Songklanakarin J. Sci. Technol.
41 (2), 421-435, Mar. - Apr. 2019

http://www.sjst.psu.ac.th

Original Article

Change in economic value of forest ecosystem services caused by landslides in the upstream region of the lower northern Thailand

Kanchaya Maosew[1], Alongkorn Wongmun[1], and Jaruntorn Boonyanuphap[2*]

[1] *The Graduate School, Naresuan University, Phitsanulok, Mueang, 65000 Thailand*

[2] *Faculty of Agriculture Natural Resources and Environment, Naresuan University, Mueang, Phitsanulok, 65000 Thailand*

Received: 24 June 2017; Revised: 4 November 2017; Accepted: 30 November 2017

Abstract

The objective of this study is to assess the change in economic value of forest ecosystem services damaged by landslide in the upstream region. The valuation of forest ecosystem services in the upstream region of Maepoon Sub-district indicate that mixed deciduous forest with bamboo provided the higher value of ecosystem services of 54,780.88 $US/ha compared to mixed deciduous forest with the values of 49,780.31 $US/ha, respectively. Comparing the total values of forest ecosystem services after landslide condition (9 years ago) to normal condition of forest ecosystem services in the same ecosystem type can provide information on change in ecosystem services values damaged by landslides. In case of 9-year landslide condition, mixed deciduous forest with bamboo showed that there is the higher change in economic value of ecosystem services with 25,881.06 $US/ha, whereas mixed deciduous forest showed that there is the change in ecosystem services values of 25,895.69 $US/ha.

Keywords: forest ecosystem services, economic value, landslide, mixed deciduous forest, mixed deciduous forest with bamboo

1. Introduction

Services provided by natural ecosystems are crucial to our survival and humans who probably could not live without them (Nasi, Wunder, & Campos, 2002). Forests, particularly tropical forests, contribute more than other terrestrial biomes to climate-relevant cycles and also related biophysical processes (Luque & Iverson, 2016). Forest ecosystem services, as with other nature's services, have also been claimed to be of great economic value (Costanza *et al*., 1997; Pearce & Moran, 2001; Pearce & Pearce, 2001). In forest valuation studies, service components like carbon storage or hydrological protection frequently fetch higher values than forest products (Nasi *et al.*, 2002). Forest ecosystem functions support the provision of ecosystem services to humans. Those constitute the direct and indirect contributions of forest ecosystems to human wellbeing. In this context, ecosystem functions are a subset of the interactions between the ecosystem structure and the processes that underpin the capacity of an ecosystem to provide goods and services. Therefore, information and assessments of forest functions and services are of paramount importance for the design and implementation of effective sustainable forest management options and forest related policies (European Commission, 2015).

A landslide is currently common to mountainous and steeply sloping region around the globe. It is a critical problem affecting the economic welfare, food security, and public health of communities. Landslide can cause serious damages to ecological processes and ecosystem functions, and consequently lose to ecosystem services. On the 23rd of May 2006, the landslide-debris flow occurred in several places of the Lower Northern Thailand. Those destroyed about 4,000 houses resulting in about 10,000 people having to be permanently evacuated. They also damaged large areas of high potential agricultural growth in the highland and mountains in the region (Boonyanuphap, 2013). The impact of the 2006 landslide on functions of forest ecosystems has been a major cause of the limitation of local

*Corresponding author
Email address: charuntornb@nu.ac.th

economic and social developments in Maepoon Sub-district. Therefore, the main purpose of the study is to assess the change in economic values of forest ecosystem services damaged by landslide in the upstream region. The hypothesis of this study is "the value of ecosystem services, particularly in provisioning and regulating services, obtained from upstream forests of Mapoon Sub-district will be decreased caused by the 2006 landslide event". This study provided significant information on changes in forest ecosystem services and their economic values caused by the landslides, which can contribute to understanding the impacts of landslide on human welfare of the local communities and the downstream areas. Changing ecosystem service values caused by the landslides can also provide more effective local government policy-making for protecting and managing the natural upstream forests of Maepoon Sub-district with new insights.

1.1 Impacts of landslide on forest ecosystem

A landslide is a downslope movement of rock or soil, or both, occurring on the surface of rupture either curved (rotational slide) or planar (translational slide) rupture (Highland & Bobrowsky, 2008). This phenomenon results from the failure of the materials which make up the hill slope and are driven by the force of gravity. Landslides are currently common to almost every mountainous region around the globe, particularly in steeply sloping areas. It is a critical problem affecting the economic welfare, food security, and public health of communities. Landslides can be triggered by earthquakes, volcanic activity, changes in groundwater, a disturbance or change of slope and are typically associated with periods of heavy rainfall. Consequently, the areas exposed by landslide are completely changed and contributed to soil erosion, sediment deposition, and land degradation (Bockheim, 1997). Moreover, landslide causes a series of on-site and off-site damaged including soil and nutrient loss (Martı´nez-Casasnovas & Ramos, 2006), long-term productivity loss of degraded soils (Gunatilake & Vieth, 2000) and a wide range of environmental problems derived from sediment delivery to the drainage network and reservoirs (Verstraeten *et al.*, 2003). Therefore, landslide can be a natural direct cause of forest degradation resulting from significant changes in forest structure that diminishes or destroys its ability to deliver certain services.

1.2 Valuation of forest ecosystem services

Forest ecosystem services can be grouped under use and non-use, direct and indirect values. Examples of direct use values in forests include timber, non-timber products and non-commodity benefits such as forest recreation. Indirect use values include the services of forests in protecting watersheds, fisheries and carbon storage. Non-use (option, existence and bequest) values include values attached to forests merely because they exist, or values attached to maintaining them for future options to use them or as bequests to coming generations (Nasi *et al*., 2002).

One of the first studies to estimate the annual value of world's ecosystem services was by Costanza *et al*. (1997). Costanza *et al*. (2014) reported that the valuation of tropical forest ecosystem service in year 2011 provided the average values of 5,382, 3,137, and 13,786 $US/ha/yr (international USD for the year 2007) for tropical forests, temperate/boreal forests, and tidal marsh/mangroves forests, respectively. Peng, Chen, Liu, and Wang (2008) assessed the values of ecological functions of forests at local scale of Nanjing, which showed the values of 111 $US/ha/yr (international USD for the year 2013) for runoff reduction by vegetated land versus non-vegetated lands.

However, valuation of forests is nevertheless fraught with complexity and ambiguity. Most forest ecosystem services accrue to the recipients as public goods. They may be enjoyed by a number of people without affecting other people's enjoyment. Other services may be quasi-public goods, where at a certain level of use, other people's enjoyment may be diminished. The problem with public goods is that, although people value them, no one person has an incentive to pay to maintain the goods (Nasi *et al*., 2002).

Gregersen, Arnold, Lundgren, and Contreras-Hermosilla (1995) assumed that the incomplete valuation of the forest goods and services is one of the main reasons contributing to deforestation and forest degradation. If the total economic value of forests was really taken into account, then people would recognize their importance and better protect and manage forest ecosystems. Valuation results can also influence or justify land-use and natural resources management decisions, including in terms of fiscal accountability and public support and internalization of costs. Forest valuation is therefore a tool that can provide society and decision-makers with information for deciding among alternatives or upon preferred combinations of possible interventions (Kengen, 1997).

Economic valuation studies can be useful tools in pointing out the structure of costs and benefits, and have frequently illustrated the dominance of forest-service elements in the total economic value of forests. However, valuation studies should generally pay greater attention to per household (rather than exclusively per-hectare) values, to the real possibility to capture this value and to the distribution of costs and benefits among different stakeholders. As scientists get a clearer picture of ecosystem functions, new services from forests may unfold. This is in itself an argument for providing incentives to slow down forest loss, even where there are marginal economic returns to be made at the private and national levels (Nasi *et al*., 2002).

