanmar (Mon et al., 2009). In the past, upland rice was grown using shifting cultivation systems. Now, this traditional cultivation had already changed to short-fallow shifting cultivation (Aung et al., 2018), which contributed to rapid LULC dynamics in the study area. Thus, the conversion of forest into agricultural land and scrubland was observed in this study throughout the reference periods.

Moreover, illegal logging was one of the drivers of LULC change in the study area. It was observed that logging activities were significant and one of the affecting factors of deforestation in the study area (Mon et al., 2009). The local people living in the study area traditionally and highly depend on natural resources, mainly forest resources, for their livelihood. According to timber extraction data of Taunggyi District (Local Forest Department), teak and hardwood were cut over the designated amount of timber extraction from 2014 to 2015. Moreover, the rural people extracted forest resources such as timber, firewood, and charcoal production, for household income in the study area. Thus, it was reported that the dependency on forests for fuelwood was 60 % of the consumption in Taunggyi District, including the study area (Sein et al., 2015).

Furthermore, directly or indirectly, hydropower dam construction interferes with natural ecosystem dynamics and can cause significant deforestation and forest degradation across the dam neighbourhoods (Chen et al., 2015). It was reported that water invasion was the second-largest driver of deforestation in the Bago Mountains, Myanmar (Shimizu et al., 2017). Infrastructure developments have emerged across Shan State in the last one or two decades. Forests were the major target of infrastructure developments for hydropower dam construction (Aung et al., 2018). In the study area, a hydropower dam was established in 2015 to generate electricity and provide water for agriculture (Kitahara, Sato, Win, et al., 2019). After dam construction, the areas of water bodies increased in terms of the massive conversion of forest into the water. As a result, the dam construction was a significant driver of LULC and the major cause of ESV change because there was a dramatic increase in the area of water bodies in the study area after the dam construction (Swe & Funakawa, 2019).

Consequently, LULC dynamics can degrade many ecosystems and significantly impact ecosystem services. ESV changes had occurred in the study due to LULC change during different study periods (2005-2010, 2010-2015 and 2015-2020). Specifically, the ESV of forest decreased significantly throughout the study periods, while the ESV of cropland, water and the built-up area gradually increased in Paung Laung Reserved Forest (Figure 12 and Table 13). In this study, the estimated total ESV was 917.89 million USD yr^{-1} in 2005, 909.59 million USD yr^{-1} in 2010, 952.68 million USD yr^{-1} in 2015, and 952.07 million USD yr^{-1} in 2020, respectively.

Forest is the major land cover in the study area and is identified to be the main provider of ecosystem services (Martínez et al., 2009). However, the ESV of forest decreased throughout the study period (2005-2020) mainly due to a decline in forested land. Thus, it was significantly observed that there was a decrease in the total estimated ESV during 2005-2010 and 2015-2020. The increased total ESV in 2010-2015 was mainly due to the huge increase in ecosystem services due to the water area expansion, which more than offset the decrease in ecosystem services due to the forest loss. As a result, this study revealed that a continuous decline in forest cover in the reserved forest over the periods was strongly linked to a decrease in total estimated ESV in the corresponding reference years. The results showed consistency with the previous findings. It was found that total ESV decreased by 25.4% from

1974 to 2004 due to forest loss in Pingbian County, China (R.-Q. Li et al., 2007). It was reported that there was a significant loss of ESV in Southwest China due to a huge conversion of forested areas to rubber plantations (Hu et al., 2008). A dramatic reduction of ESV has occurred in the Niger Delta of Nigeria due to forest degradation (Ayanlade, 2016). A decline in ESV was found in Ethiopia due to the loss of natural forests (Kindu et al., 2016a). A recent study revealed the decrease in ESV primarily due to forest loss in the Terai Arc Landscape of lowland Nepal (R. Sharma et al., 2019). On the other hand, the ESV increased from 19.78 billion Yuan from 1990-2000 due to expanded forest and grassland in the Qinghai Lake region (Gong et al., 2017). Similarly, the total ESV increased due to increased forested land in the Trans-Boundary Gandaki River Basin, Central Himalayas (Rai, 2018).