2. Materials and Methods

2.1 Study area

This study was conducted in the upstream region of Maepoon Sub-district, located in Lablae District, Uttaradit province with geographical location at 17°39′10″ to 17°48′ 40″N and 99°57′10″ to 100°02′10″E. It is a total area of about 13,178 ha. The altitude varies from about 80 m above mean sea level in the flat area in the southeast region to 950 m in mountainous and steeply sloping areas in the western and northern regions. The slope of the mountainous areas is commonly ranging from 30 to 75 degree. The local climate is classified as tropical monsoon and trade-wind littoral climate or Köppen's Am (Land Development Department, 1998). The mean annual rainfall in the study area is 1,610.61 mm with mean annual evaporation of 1,914 mm. This area, 5 to 6 months of rain, is observed in a year (May to October), and the mean annual humidity is 75 % while, the mean annual temperature is 28.2°C (data averaged from 1987 to 2016). Land use map of year 2016 was made by visual interpretation of GeoEye-1 satellite images (Boonyanuphap, Thonglem, & Raksanok, 2016). The study area consists of several landuse types with different purposes and situations such as natural mixed deciduous forest, mixed deciduous forest with bamboo, mixed fruit tree-based agroforestry on mountainous area, flat land mixed-fruit tree orchard, lowland paddy field, rural community and residential areas, building and commercial areas, and water body and streams. Most of the upstream region in the study was covered by mixed fruit tree-based agroforestry approximately 5,477 ha (51.88% of the study area), whereas, the natural forests were about 2,900 ha (27.45% of the study area). The landslide damaged-forests was about 428 ha (4.05%), whereas, the landslide damaged mixed-fruit tree agroforestry was found in 724 ha (6.86%), The natural upstream forest areas have decreased by 851 ha during year 2006 to 2016, which damaged of 428 and 423 ha by landslide and illegal land clearing, respectively (Boonyanuphap *et al*., 2016).

The 2006 landslide-debris flows occurred in several places of lower Northern Thailand such as Uttaradit, Sukhothai, Phrae, Lampang, and Nan Provinces. The total economic losses were recorded as 6,000 million Baht (about US$ 150 million), with at least 87 fatalities while 29 people are still missing. A number of 697 house buildings were completely destroyed by this event, whereas 2,970 house buildings were partially destroyed (Asian Disaster Preparedness Center, 2006). The landslide also seriously damaged large areas of natural forest in the highland and mountainous regions of the lower Northern Thailand (Figure 1). The upstream region of Maepoon Sub-district, Lablae District was the worst affected area from this event. About 1,021 hectare of mountainous highland in the upstream region has completely been destroyed by the landslide, while some hundred hectares of lowland and property were damaged by the debris and mud flash flood (Land Development Department, 2006).

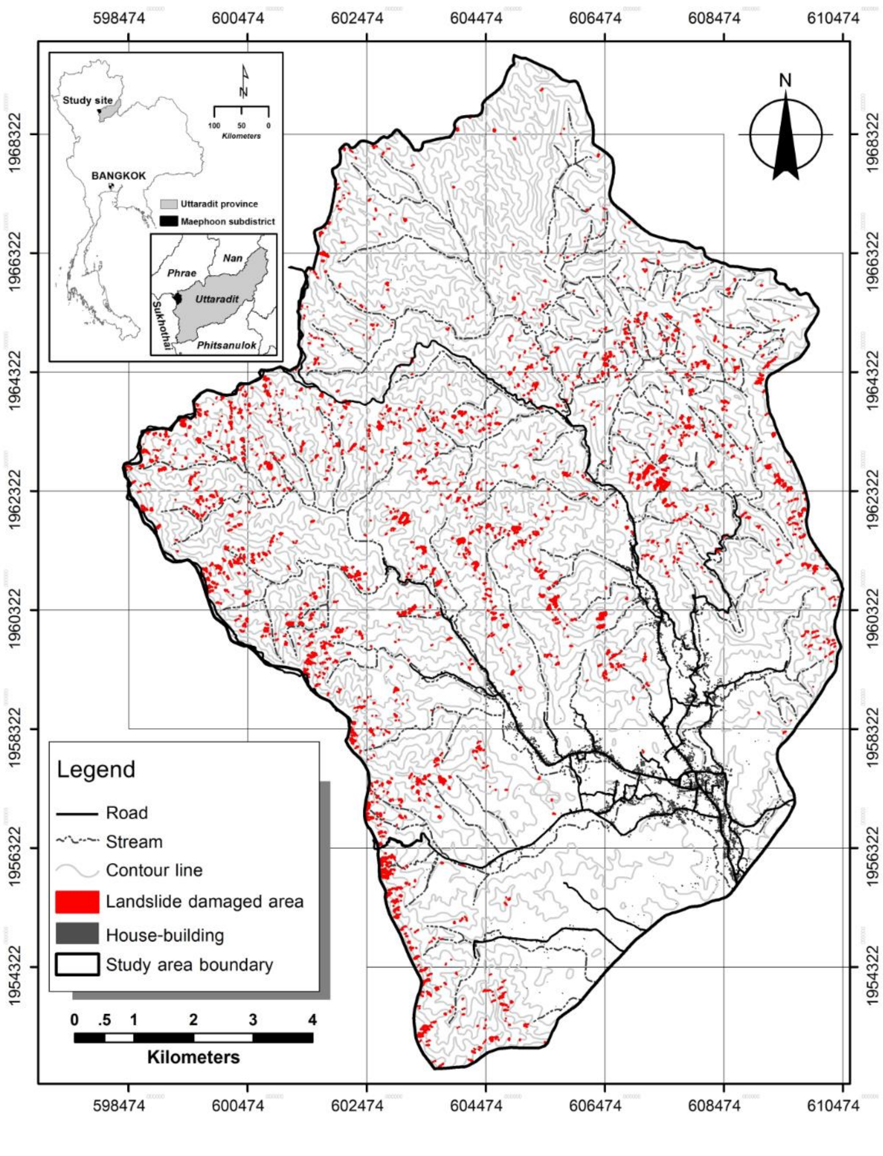

Figure 1. Locations of the study area and landslide in year 2006 at Maepoon Sub-district, Uttaradit Province, Thailand (Boonyanuphap 2013).

2.2 Categories of forest ecosystem services

This study emphasized on economic valuation of goods and services, which are provided from each forest type regarding the Millennium Ecosystem Assessment (MA) (Millennium Ecosystem Assessment, 2005). There are three basic categories of forest ecosystem services shown in Table 1. Comparing the values of ecosystem services after landslide (9 years ago) and normal condition in the same forest type can provide information on change in economic values of forest ecosystem services damaged by landslides. It is evident not a recreational and aesthetic experiences or any spiritual enrichment that the local communities or downstream people can obtain from forest ecosystem in the upstream region of Maepoon Sub-district. Thus, the valuation of cultural services was not included in this study

Table 1. Ecosystem services categories for this study

Ecosystem services categories	Items
Provisioning services	- Fuel (Fuelwood: Bio-energy) - Timber (Construction, Furniture, Agricultural tools & equipment) - Natural bamboo poles - Soil material (Source of raw materials for real estate landscaping, road and building construction)
Regulating services	- Soil nutrient storage (N, P, K, Ca, Mg) and organic matter storage - Soil water storage for agricultural propose - Erosion control (soil loss prevention)

2.3 Data collection and analysis

The natural forest ecosystems in the upstream regions of Maepoon Sub-district were classified into 2 types, both normal condition and 9-year landslide condition, 1) mixed deciduous forest and 2) mixed deciduous forest with bamboo. Five 0.1-ha rectangular plots (20m x 50m) were established within four different ecosystem types: mixed deciduous forest (MNSL), mixed deciduous forest after 9-year landslide (MNSL), mixed deciduous forest with bamboo (BNSL), and mixed deciduous forest with bamboo after 9-year landslide (BSSL). A 0.1-ha plot was subdivided into ten of 10m x 10m sub-plot, where all tree and lianas are larger than 4.5 cm diameter at breast height (DBH) were intensively counted, measured and identified. In most cases the diameter of each tree was measured at breast height, 1.3 m above ground. However, stems with irregular trunks were measured at the nearest lower point where the trunk was cylindrical (Makana, 1999). Trees with buttresses rising near or beyond 1.3 m were measured at least 0.5 m above buttresses. Tree diameter was measured by diameter tapes and recorded to the nearest 0.1 cm. Trees with multiple stems were counted as single individuals, but the diameter of each stem was measured and recorded separately. Tree height was determined by Haga altimeter combined with fiberglass measuring tape.

A sub-plot size of 4 m x 4 m and 1 m x 1 m was designated at the lower left corner of each 10 m x 10 m sub-plot. On the 4 m x 4 m sub-plots, shrub and poling plant species with less than 4.5 cm DBH and taller than 1.30 m height were surveyed and recorded. Species of sapling, seedling, herb, climber, and all understory plant were recorded for each 1 m x 1 m sub-plot. The most common tree and other plant species, identification was made directly in the field. When definitive field identification was not possible, the dried plant specimens were collected and later identified with the help of local floras (Bunyavejchewin, LaFrankie, Baker, & Davies, 2009; Gardner, Sidisunthorn, & Anusarnsunthorn, 2000). In addition to botanical data, site observation was carried out at the center of each 0.1-ha plot to obtain environmental information, including geocoordinate locations (x,y), slope, aspect, altitude, canopy cover, and level of landslide damage. However, landslide situation in this study area was under the ecological secondary succession, which happened nine years ago of the 2006 landslide events.

Twenty soil profiles with the depth of 150 centimeters were conducted at the center of each 0.1-ha plot for describing morphological characteristics and analyzing physical chemical and hydrological properties of both ecosystem types including normal condition and 9-year landslide condition. Because of the spatial variability of soil properties on given forest ecosystems, five replicate samples were required to estimate nutrient pools and soil organic matter (SOM) content for both forest types including normal condition and 9-year landslide condition. All soil profiles were taken at least 50 m distance from the edge of each forest area to minimize the edge effects, however, it was dependent on size and shape of the selected sampling areas.

The questionnaire was designed based on the important required data used for valuation of ecosystem service, particularly in provisioning services. It was contained both open- and closed-ended questions. The questionnaire was used to obtain data on the annual usage number and values of timber and non-timber forest products. The target beneficiaries were the local households that can gain goods and income from forest products and some of other material benefits provided by forest ecosystem (such as fuelwood, bamboo poles, timbers, water for agricultural purpose), including forest product collectors and mixed fruit tree-based agroforestry landowners in the upstream region of Maepoon Sub-district. There were 59.50 percent or 972 households of the total number of households in Maepoon Sub-district (1,635 households in 2015). Therefore, the 284 respondent was calculated by using Taro Yamane (Yamane, 1973) formula with 95% confidence level (Equation 1).

$$n = \frac{N}{1 + N(e^2)} \tag{1}$$

where n is sample size, N is total population (972 households), and e is the level of significance (0.05).

The basic characteristics of the respondents shows that about 89.8 % of the respondents were agriculturists particularly, fruit tree horticulturists. The respondents were about 46.5% males and 53.5% females, aged mostly between 51-60 years old. Most of the respondents (94.5%) had been living in the area for more than 20 years. About 26% of them own agricultural lands in the upstream region of 5-10 Rai (0.8-1.6 ha) and 19% own lands of 11-15 Rai (1.76-2.4 ha) in size. The annual household income of most of the respondents (24.4%) was between 50,001-100,000 Baht.

2.4 Quantification and valuation of forest ecosystem services

Generally, all provisioning services i.e. timber, fuelwood, and natural bamboo culm can be directly valued in local market prices, which are available in local communities. However, this study provided an estimate of gross values, not economic values or net benefits, of timber, fuelwood, and natural bamboo culm obtained from the forest ecosystems due to a variation of travel costs and landscape conditions to harvest the woody plant and bamboo in the upstream regions of Maepoon Sub-district. The values of nutrient storage, soil water storage, erosion control, and soil formation could not be easily measured or quantified in physical units. Sometimes shadow prices were necessary for accurate economic estimation where market imperfection and distortions existed (Boonyanuphap, 2013).

2.4.1 Timber valuation

In this study, the characteristic of selected good quality timber tree species that were valued should have smooth erect stems with greater than 15 cm in diameter and longer than 6 m in length. Timber price of each selected economic tree species was calculated by median price per timber (6 m length for each timber), which information on median timber price of each selected species was obtained by interviewing the local communities. The total timber value per area unit of each forest ecosystem was estimated by the sum of each tree species density multiplying by number of timber per individual tree and timber price of each tree species as shown in Equation 2.

$$TimberValue \ = \sum_{i=1}^{n} (D_i \times Tm \times P_i) \quad (2)$$

where D_i is density of the ith selected economic tree species (trees/Rai), Tm is the number of timber per individual tree, P_i is timber price of the ith species (Baht/timber).

2.4.2 Valuation of fuelwood plants

All woody plant species with less than 15 cm in diameter and non-economic tree species were selected for fuelwood valuation, which did not include all selected economic trees that were used for timber valuation. The total height (Ht) and diameter at breast height (DBH) of the selected fuelwood species were measured in the field. Aboveground biomass of individual tree was calculated by summing the stem, branches and leaf mass of individual tree, using the allometric equation of Ogawa, Yoda, Ogino, and Kira (1965) for both forest ecosystem types, as follows:

$$\text{Stem (Ws)} = 0.0396 * ((DBH^2\ Ht)^{0.9326})$$
$$\text{Branch (Wb)} = 0.003487 * ((DBH^2\ Ht)^{1.027})$$
$$\text{Leaf (Wl)} = ((28.0/Ws+Wb) + 0.025)^{-1}$$

where Ws is stem mass (kg/individual tree), Wb is branches mass (kg/individual tree), and Wl is leaf mass (kg/individual tree).

The local price of mixed fuelwood from both forest ecosystems was about 1.50 Baht per kg (0.041 $US per kg). The total fuelwood value per area unit of each forest ecosystem was calculated as shown in Equation 3.

$$\text{Fuelwood value} \quad = \sum_{i=1}^{n} (AGB_i \times P_i) \quad (3)$$

where AGB_i is above ground biomass of the ith selected fuelwood species (kg /Rai), P_i is timber price of the ith species (Baht/kg).

2.4.3 Valuation of natural bamboo culm

The bamboo culm (or stems) of all species have traditionally been used in local communities. A bamboo culm was mainly used as a construction and furniture materials. The usable good-quality bamboo culm is commonly higher than 6 m. The information of total bamboo clumps and number of culms per clump occurring in each 0.1 ha plot was recorded. The total value of bamboo culm per area unit was calculated as shown in Equation 4.

$$\text{Bamboo culm value} \quad = \sum_{i=1}^{n} (D_i \times P_i) \quad (4)$$

where D_i is culm density of the i[th] bamboo species (culm/Rai), P_i is bamboo culms price of the i[th] bamboo species (Baht/culm).

2.4.4 Valuations of soil nutrient pools

Soil is one of the principal substrata of life on Earth, serving as a reservoir of water and nutrients, as a medium for the filtration and breakdown of injurious wastes, and as a participant in the cycling of carbon and other elements through the global ecosystem. Nutrient pools are generally reported in terms of kg/ha. Chemical analyses of solid-phase nutrient concentrations are determined on a weight basis (g nutrient per kg of soil) for each soil horizon. To convert nutrient concentrations on a weight basis to a unit area basis (i.e., kg/ha), the effective volume of the rooting zone and the mass of soil contained within this zone must be determined. The soil mass of each horizon is calculated by measuring the thickness of each horizon and multiplying by the bulk density (BD.), which can be obtained by the coring method (Dahlgren, 1999).

Soil analyses are typically performed on the less than-2 mm soil fraction and it is assumed that the larger 2-mm fraction has a negligible nutrient supplying capacity. Thus, to determine the effective nutrient storage volume of each horizon, the coarse fragment volume (>2-mm), such as rock fragments and root distribution, is subtracted from the total volume of soil within a given horizon. Soil samples in each soil pit were collected for five horizons i.e. 0-5, 20-30, 50-60, 90-100, and 100-150 cm in depths. The soil nutrient pools associated with a given soil were then determined by summing the nutrient pool associated with each soil horizon within the depth of 150 cm as shown in Equation 3 (Dahlgren, 1999):

$$\text{Nutrient pool}\left(kg/ha\right) = SH_1^n \times \left[\left[T \times BD\right] \times V_{<2-mm}\right] \times \text{NC} \times 10^5 \quad (5)$$

where SH_1^n is the summation of each individual soil horizon within the depth of 150 cm, T is horizon thickness (cm), BD is bulk density (g/cm^3), $V_{<2\text{-mm}}$ is the less than 2-mm volume percentage (%), NC is nutrient concentration (g/kg), and 10^5 is the conversion factor to obtain the final unit of kg/ha (1 ha = 6.25 Rai).

Changes in contents and values of nutrients (N, P, K, Ca, and Mg) and soil organic matter (considered as the primary pools or reservoirs of nutrients in a soil) could be obtained and then monetized corresponding to the local market prices of commercial chemical and organic fertilizers (Boonyanuphap, 2013). The amounts of N, P, K, Ca, Mg, and organic matter available in soil were valued in relation to the fertilizer price of 46-0-0, 18-46-0 (DAP), 0–0–60 (MOP), 75% of Ca for CaO fertilizer, 9.8% of Mg for $MgSO_4$ fertilizer, and 75% of organic matter for organic fertilizer, respectively.