The water bodies in the landscape provide a wide range of goods and services that are important for maintaining ecosystems (R. Sharma et al., 2019). In terms of ESV, the water bodies provide the highest values of ecosystem services per hectare (Table 5). During the second period (2010-2015), total ESV increased mainly due to the enormous increase in ESV of water bodies, which more than offset the decrease in ESV of forest loss. Thus, a dramatic rise in total ESV was observed during 2010-2015 due to increased water bodies resulting from the dam construction. It was consistent with the findings of other studies. A recent study on the impact of land use change on ecosystem services in the tropical forested landscape of Nepal showed a significant decrease in ESV due to the loss of water resources (R. Sharma et al., 2019). Similarly, it was observed that total ESV decreased by 25.9% from 1985 to 2010 due to the significant losses of water bodies and farmland in Tianjin Binhai New Area, China (Long et al., 2014).

On the other hand, Costanza et al. (Costanza et al., 2014) developed valuation coefficients for each land class based on per hectare level. In the study area, there was a huge conversion of forest area into water bodies. For the estimation of ecosystem services value of each LULC class in a reference year, the area (hectare) of LULC class was multiplied by the valuation coefficients of ecosystem services. Moreover, the ecosystem services value of water per hectare per year is very high (12,512 USD ha^{-1} yr^{-1}). Thus, it was found that if the water area increases, the ecosystem services value will increase in the study. This finding was non-linear in the reality. In many previous studies, the adverse effects on the ecosystems and environment have been caused by the dam construction. Actually, it is necessary to evaluate the effects of dam construction in the downstream area because the water supply will decrease in the downstream area after the dam construction. However, the dam is located on the boundary of the study area. Thus, it was estimated ESV changes based on the extent of water area found within the study area. Moreover, the coefficients of value of ecological services for different types of land use are dynamic and complex. In addition, the valuation coefficient is not only related to the type of land use, biodiversity, and environment, but also closely related to scarcity of resources and local conditions. Thus, accurate assignments to local ecosystems should be based on long-term field studies and long-term experiments. It is necessary to accurately quantify the change in the regional ecological service value in a monetary form.

Furthermore, this study revealed ESV changes of individual ecosystem service functions due to LULC change. It was observed that the contribution of climate regulation, gas regulation, disturbance regulation, erosion control, genetic resources, habitat/refugia and pollination services decreased in the study area. In contrast, food production, water regulation, water supply and soil formation services increased throughout the study period. Previous studies reported adverse effects on soil erosion and biodiversity loss in the study area due to forest loss resulting from population growth and shifting cultivation (Mon et al., 2009; Myint, 2002).

Shifting cultivation, which altered forests into agricultural lands and scrublands, was one of the main drivers of deforestation in the study area (Mon et al., 2009; Myint, 2002; Zin, 2005b). In the study area, cropland expansion using the shifting cultivation system has significantly occurred during the study periods. Land use change into agricultural land in Paung Laung Reserved forest led to increased food production. Consequently, the ESV of food production services increased continuously throughout the periods, mainly provided by a significant increase in cropland during the study periods. It was consistent with the findings of previous studies from different regions of the world (Arowolo et al., 2018; Kindu et al., 2016b; Z. Wang et al., 2006). On the other hand, it was highlighted that the increased ESV of food production was the ESV loss of natural ecosystems in the long term (Arowolo et al., 2018) because the significant reduction of natural forests may result in the long-term degradation of environmental quality. Thus, forest conservation and reducing shifting cultivation in the study area should be fully focused on restoring and contributing ecosystems and services sustainably.

It was observed that the water-related ecosystem functions (water regulation and water supply) increased its ESV in four different study periods due to the impact of dam construction in the study area. The ESV gain from the ecosystem services of water regulation and water supply was also the same in other findings (Arowolo et al., 2018; Badamfirooz & Mousazadeh, 2019; Yong Liu et al., 2012). However, it was reported that the forest cover in the Paung Laung watershed area plays a vital role in getting adequate water supply for the dam (Mon et al., 2009). Thus, the ESV loss of water regulation and water supply services may be encountered in the near future because of a continuous decline in forest cover during the study periods.

LULC dynamics was observed in Paung Laung Reserved Forest in terms of the huge conversion of forests into other land types. Consequently, there was a continued decrease in forest area throughout the reference periods in the study area. Climate regulation, genetic resources and recreation were the main ecosystem services among 17 functions in the study area, accounting for 77.14% of the total ESV in 2005, 75.50% in 2010, 70.20% in 2015 and 69.94% in 2020, respectively. It was observed that the ESV of these ecosystem services continuously decreased throughout the periods. A continued decrease of ESV was mainly linked to forest loss because the forest was the dominant land cover in the study area and provided a wide range of ecosystem services such as climate regulation, biomass production, pollination, and the provision of habitats for forest species (Brockerhoff et al., 2017).