2.4.5 Valuation of soil material

Soil has been used as a raw material for road and building construction, in real estate landscaping, and in kitchenware and fuel industries (Comerford *et al*., 2013). Soil materials can give the benefits of provisioning services to human well-being and economy. Moreover, Daily *et al*. (1997) suggested that soils are one of the important determinants of a nation's economic status, and that the inclusion of soils in ecosystem services frameworks and policy and decision-making is essential. Soil materials value was assessed by using a local price of the whole soils for real estate, road and building construction, which were calculated from Equation 6.

$$S_m = Q_m \times P_m \quad (6)$$

in which S_m is the soil materials value (Baht/Rai), Q_m is an amount of soil volume (Cubic meter), and P_m is a local price of the soils for construction (133.33 Baht/cubic meter).

2.4.6 Valuations of erosion control

The Universal Soil Loss Equation (USLE) developed by Wischmeir and Smith (1978) was used to estimate soil erosion for each forest ecosystem, which is mathematically denoted as Equation 7.

$$A_i = \text{R} \times \text{K} \times \text{L} \times \text{C} \times \text{P} \quad (7)$$

where A_i is annual soil loss of the i^th ecosystem (tons/ ha), R is rainfall and runoff factor representing the summed erosive potential of all rainfall events in a year, K is soil-erodibility factor representing units of soil loss per unit of rainfall erosivity, L is length of slope factor, S is slope gradient factor, C is cropping-management factor, and P is conservation practice values.

Soil loss values of each forest ecosystem (SL_i) was calculated by multiplying an annual soil loss (A_i) of each forest ecosystem to a local price of the whole soils for construction and real estate landscaping (1 cubic meter of soil is estimated as 1.5 tons, which is noted by Nuanmano, 2013). The valuation of soil loss prevention for each forest ecosystem is on the basis of comparing the difference in soil loss values between normal condition and 9-year landslide condition in the same forest type, which is calculated as following equations:

$$SL_i = A_i \times P_S \text{ ; and } SLV = SL_{NS} - SL_{SS}$$

Where *SL* is soil loss values (Baht/Rai); *i* is condition of forest ecosystem (NS: normal condition; SS: 9-year landslide condition); A_i is annual soil loss (tons/Rai); P_S is a local price of soils (133.33 Baht/cubic meter or 88.67 Baht/tons); *SLV* is soil prevention value of each forest ecosystem (Baht/Rai).

2.4.7 Valuations of soil water storage

The value of yearly soil water storage for each forest ecosystem was calculated regarding the total available water holding capacity or available water content (AWC) for each soil horizon of each forest type. Total available water capacity is a range of available water that can be stored in soil and be available for growing common plants, which can be assessed by finding the difference between water content at field capacity (θ_{fc}) and permanent wilting point (θ_{pwp}) over the depth of rooting (150 cm for this study). The water contents at field capacity and permanent wilting point for each soil horizon were estimated from texture-based method reported by Saxton *et al*. (1986). The amount of total soil water holding capacity downward through a depth of 150 cm ($SWHC_T$) for each forest ecosystem type was calculated from the sum of total soil water holding capacity for each horizon, which is defined as Equation 8.

$$SWHC_T = \sum_{i=1}^{n} SWHC_i \quad (8)$$

where n is the number of soil horizon.

However, calculation of a yearly total soil water holding capacity ($SWHC_R$). must be related to mean monthly rainfall in the study area. The series data of monthly rainfall has been recorded between year 2008 and 2016. The mean monthly rainfall was converted in terms of volume (cubic meter per Rai; 1 Rai=0.16 ha), which was used to estimate the monthly maximum soil water holding capacity ($SWHC_{MRi}$). On the basic assumption that the amount of mean monthly rainfall *(NR)* in area of 1 Rai is defined as a total rainfall of particular months without any consideration for topography and some hydrological processes such as infiltration rate, evapotranspiration, canopy interception and litter cover. Therefore, calculation of yearly total soil water holding capacity ($SWHC_R$) was under specified conditions as follows.

IF $MR_i < SWHC_T$, then $SWHC_{MRi} = MR_i$;
IF $MR_i \geq SWHC_T$, then $SWHC_{MRi} = SWHC_T$

$$SWHC_R = \sum_{i=1}^{n} SWHC_{MRi} \quad (9)$$

where $SWHC_{MRi}$ is the monthly maximum soil water holding capacity in area of 1 Rai, *i* is each month of the year (n=12).

In this study, the total available water holding capacity was assumed as soil water used for agricultural purposes. Therefore, the value of yearly soil water used for agricultural purposes (V_{AWC}) can be estimated by the sum of the values of monthly soil water used for agricultural purposes (V_{AWCi}) in a year. The monthly soil water used for agricultural purposes can be calculated by multiplying the monthly maximum soil water holding capacity $SWHC_{MRi}$ to the cost of water pumping service for agricultural purposes (S). The cost of water pumping service for normal rate was 2.0889 Baht per unit (0.0603 $US per unit; 1 $US = 34.64 Baht) for the first hundred units (1 Unit=1 Cubic meter), whereas the next unit was 3.2405 Baht or 0.0884 $US (Metropolitan Electricity Authority, 2015), which was calculated from Equation 10.

$$V_{AWCi} = (SWHC_{MRi100} \times S_1) + (SWHC_{MRi>100} \times S_2) \quad (10)$$

where V_{AWCi} is the value of monthly soil water used for agricultural purposes (Baht), S_1 is 2.0889 Baht per unit, S_2 is 3.2405 Baht per unit, *i* is each month of the year, $SWHC_{MRi100}$ is monthly maximum soil water holding capacity within the first hundred units (Cubic meter), $SWHC_{MRi>100}$ is monthly maximum soil water holding capacity ($SWHC_{MRi}$) for exceed the first hundred units (Cubic meter), which was defined that if $SWHC_{MRi}$ is not exceed the first hundred units then $SWHC_{MRi>100}$ is set as zero.

The value of yearly soil water used for agricultural purposes (V_{AWC}) can be estimated by the sum of the values of monthly soil water used for agricultural purposes (V_{AWCi}) in a year as Equation 11.

$$V_{AWC} = \sum_{i=1}^{n} V_{AWCi} \quad (11)$$

where n is month of the year (n=12).

3. Results and Discussion

3.1 Timber values

Tree densities were 702.5 trees per hectare (112.4 trees per Rai) and 576.67 trees per hectare (92.27 trees per Rai) for mixed deciduous forest and mixed deciduous forest with bamboo, respectively. The tree density after 9-year landslide condition was lower than that of normal condition for both forest types. Mixed deciduous forest damaged by the landslide had tree density of 206.67 trees per hectare (33.06 trees per Rai), whereas mixed deciduous forest with bamboo damaged by the landslide had higher tree density of 520 trees per hectare (83.2 trees per Rai). The healthy forest ecosystems under normal condition generally had higher economic tree species richness and density than that of the forest ecosystem damaged by 9-year landslide condition. The medium to large-sized trees (DBH of 21-108 cm with higher than 10 m) with high economic value were commonly found in both forest types. These economic tree species, such as *Pterocarpus macrocarpus* Kurz, *Xylia xylocarpa*, *Lagerstroemia calyculata*, *Crypteronia paniculata*, *Diospyros mollis*, *Anogeissus acuminate*, *Lagerstroemia calyculata* are suitable for construction, furniture, local agricultural tools and any equipment. The forest ecosystems damaged by 9-year landslide condition were dominantly composed of the smaller-sized economic trees species with DBH of 10-39 cm such as *Mallotus paniculatus* Mull. Arg., *Fernandoa adenophylla*, *Albizia odoratissima*, *Crypteronia paniculata* Blume, *Lagerstroemia venusta*, and *Xylia xylocarpa*.

The timber values categorized by different forest ecosystems shows that mixed deciduous forest with bamboo had the highest timber value of 54,240 Baht per Rai, followed by mixed deciduous forest with the timber value of 40,426.67 Baht per Rai. The forest damaged by 9-year landslide condition had much less timber value of 373.33 and 5,333.33 Baht per Rai for mixed deciduous forest and mixed deciduous forest with bamboo, respectively (Table 2).

3.2 Fuelwood values

The fuelwood consumption was quite high in communities of Maepoon Sub-district. Most of respondents usually used woody plants and even large-sized non-economic trees (such as *Nephelium hypoleucum*, *Harrisonia perforata*) as fuelwood for household cooking and local food shops. Mixed deciduous forest provided the biomass of 4,784.95 kg per Rai (29,905.93 kg per ha) for fuelwood, followed by mixed deciduous forest with bamboo and could also provide the biomass of 1,586.79 kg per Rai whereas mixed deciduous forest and mixed deciduous forest with bamboo under the landslides had the biomass of 407.90, and 928.13 kg per Rai, respectively.

Mixed deciduous forest had the highest fuelwood value of 7,177.43 Baht per Rai (1,224.32 $US per ha), followed by mixed deciduous forest with bamboo with providing the value of 2,380.19 Baht per Rai whereas the forest damaged by the landslide had much less fuelwood value of 611.85 and 1,392.19 Baht per Rai for mixed deciduous forest and mixed deciduous forest with bamboo, respectively.

Table 2. The timber values of individual economic tree species categorized by different forest ecosystems.

Species	Number of trees per Rai	Price (Baht)	Value of timber (Baht)
MNSL			
Albizia odoratissima Benth.	2.67	700.00	1,866.67
Colona flagrocarpa Craib var. siamica Craib	2.13	500.00	1,066.67
Vitex canescens Kurz	1.60	900.00	1,440.00
Pterocarpus macrocarpus Kurz	1.07	5,500.00	5,866.67
*Canarium subulatum*Guillaumin	1.07	8,500.00	9,066.67
Crypteronia paniculata Bl.	1.07	700.00	746.67
Colona floribunda (Kurz) Craib	0.53	500.00	266.67
Mesua ferrea L.	0.53	5,500.00	2,933.33
Xylia xylocarpa Taub. var. kerrii Nielsen.	1.07	10,000.00	10,666.67
Lagerstroemia calyculata Kurz	0.53	3,500.00	1,866.67
Vitex peduncularis Wall. ex Schauerr	0.53	700.00	373.33
Garuga pinnata Roxb.	0.53	8,000.00	4,266.67
		Total value	40,426.67
MSSL			
Crypteronia paniculata Bl.	0.53	700.00	373.33
		Total value	373.33
BNSL			
Pterocarpus indicus Willd.	1.07	5,500.00	5,866.67
*Canarium subulatum*Guillaumin	0.53	8,500.00	4,533.33
Terminalia bellirica (Gaertn.) Roxb.	1.07	900.00	960.00
Albizia odoratissima (L.f.) Benth.	0.53	700.00	373.33
*Lagerstroemia duperreana*Pierre ex Gagnep.	1.07	3,500.00	3,733.33
Vitex quinata (Lour.) F. N. Williams	0.53	500.00	266.67
Vitex canescens Kurz	2.67	900.00	2,400.00
Sterculia guttata Roxb. ex	1.07	500.00	533.33
Tetrameles nudiflora R.Br.	0.53	1,500.00	800.00
Diospyros mollis Griff.	0.53	25,000.00	13,333.33
Senna garrettiana (Craib) H.S.Irwin & Barneby	1.60	2,000.00	3,200.00
Terminalia nigrovenulosa Pierre	1.07	500.00	533.33
Anogeissusacuminata (Roxb.ex DC.)	1.07	7,000.00	7,466.67
Artocarpus lacucha Buch.-Ham.	1.07	1,000.00	1,066.67
Garuga pinnata Roxb.	0.53	6,000.00	3,200.00
Cananga latifolia (Hook.f. & Thomson)	0.53	700.00	373.33
*Dipterocarpus turbinatus*C. F. Gaertn.	0.53	4,500.00	2,400.00
Polyalthia viridis Craib	0.53	6,000.00	3,200.00
		Total value	54,240.00
BSSL			
Xylia xylocarpa Taub. var. kerrii Nielsen.	0.5333	10,000.00	5,333.33
		Total value	5,333.33

Site's names were designed by forest ecosystem at plan communities survey; MNSL, Mixed deciduous forest; MSSL, Mixed deciduous forest under landslide; BNSL, Mixed deciduous forest with bamboo; BSSL, Mixed deciduous forest with bamboo under landslide; Unit, Rai = 1,600 m^2 or 0.16 ha.

3.3 Values of natural bamboo poles

Five native usable bamboo species were originally found that they grew in upstream ecosystem of Maepoon Sub-district, namely *Dendrocalamus strictus* (Roxb.) Nees, *Gigantochloa hasskarliana*, *Gigantochloa albociliata* (Munro) Munro, *Melocanna bumillis* Kurz, *Cephalostachyum virgatum*, and *Gigantochloa densa*. Bamboo pole prices were 5 Baht per stem for *Melocanna bumillis* Kurz and *Gigantochloa densa*, 7 Baht per stem for *Cephalostachyum virgatum*, and 8 Baht per stem for *Gigantochloa albociliata*. While the pole of *Dendrocalamus strictus* was the highest price of 15 Baht per stem. The bamboo densities after 9-year landslide condition were much less than the healthy forest ecosystems. *Dendrocalamus strictus* was the only bamboo species found in both forest types after 9-year landslide condition with an average of 6.67 stem per Rai (41.65 stem per ha). Mixed deciduous forest with bamboo had bamboo density of 186.13 stem per Rai (1,163.31 stem per ha), which was denser than that of the mixed deciduous forest with the bamboo density of 89.6 stem per Rai (560 stem per ha).

Mixed deciduous forest with bamboo provided the value of 2,931.14 Baht per Rai (499.99 $US per ha), followed by mixed deciduous forest with providing the value of 676.0 Baht per Rai. In case of 9-year landslide condition, mixed deciduous forest with bamboo and mixed deciduous forest provided the bamboo values of 120.00 and 79.95 Baht/Rai, respectively.

3.4 Values of soil nutrient and organic matter storages

Soils play a pivotal role in major global biogeochemical cycles (carbon, nutrient, and water), which the largest diversity of organisms on land. Soils also deliver fundamental ecosystem services, and management to change a soil process in support of one ecosystem service and can either provide co-benefits to other services or results in trade-offs. (Smith *et al.*, 2015). Adhikari and Hartemink (2016) noted that most studies on the valuation of ecosystem services lack a soil component or the soil component is poorly defined or too generalized. Only a few studies have linked soil properties to ecosystem services, which related soils to the defined soil functions that ultimately determined the delivery of ecosystem services. Similarly, the relationship between soil carbon, soil biota, soil nutrient cycling, and moisture retention to ecosystem services has been well documented (Barrios, 2007; Ghaley, Porter, & Sandhu, 2014; Krishnaswamy *et al*., 2013; Porter & Sandhu, 2014; Williams & Hedlund, 2013). According to, the natural ecosystems, soil nutrient contents are dynamics, and are also influenced by environmental conditions and their properties. This study assumed that the natural forest ecosystems in the upstream region of Maepoon Sub-district are currently in balances of nutrient and organic cycling, although their properties are much more changeable after 9-year landslide condition. All soil samples of each horizon were collected from the same soil profiles taken at once for this study. Therefore, estimation on soil nutrient and organic matter storages was rather relate to contents of nutrient and organic matter at the specific of time.

Mixed deciduous forest with bamboo showed the highest storage of SOM at 37,550.48 kg per Rai (234.69 ton per ha), whereas the same forest types after 9-year landslide condition had less SOM storage of 11,730.75 kg per Rai (73.32 ton per ha). Moreover, the contents of N, P, K, and Ca in the soil of the mixed deciduous forest showed the higher levels than that of others. The averages of soil nutrient and organic matter contents in the forest ecosystems are shown in Table 3. The values of soil nutrient and organic matter storages in forest ecosystems are strongly related to their storage levels. Mixed deciduous forest with bamboo provides total value of 44,007.70 Baht per Rai (7,506.77 $US per ha) for the services from soil nutrient and organic matter storages, followed by mixed deciduous forest with the value of 33,339.15 Baht per Rai, whereas mixed deciduous forest with bamboo had the total value about 16,682.96 Baht per Rai (Table 4).

Table 3. Average values of soil nutrient and organic matter contents in the forest ecosystems (Unit = kg per Rai).

Soil Nutrient and OM		MNSL	MSSL	BNSL	BSSL
Organic matter	Mean	28,837.32	21,098.21	37,550.48	11,730.75
	SD	±5,398.79	±15,523.85	±7,966.26	±4,709.00
Total nitrogen	Mean	1,496.50	886.96	1,922.03	808.77
	SD	±251.99	±383.03	±414.54	±203.62
Availablephosphorus	Mean	4.29	5.00	5.99	3.41
	SD	±0.16	±2.79	±2.39	±0.74
Exchangeable potassium	Mean	43.48	32.92	44.20	34.96
	SD	±3.19	±9.21	±11.35	±7.24
Exchangeable calcium	Mean	145.74	306.21	591.03	266.47
	SD	±88.35	±282.28	±295.43	±230.31
Exchangeable magnesium	Mean	301.86	458.34	465.35	685.38
	SD	±112.11	±317.75	±269.08	±515.16

Site's names were designed by forest ecosystem at soil sampling; MNSL, Mixed deciduous forest; MSSL, Mixed deciduous forest under landslide; BNSL, Mixed deciduous forest with bamboo; BSSL, Mixed deciduous forest with bamboo under landslide; Unit, Rai= 1,600 m^2 or 0.16 ha.