Forest loss is mainly attributable to human activities and natural factors in Myanmar and the world, which continue to threaten forest ecosystems, contributing to the loss of ecosystem services provided by forests (Brockerhoff et al., 2017). Previous studies showed forest cover decreased due to population growth (Myint, 2002), shifting cultivation (Aung et al., 2018; Mon et al., 2009), illegal logging (Mon et al., 2009), dam construction (Swe & Funakawa, 2019) in Paung Laung Reserved Forest, contributing an increase in croplands, scrublands, water bodies and built-up area. In this study, LULC dynamics was occurred mainly due to deforestation and forest degradation in the study area. Therefore, forest conservation is critical in Paung Laung Reserved Forest. Myanmar Forest Department mainly focused on forest conservation and protection under Myanmar Forest Law (1992) by establishing reserved forest (RF), protective public forest (PPF) and protected area systems (PAS) across the country. However, forests were still converted to other LULC types, which significantly impacted ecosystem services.

Based on the findings, the study suggested that public awareness for forest conservation, advanced agricultural technology, and alternative livelihoods should be introduced in the Paung Laung Reserved Forest to reduce deforestation and forest degradation because forests provide a wide range of ecosystem services. Community forestry should be encouraged to reduce the dependency of the locals on forests for their livelihoods. Some studies have shown that community forests can reduce the rate of deforestation and forest degradation in Myanmar (Feurer et al., 2018). Moreover, to create alternative livelihoods and reduce local dependency on forests, training on the production of value-added products (e.g., bamboo handicrafts) should be given to the locals. Furthermore, policymakers, environmentalists, conservationists, and land resource managers should take effective measures to restore the natural ecosystems of Paung Laung Reserved Forest because the ESV loss from natural ecosystems may contribute to the long-term degradation of environmental quality.

5.2 Limitations of the study

This study estimated the ESV changes based on LULC types derived from the satellite imagery using remote sensing and valuation coefficients of the corresponding ecosystems developed by Costanza et al. (Costanza et al., 2014) using the benefit transfer method. There are some limitations in the study to evaluate ESV change due to LULC change. Remote sensing data plays an essential role in assessing ecosystem services (Dawson et al., 2016), and LULC is widely used as a proxy measure to estimate the process of ecosystem services and their changes (Arowolo et al., 2018; Kindu et al., 2016b; Kreuter et al., 2001; Jinchang Li et al., 2010; Yong Liu et al., 2012; Rai et al., 2018; Song, 2018; Tolessa et al., 2017). All LULC types of the study were not perfectly the same as the 16 biomes identified by Costanza et al. (Costanza et al., 2014). For example, urban was used as a proxy for built-up area in the study. Thus, this study applied the nearest equivalent ecosystem type as a surrogate, contributing to estimating ESV.

In the case of LULC data, which were used as a variable to estimate ESV change, the main limitations were the resolution of the satellite imagery and the accuracy of LULC classification. Moreover, these limitations were linked with each other. It was pointed out that the LULC datasets derived from the satellite imagery with a high resolution provided more accurate ESV in the assessment of ecosystem services (Jiangyue Li et al., 2019). However, the satellite imagery with 30 m resolution was used in this study to derive LULC datasets for four different study periods because the imagery had no cost and was freely downloaded from the USGS. Thus, due to the limitation of satellite image resolution, a detailed classification of LULC cannot be performed in the study, contributing to the ESV change in the estimation of ESV due to LULC change. For example, forest land and scrubland cannot be classified in some areas in this study because it is challenging to classify forests and scrublands using satellite imagery with 30 m resolution. Moreover, the classification methods of LULC may have some uncertainties in the classification process (Jiangyue Li et al., 2019). On the other hand, the overall accuracy of LULC classification should meet at least 85% in the assessment LULC change (Anderson, 1976). The overall accuracy of LULC classification in the study was 89.46% in 2005, 87.14% in 2010, 86.34% in 2015 and 86.23% in 2020. However, some minor misclassifications may still have in the LULC classification, leading to some influence on ESV estimation. As a result, the ESV quality partly depends on the accuracy of LULC classification (Arowolo et al., 2018; Kindu et al., 2016b; Konarska et al., 2002; Yubin Liu et al., 2020). Thus, based on high-resolution satellite imagery, a more detailed LULC classification are essential to overcome these limitations (Arowolo et al., 2018; Kindu et al., 2016b; Konarska et al., 2002; Yubin Liu et al., 2020).

The benefit transfer method was used to estimate ESV in the study. This method plays a critical role in assessing ecosystem services (Costanza et al., 2014; Yubin Liu et al., 2020; Martínez et al., 2009). In this method, it is assumed that the values of ecosystem services are the same in the types of ecosystems (Arowolo et al., 2018; Kindu et al., 2016b). However, there may be a difference in most ecosystems and a high variation in the service beneficiary population in the actual situation. Thus, the method has been criticized because the estimated ESV produced by this method has high uncertainties due to the complex, dynamic and nonlinear properties of the ecosystems (Anderson, 1976; Turner et al., 2003). However, the method for ESV estimation has been widely applied in many previous studies (Arowolo et al., 2018; Kindu et al., 2016b; Yubin Liu et al., 2020) due to a quick assessment of multiple ecosystem services and a low cost in primary data collection. Moreover, the benefit transfer method is the only feasible option for estimation of ESV in the countries that faced financial crises with collecting primary data, especially in developing countries (Arowolo et al., 2018). Thus, the assessment of ESV using the benefit transfer method is very important in developing countries because of a large data and information gap, a high cost for ground data collection and less time-consuming.

On the other hand, the scale of the study is very important. In the study area, there was a dam in the study area in 2015-2020. This dam construction changed the watershed area of the study area. Consequently, the water area increased in the study area. However, for the down side of the watershed or the downstream area of the study area, it is necessary to conduct evaluating the effects of dam on ESV changes because the water supply will decrease because of the dam construction. However, the dam is located on the boundary of the study area. Thus, water-related ecosystem functions may decrease in the downstream area. In this study, evaluating ESV change was not conducted in the outside area of the study area.

As a final limitation of the study, it was challenging to fully focus on the research due to the Covid-19 outbreak and unstable political situations in Myanmar.

6. Conclusions

In this study, the estimation of ESV change in Paung Laung Reserved Forest during four different periods was conducted based on the LULC data gained from the satellite imagery using remote sensing techniques and the valuation coefficients using the benefit transfer method. It was the first study in Myanmar to estimate ESV change based on LULC data and the valuation coefficients.

(1) It was observed in the study that a continuous decline in forest cover was occurred throughout the study periods, while there was a rocketed increase in water bodies in 2015 due to the dam construction.

(2) It was observed that there was decreased total ESV in 2005-2010 and 2015-2020, and an increase in 2010-2015 due to a huge water area in the study area. It accounted for 917.89 million USD yr^{-1} in 2005, 909.59 million USD yr^{-1} in 2010, 952.68 million USD yr^{-1} in 2015, and 952.07 million USD yr^{-1} in 2020, respectively.

(3) It was observed that water-related ecosystem functions increased after the dam construction, while food production services also increased due to the impact of agricultural expansion, which was mainly caused by shifting cultivation.

(4) Deforestation and forest degradation occurred in the study area. Thus, the study revealed ESV loss in some ecosystem services (e.g., gas regulation, erosion control, genetic resources, etc.), mainly linked with a huge conversion of forests to other LULC types because the forest was the main provider of ecosystem services.

(5) Moreover, the study showed that climate regulation, genetic resources and recreation, which was mainly provided by forests, are important ecosystem services among 17 functions in the study area, accounting for 77.14% of the total ESV in 2005, 75.50% in 2010, 70.20% in 2015 and 69.94% in 2020, respectively.

However, the three crucial ecosystem functions for the study area have been gradually decreased due to a continuous decline in the forest throughout the periods, mainly caused by agricultural expansion, shifting cultivation, and dam construction. Consequently, if the drivers on natural ecosystems (e.g. deforestation and agricultural expansion, etc.) resulted from human activities cannot control in the study area, loss of ESV may continue to grow in the future. For the sustainable contribution of ecosystem services from natural ecosystems, Myanmar Forest Department should protect and conserve natural forests by establishing community forests to decline forest loss, creating alternative livelihoods to reduce the dependency on forests, formulating effective measures and conducting other activities to provide forest cover gain and prevent forest cover loss. The study can provide updated scientific data and information of ecosystem services in Paung Laung Reserved Forest, Myanmar, for policymakers, environmentalists, conservationists and land resource managers in the decision-making process of sustainable ecosystem management and forest management.

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