Table 4. Total values of soil nutrient and organic matter contents in the forest ecosystems (Unit = Baht per Rai).

Soil Nutrient and OM	MNSL	MSSL	BNSL	BSSL
Organic matter	21,627.99	15,823.66	28,162.86	8,798.07
Total nitrogen	10,325.84	6,120.04	13,261.98	5,580.51
Availablephosphorus	47.34	55.23	66.12	37.64
Exchangeable potassium	443.49	335.76	450.88	356.62
Exchangeable calcium	273.26	574.15	1,108.18	499.62
Exchangeable magnesium	621.23	943.27	957.68	1,410.50
Total values	33,339.15	23,852.11	44,007.70	16,682.96

MNSL, Mixed deciduous forest; MSSL, Mixed deciduous forest under landslide; BNSL, Mixed deciduous forest with bamboo; BSSL, Mixed deciduous forest with bamboo under landslide; Unit, $US = 36.64 Baht.

3.5 Values of soil water storage for agricultural propose

Mixed deciduous forest with bamboo showed the highest potential for soil water storage of 214.18 m^3 per Rai (1,338.63 m^3 per ha), followed by mixed deciduous forest (190.11 m^3 per Rai), mixed deciduous forest with bamboo after 9-year landslide condition (144.09 m^3 per Rai), and mixed deciduous forest after 9-year landslide condition (105.99 m^3 per Rai), respectively. However, the yearly total soil water holding capacity ($SWHC_R$) must be related to the monthly maximum soil water holding capacity ($SWHC_{MRi}$) in the study area. Table 5 shows the mean monthly soil water holding capacity in forest ecosystems. Mixed deciduous forest with bamboo provided the highest values of soil water storage over the year, followed by mixed deciduous forest, and other forest types after 9-year landslide condition as shown in Figure 2.

3.6 Value of erosion control

Forest vegetation holds soil in place and captures sediment, preventing erosion and keeping sediment out of drainage systems and waterways. Vegetation that is maintained or restored in the upstream reduces the amount of sediment in runoff and storm water from reaching landscapes (Mandle, Griffin, & Goldstein, 2014). However, exposed landscape upstream regions can facilitate surface runoff generation and soil erosion rates, which are often the sources of sediment. Natural ecosystems and conservation-managed agroecosystems are well known for controlling erosion (Zobeck & Schillinger, 2010). In contrast, unprotected soil from frequent tillage or deforestation lacks such water delivery mechanisms (Comerford *et al*., 2013). Thus, this study assumed that the healthy forest ecosystems have a higher potential for preventing soil loss than those of the forest after 9-year landslide condition.

One of the most widely applied empirical models for assessing the sheet and rill erosion is the Universal Soil Loss Equation (USLE) developed by Wischmeir and Smith in 1978. USLE was developed mainly for estimating soil loss from a hillslope caused by raindrop impact and overland flow (interrill erosion), plus rill erosion. It does not estimate gully or stream-channel erosion. Although USLE has many shortcomings and limitations, it is widely used, because of its relative simplicity and robustness (Desmet & Govers, 1996). In this study, an attempt has been made to estimate the annual soil loss in two types of forest ecosystems under normal condition and 9-year landslide condition using USLE.

Wischmeier and Smith (1958) reported that, when factors other than rainfall are held constant, soil loss is directly proportional to R-Factor of USLE, which is calculated by multiplying total storm kinetic energy (E) by the maximum 30-minute intensity (I30). The numerical value of R is the average annual sum of EI30 for storm events during a rainfall record of at least 22 years (Renard & Foster, 1998). Srikhajon, Somrang, Pramojanee, Pradabwit, and Anecksamphan (1984) has developed the linear regression equation for estimating the correlation between rainfall and runoff erosivity factor (r=0.9482) according to Köppen's Am climate. The R factor of 739.86 was calculated from mean annual rainfall of 1,610.61 mm, which was used all forest ecosystems.

Table 5. Mean monthly soil water holding in the forest ecosystem types.

Ecosystems	Mean monthly soil water holding (m^3 per Rai)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MNSL	22.4	9.6	8.0	171.90	190.11	190.11	190.11	190.11	190.11	190.11	65.79	27.9
MSSL	22.4	9.6	8.0	105.99	105.99	105.99	105.99	105.99	105.99	105.99	65.79	27.9
BNSL	22.4	9.6	8.0	171.90	214.18	214.18	214.18	214.18	214.18	210.20	65.79	27.9
BSSL	22.4	9.6	8.0	127.36	144.09	144.09	144.09	144.09	144.09	144.09	65.79	27.9

MNSL, Mixed deciduous forest; MSSL, Mixed deciduous forest under landslide; BNSL, Mixed deciduous forest with bamboo; BSSL, Mixed deciduous forest with bamboo under landslide; Unit, Rai= 1,600 m^2 or 0.16 ha.

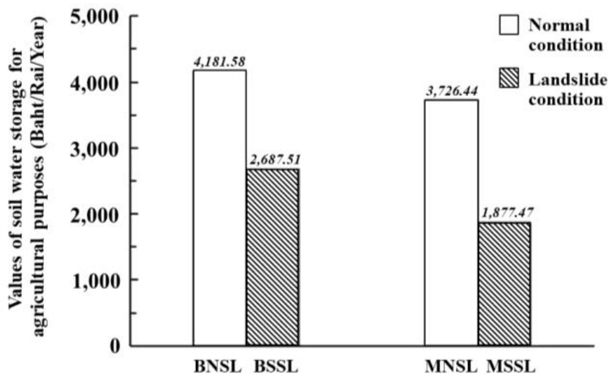

Figure 2. Values of yearly soil water storage for agricultural purposes in the forest ecosystem types; Unit, $US = 36.64 Baht; Rai = 1,600 m^2 or 0.16 ha.

The soil-erodibility factor (K-factor) corresponds to the collective effects of the detachment susceptibility of soil and the sediment transportability as well as the amount and rate of runoff under a given rainfall erosivity (Shabani, Kumar, & Esmaeili, 2014). Values K-factor typically range from about 0.10-0.45, with high-sand and high-clay contents soils having the lower values and high-silt content soils having the higher values (Renard, Laflen, Foste, & McCool, 1994). The studied top soil (0-10 cm depth) of mixed deciduous forest and mixed deciduous forest with bamboo were classified as sandy clay loam and sandy loam, K-factor values were defined as 0.27 and 0.21, respectively, whereas K factor of both forest ecosystems after 9-year landslide condition were defined as 0.19 due to clay soil dominance (K-factor values were adjusted from Land Development Department, 1983).

L-factor and S-factor are usually considered together. L-factor is the ratio of soil loss from the field slope length to that from 22.13-meter length on the same soil type and gradient, whereas the slope steepness factor (S-factor) reflects the influence of slope gradient on erosion. This study assumed that the slope length of each forest ecosystem is generally 40 m. Since the slope gradient of upstream regions are generally greater than 21.0%, L-factor values of all forest ecosystems were calculated as 0.1513. In the meanwhile, S-factor values were calculated based on the mean slope gradients of study plots for each forest ecosystem as shown in Table 6. C-factor, particularly in this study, represents the effects of plants, soil cover, soil biomass, and soil disturbing activities on erosion. The C-factor values of each forest ecosystems were defined according to C-factor value of main land use types developed by Land Development Department, (2000). Since mountainous topography with slope gradient exceed 30 degree dominates the upstream regions of Maepoon Sub-district, and associated with the absence of soil and water conservation measures, the conservation practice factor (P factor) was assigned as 1.0 for all conditions of forest ecosystems according to Land Development Department (1983).

The details of USLE factor scores used to estimate the yearly soil loss for all conditions of forest ecosystems are shown in Table 6. The highest level of soil loss was found in mixed deciduous forest with bamboo after 9-year landslide condition (13.77 ton/Rai/Year). Mixed deciduous forest with bamboo had the lowest level of soil loss with 0.67 ton/Rai/Year, and provided the higher value of 1,164.43 Baht/Rai/Year for soil prevention (Table 6).

3.7 Value of soil materials

Soils are used as construction materials, and some types of soil can have a dramatic impact on a foundation for building, construction or infrastructure. Building foundation needs to be on stable and strong soils. Basically, the strength and stability of soil depend on its physical properties, and soil with good structure is more stable (Mrema, Gumbe, Chepete, & Agullo, 2011). Since clay textures are often more stable than sand textures because they have better structure, Comerford *et al*. (2013) stated that clay soils are suitable for construction purposes, particularly in landfill barriers and dam construction. However, the whole soil can be used as suitable materials for real estate landscaping, whereas gravelly soils and gravelly sands are well used for road surfacing and base material, respectively.

The soil textures in this study area showed that top soils (0-10 cm) were mainly composed of silt and clay particles, whereas the soils at subsurface layer (10-30 cm) and sub-soil layer (>30 cm) were clay-dominated soils coupled with high fraction of weathered rock, which were weathered dominantly from shale and claystone (Boonyanuphap *et al*., 2016). All soil types found in the sampling areas were assumed that they were suitable for construction and landscaping purposes.

Mixed deciduous forest with bamboo showed the highest mean soil volume of 1,595.77 (±305.26) m^3 per Rai (9,973.56 m^3 per ha), followed by mixed deciduous (1,533.60 ±157.70 m3 per Rai), mixed deciduous forest with bamboo after 9-year landslide condition (1,079.94 ±333.25 m^3 per Rai), and mixed deciduous forest after 9-year landslide condition (847.41 ±350.99 m^3 per Rai), respectively. Therefore, mixed deciduous forest with bamboo provided the highest value of soil for construction about 143,987.87 (±44,432.45) Baht per Rai. Mixed deciduous forest after 9-year landslide condition had the lowest values of soil for construction with about 112,985.62 (±46,798.15) Baht per Rai.

Table 6. Factor scores used to estimate the amount and value of yearly soil loss for each forest type.

Ecosystems	Mean slope (percent)	R[a]	K	L[b]	S[c]	C[d]	P	Soil loss (ton/Rai/Year)	Soil loss prevention (ton/Rai/Year)[e]	Value of soil loss prevention (Baht/Rai/Year)[*]
BNSL	42.00	739.85	0.27	1.513	13.52	0.003	1.0	0.67	13.10	1,164.43
BSSL	67.33	739.85	0.19	1.513	33.08	0.015	1.0	13.77		
MNSL	41.00	739.85	0.21	1.513	12.91	0.003	1.0	1.47	6.10	542.41
MSSL	55.33	739.85	0.19	1.513	22.54	0.015	1.0	7.57		

[a]R factor values were calculated from (0.4669 x RF) - 12.1415, RF is mean annual rainfall (mm); [b]L-factor values were calculated from (slope length x 22.13)$^{0.7}$;[c]S-factor values were calculated from (0.065 + (0.045 x S_p) + (0.0065 x S_p^2), S_p is slope gradient (%);[d]C-factor values were defined based on main land use types developed by Land Development Department, (2000); [e]the difference between amounts of soil loss under normal condition and 9-year landslide condition in the same forest type; [*]Unit, Rai = 1,600 m^2 or 0.16 ha.

3.8 Change in economic values of forest ecosystem services damaged by landslide

The total economic values of forest ecosystem were assessed from the sum of all ecosystem service categories calculated above. The result shows that mixed deciduous forest with bamboo provided the highest total value of ecosystem services of 321,147.38 Baht/Rai (54,780.88 $US/ha) followed by mixed deciduous forest with the total values of 291,832.3 Baht/ Rai (49,780.31 $US/ha), respectively. Table 7 shows the different values in categories of ecosystem services both normal condition and 9-year landslide condition. Comparing the values of ecosystem services after 9-year landslide condition and normal condition in the same ecosystem type can provide information on change in the values of ecosystem services damaged by after 9-year landslide condition. In case of landslide, mixed deciduous forest with bamboo showed a higher change in value of ecosystem services with the value of 151,725.29 Baht/ Rai (25,881.06 $US/ ha), whereas mixed deciduous forest showed the change in value of ecosystem services about 151,810.90 Baht/Rai (25,895.69 $US/ha).

4. Conclusions

The comprehensive framework for the economic value assessment of forest ecosystem services in the upstream region was conducted for developing better decision-making at local level regarding the upstream forests management and landslide prevention. This study shows the significant changes in economic values of forest ecosystem services damaged by landslide, which are derived from direct and indirect uses of two forest ecosystems of Meapoon Sub-district. The mixed deciduous forest with bamboo showed the higher loss value of ecosystem services than mixed deciduous forest. However, the practical guide for developing payment for ecosystem services (PES) deals is needed for the purpose of natural resources management and conservation of upstream ecosystem in the study area. Implementation of PES deals with development needs mechanisms for determining individual group or organization, which maintains the ecosystem and natural resources in upstream region and gets the rights to use and manage the resources with legitimacy based on the concepts of local community rights and co-management of natural resources. This leads to the sustainability of resource utilization and benefits obtained from the balance of ecosystem in the upstream region of Maepoon Sub-district in the future

Acknowledgements

This research was funded by The Chaipattana Foundation. The authors are grateful to the staffs of Maephoon Subdistrict Administration Office and Uttaradit Land Development Office. The author also thanks the local farmers and communities for their excellent participation in the survey, interviews, and discussions.

References

Adhikari, K., & Hartemink, A. E. (2016). Linking soils to ecosystem services - A global review. *Geoderma, 262,* 101–111. doi:10.1016/j.geoderma.2015.08.009

Asian Disaster Preparedness Center. (2006). Rapid Assessment: Flashflood and Landslide Disaster in the Provinces of Uttaradit and Sukhothai, Northern Thailand (in Thai). Asian Disaster Preparedness Center, Bangkok, Thailand.

Barrios, E. (2007). Soil biota, ecosystem services and land productivity. *Ecological Economics, 64*(2), 269–285.

Bockheim, J. G. (1997). Proposal to study economic and environmental benefits of reducing soil erosion in Albania. Retrieved from https://core.ac.uk/download/pdf/70 66424.pdf

Table 7. Change in total economic values of forest ecosystem caused by the 2006 landslide (Unit = Baht per Rai).

Values of ecosystem	BN		MN	
	BNSL	BSSL	MNSL	MSSL
Provisioning services				
- Timber	54,240.00	5,333.33	40,426.67	373.33
- Fuelwood for bio-energy	2,380.19	1,392.19	7,177.43	611.85
- Natural bamboo poles	2,931.14	120.00	676.00	79.95
- Soil materials	212,763.93	143,987.87	204,474.89	112,985.62
Value of provisioning services	272,315.26	150,833.39	252,754.99	114,050.75
Regulating services				
- Soil nutrient and OM storage	44,007.70	16,682.96	33,339.15	23,852.11
- Soil water storage	3,659.99	1,905.74	5,195.75	2,118.54
- Erosion control	1,164.43	-	542.41	-
Value of regulating services	48,832.12	18,588.70	39,077.31	25,970.65
Total economic values	321,147.38	169,422.09	291,832.3	140,021.4
Change in total economic values	151,725.29		151,810.90	

BN: Mixed deciduous forest with bamboo, MN: Mixed deciduous forest, Note: MNSL, Mixed deciduous forest; MSSL, Mixed deciduous forest under landslide; BNSL, Mixed deciduous forest with bamboo; BSSL, Mixed deciduous forest with bamboo under landslide; Unit, $US = 36.64 Baht.

Boonyanuphap, J. (2013). Cost-benefit analysis of vetiver system- based rehabilitation measures for landslide-damaged mountainous agricultural lands in the lower Northern Thailand. *Natural Hazards, 69*, 599-629. doi:10.1007/s11069-013-0730-y

Boonyanuphap, J., Thonglem, P., & Raksanok, L. (2016). Economic valuation of slop stabilization methods for landslide prevention in Maepoon Subdistrict: its implication on payment for ecosystem services (in Thai). The Chai Pattana Foundation, Bangkok, Thailand.

Bunyavejchewin, S., LaFrankie, J. V., Baker, P. J., & Davies, S. J. (2009). *Forest trees of Huai Kha Khaeng Wildlife Sanctuary, Thailand: Data from the 50-hectare forest dynamics plot*. Bangkok, Thailand: National Parks, Wildlife and Plant Conservation Department.

Comerford, N. B., Franzluebbers, A. J., Stromberger, M. E., Morris, L., Markewitz, D., & Moore, R. (2013). Assessment and evaluation of soil ecosystem services. *Soil Horizons, 54*(3). doi:10.2136/sh12-10-0028

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., . . . van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387*, 253-260.

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Andison, S. J., Kubiszewski, I., . . . Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change, 26*, 152-158.

Dahlgren, R. (1999). Soil Nutrient Pools in the Geosphere. Retrieved from http://lawr.ucdavis.edu/classes/ssc219/biogeo/menu6.htm

Daily, G. C., Matson, P. A., & Vitousek, P. M. (1997). Ecosystem services supplied by soil. In G. C. Daily (Ed.), *Nature Services: Societal Dependence on Natural Ecosystems* (pp. 113–132). Washington, DC: Island Press.

Desmet, P. J. J., & Govers, G. (1996). A GIS procedure for automatically calculating the USLE LS factor on topographically complex landscape units. *Journal of Soil and Water Conservation, 51*, 427-433.

European Commission. Forest Ecosystem Services. (2017, April 11). Joint Research Centre: The European Commission's Science and Knowledge Service. Retrieved from http://forest.jrc.ec.europa.eu/activities/forest-ecosystem-services/

Gardner, S., Sidisunthorn, P., & Anusarnsunthorn, V. (2000). A field guide to forest trees of Northern Thailand. Bangkok, Thailand: Kobfai Publishing Project.

Ghaley, B. B., Porter, J. R., & Sandhu, H. S. (2014). Soil-based ecosystem services: a synthesis of nutrient cycling and carbon sequestration assessment methods. *International Journal of Biodiversity Science, Ecosystem Services and Management, 10*(3), 177-186.

Gregersen, H. M., Arnold, J. E. M., Lundgren, A. L., & Contreras-Hermosilla, A. (1995). *Valuing forests: context, issues and guidelines*. Rome, Italy: Food and Agricultural Organization of the United Nations.

Gunatilake, H. M., & Vieth, G. (2000). Estimation of on-site cost of soil erosion: a comparison of replacement and productivity change methods. *Journal of Soil and Water Conservation, 55*, 97-204.

Highland, L. M., & Bobrowsky, P. (2008). The landslide handbook - A guide to understanding landslides. Retrieved from https://pubs.usgs.gov/circ/1325/pdf/ C1325_ 508.pdf

Kengen, S. (1997). Linking forest valuation and financing. Retrieved from http://www.fao.org/3/w3247e/w3247e0a.htm#linking%20forest%20valuation%20and%20financing

Krishnaswamy, J., Bonell, M., Venkatesh, B., Purandara, B. K., Rakesh, K. N., Lele, S., . . . Badiger, S. (2013). The groundwater recharge response and hydrologic services of tropical humid forest ecosystems to use and reforestation: support for the "infiltration–evapotrans -piration trade-off hypothesis". *Journal of Hydrology, 498*, 191–209.

Land Development Department. (1983). Using of universal soil loss equation and soil conservation methods (in Thai). Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

Land Development Department. (1998). Soil resource management report in the lowland area [CD-ROM]. Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

Land Development Department. (2006). A study on the causes of debris flow damage in Provinces of Uttaradit, Sukhothai and Phrae Northern (in Thai). Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

Land Development Department. (2000). Soil erosion in Thailand (in Thai). Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

Luque, S., & Iverson, L. (2016). Forest-related ecosystem services. In M. Potschin, H. Y. Roy, F. Robert & T. R. Kerry (Eds.), *Routledge handbook of ecosystem service* (pp. 383-393). New York, NY: Routledge.

Makana, J. R. (1999). *Forest structure, species diversity and spatial patterns of trees in monodominant and mixed stands in the Ituri Forest, Democratic Republic of Congo* (Master thesis, Oregon State University, Corvallis, OR). Retrieved from file:///C:/Users/Sony/Downloads/Makana_Jean-Remy_M_1999.pdf

Mandle, L., Griffin, R., & Goldstein, J. (2014). Natural Capital & Roads: Managing dependencies and impacts on ecosystem services for sustainable road investments. Retrieved from https://www.naturalcapitalproject.org/pubs/Natural_Capital_and_Roads.pdf

Martı´nez-Casasnovas, J. A., & Ramos, M. C. (2006). The cost of soil erosion in vineyard fields in the Penede`s–Anoia Region (NE Spain). *Catena, 68*, 194-199.

Metropolitan Electricity Authority. (2017, April 8). Type 7: Water pumping for agricultural purposes (in Thai). Retrieved from http://www.mea.or.th/download/download_file/17920

Millennium Ecosystem Assessment. (2005). Ecosystems and human well-being: a framework for assessment. Retrieved from http://pdf.wri.org/ecosystems_human_wellbeing.pdf

Mrema, G. C., Gumbe, L. O., Chepete, H. J., & Agullo, J. O. (2011). Rural structure in the tropics: design and development. Retrieved from https://publications.cta.int/media/publications/downloads/1690_PDF.pdf

Nasi, R., Wunder, S., & Campos, J. J. (2017, April 11). Forest ecosystem services: can they pay our way out of deforestation. Retrieved from http://www.cifor.org/pes/publications/pdf_files/bnasi0201.pdf

Nuanmano, N. (2013). *Soil erosion on Kho Hong hill and its economic loss, Hat Yai District, Songkhla Province* (Master thesis, Prince of Songkla University, Hat Yai, Thailand).

Ogawa, H., Yoda, K., Ogino, K., & Kira, T. (1965). Comparative ecological studies on three main types of forest vegetation in Thailand. II. Plant Biomass. *Nature and Life in Southeast Asia*, *4*, 49-80.

Pearce, D. W., & Moran, M. (2001). *The value of biological diversity: a handbook*. Paris, France: Organisation for Economic Co-operation and Development.

Pearce, D. W., & Pearce, C. (2001). *Valuing environmental benefits: case studies from the developing world*. Cheltenham, England: Edward Elgar.

Peng, L., Chen, S., Liu, Y., & Wang, J. (2008). Application of CITYgreen model in benefit assessment of local, Nanjing (urbanforest) in carbon fixation and runoff reduction. *Frontiers of Forestry in China, 3*(2), 177-182.

Renard, K. G., & Foster, G. R. (1998). R factor - rainfall/ runoff erosivity. In T. J. Toy & G. R. Foster (Eds.), *Guidelines for the use of the revised universal soil loss equation (RUSLE) version 1.06 on mined lands, construction sites and reclaimed lands* (pp. 4-1 - 4-13). Denver, CO: Office of Surface Mining.

Renard, K. G., Laflen, J. M., Foster, G. R., & McCool, D. K. (1994). The revised universal soil loss equation. *Journal of Soil and Water Conservation, 49*(3), 213-220.

Saxton, K. E., Rawls, W. J., Romberger, J. S., & Papendick, R. I. (1986). Estimating generalized soil water characteristics from texture. *Transactions of the ASAE, 50*, 1031-1035.

Shabani, F., Kumar, L., & Esmaeili, A. (2014). Improvement to the prediction of the USLE K factor. *Geomorphology, 204*, 229-234. doi:10.1016/j.geomorph.2013.08.008

Smith, P., Cotrufo, M. F., Rumpel, C., Paustian, K., Kuikman, P. J., Elliott, J. A., . . . Scholes, M. C. (2015). Biogeochemical cycles and biodiversity as key drivers of ecosystem services provided by soils. *SOIL, 1*, 665–685.

Srikhajon, M., Somrang, A., Pramojanee, P., Pradabwit, S., & Anecksamphan, C. (1984). Application of the universal soil loss equation for Thailand (in Thai). *In Proceeding of the Fifth Asian Soil Conference*. Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

Verstraeten, G., Poesen, J., Govers, G., Gillijns, K., Van Rompaey, A., & Van Oost, K. (2003). Integrating science, policy and farmers to reduce soil loss and sediment delivery in Flanders, Belgium. *Environmental Science & Policy, 6*, 95-103.

Williams, A., & Hedlund, K. (2013). Indicators of soil ecosystem services in conventional and organic arable fields along a gradient of landscape heterogeneity in southern Sweden. *Applied Soil Ecology, 65*, 1–7.

Wischmeir, W. H., & Smith, D. D. (1958). Rainfall energy and its relationship to soil loss. *Transactions of the American Geophysical Union, 39*, 285-291.

Wischmeir, W. H., & Smith, D. D. (1978). *Prediction rainfall erosion losses - A guide to conservation planning*. Prince George's County, MD: U.S. Department of Agriculture.

Yamane, T. (1973). *Statistics: an introductory analysis 3rd edition*. New York, NY: Harper and Row.

Zobeck, T. M., & Schillinger, W. F. (2010). *Soil and water conservation advances in the United States, SSSA Special Publication 60*. Madison, WI: Soil Science Society of America.