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Ecosystem Services Tradeoffs: A Case Study of Chiang Khong, Thailand

Apisom Intralawan [a] and Ithiphat Rueangkitwat [b]

[a] *Natural Resources and Environmental Management Research and Training Center, School of Science, Mae Fah Luang University, Chiang Rai, Thailand*
[b] *School of Social Sciences, Chiang Rai Rajabhat University, Thailand*

Abstract

The recent transformation of land in the Mekong River Basin has been dramatic. The changes have contributed to an increased standard of living resulting from economic and agricultural expansion, increasing urbanization and modernization. However, the changes have also resulted in major degradation of ecosystems and the services which ecosystems provide. Despite acknowledgement of the loss of the ecosystem benefits, the integration of ecosystem services tradeoffs into land use decisions is still limited. Land managers and policy makers are facing challenges in balancing the positive effects of economic development and the long term negative impacts on the environment.

This paper is based on a case study of one of the fastest growing towns along the Mekong River, namely Chiang Khong, Chiang Rai Province, Thailand. Data on the change of land use and land cover for different biomes over the past 40 years have been obtained from satellite image classification. The valuation of ecosystem services of different biomes has been quantified in monetary terms. During the last four decades, the estimated change in the value of ecosystem services in Chiang Khong shows a net decline of roughly US$ 440 million - from US$ 1,896 million/year in 1976 to US$ 1,455 million/year in 2015. There is a risk that this decline in ecosystem services will further increase if ecosystem services valuations are not included in decision making processes related to the planned economic development (infrastructure expansion, new industrial park development) in Chiang Khong.

Keywords: ecological economics; ecosystem services valuation; land use and land cover change; Mekong river basin

1. Introduction

Ecosystem services are the benefits that nature provides by their structures and processes to households, communities and local and global economies (Boyd and Banzhaf, 2007). The benefits contribute to human welfare and are derived from physical, biological, and chemical processes of ecosystem structures and functions. There is a wide range of benefits which accrue to stakeholders - cultural and provisional services, flood protection, soil formation, nutrient recycling at local and regional levels, climate regulation, carbon sequestration, and biodiversity conservation at a global scale (Costanza *et al*., 1997)

Evidence is accumulating that profound changes of an irreversible nature are quickly overtaking substantial areas of the region. For example, Sodhi *et al*. (2010) discuss the effects and tradeoffs of land use and land cover change on biodiversity, ecosystem functions and services in the whole sub-continental region of Southeast Asia. They found that the highest rate of deforestation in the tropics from agricultural expansion, habitat fragmentation and rapid urbanization resulted in a rapid decline in the variety and abundance of species. The consequences of land transformation disrupted many vital ecosystem services including the loss of habitat and gene-pool protection, loss of carbon sequestration capacity, increased anthropogenic carbon emission, changed regional climate regulation, and deteriorated local air and water quality (Zhao *et al*., 2006; Hu *et al*., 2008).

Despite growing recognition of the importance of ecosystem functions and services, integration of ecosystem service tradeoffs into land use decisions is still limited. This is because they are difficult to quantify financially and are neither recognized nor traded in the market place. However, land managers are facing the choice between maintenance and conservation of ecosystems and the continuation and expansion of the human footprint and activities. Treating nature as a free good outside conventional cost-benefit calculation threatens the ecosystems viability, and leads to sub-optimum decisions on land use planning. Thus, the process of assigning and quantifying ecosystem service value needs to be incorporated in the public policy process. In making important land use decisions, ecosystem service valuations-the economic values of ongoing provision of ecosystem services-have to be made explicit and compared with the benefits derived from continuing growth of economic activities. This tradeoff is required in order to achieve a sustainable and efficient allocation of resources.

2. Materials and Methods

In recent years, the tradeoff calculation of land use land cover change (LULC) using ecosystem service valuation framework has increasingly been accepted as a supporting tool for land use managers and policy makers. For example, Bateman *et al*. (2013) estimated comparable economic values of ecosystem services in the United Kingdom based on different land use scenarios. The authors concluded that the conventional method of land use decisions only focused on market-priced goods and resulted in lower overall values. Therefore, policy makers should place non-marketed ecosystem services on the same level playing field as marketed goods. In the USA, the concept of valuing natural capital has been gradually recognized. This is because ecosystem trade-off calculations increase the transparent, efficient use of limited resources, and enhance sustainability and resilience (Schaefer *et al*., 2015). In China, the land use land cover change in Miyun, Beijing, China has been evaluated. The results showed that the total ecosystem service value was about 2,968 million Yuan in 1991, and 3,304 million Yuan in 2006 due to better land use planning on vegetative restoration and protection of water bodies to balance the negative impacts of urbanization (Zhang *et al*., 2015). In contrast to the previous example, the ecosystem services values of the land use land cover change of Shenzhen, China resulted in a net decline of 231 million Yuan between 1996 to 2004 due to rapid urban sprawl in the area. In view of the increase in economic activities in the area, balancing economic development with the ecological health must be addressed (Tianhong *et al*., 2010). Likewise, quantification of ecosystem services and economic implications of different land use options for Kamehameha Schools' land holding (owning 147, 470 hectare of land) in Hawaii was carried out. A spatially explicit land use modeling, Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) had been applied to support the planning process. Among different land use options (The Residential Development Scenario, The Food Crops and Forestry scenario, and the Biofuels scenario), the Residential Development scenario is estimated to provide the highest net present value of US$62 million (Goldstein *et al*., 2012).

2.1. Study area

The District of Chiang Khong (Fig. 1) is located in the northern part of Chiang Rai Province (19°57′0.35″N to 20°24′12.19″N; 100°10′12.89″E to 100°28′46.48″E). Due to its strategic location right across the Mekong River from Huay Xai, Lao PDR, it is commonly used as a tourist destination en-route to Luang Prabang, Lao PDR by boat.

In 1992, the Greater Mekong Sub-region development programs were established. The infrastructure development program was initiated by Asian Development Bank (ADB) to increase the standard of living and reduce poverty in the region. Since then, large transportation network development, economic integration and resource utilization have been increasingly promoted. In December 2013, the fourth Thai-Lao friendship bridge was opened to provide a crossing over the Mekong river which links Chiang Khong, Chiang Rai, Thailand to Huay Xai, Bokeo, Lao PDR and ultimately to Kunming, Yunnan in China. Chiang Khong was once a small, remote buffer town but has now changed to a gateway to China. Along the Mekong River, there has been a major investment in port facilities (to accept Chinese boats) in the past ten years. After the fourth Thai-Lao friendship bridge has completed, trade volume has increased steadily by more than 10% and worth about Baht 12,500 million or US$ 416 million annually. The number of visitors by car has also grown exponentially and now reached a record high of 24,243 cars per year (Bank of Thailand, 2014). It has recently been promoted to be a hub of border trade area and designated by the current Thai government as a special economic zone

2.2. Land use classification

A serial set of Landsat satellite images for the period from 1976 to 2015 at ten year intervals were acquired from the U.S. Geological Survey (http://landsat.usgs.gov//index.php). All images were preprocessed and corrected both radiometrically and geographically. To maximize consistency between years, images were selected from the months of December and February, when the presence of clouds is minimal and the characteristics of plant phenology are more meaningful to the study. To evaluate the land use and land cover change in the area, these images were then classified by converting spectral data into six land cover types using a supervised classification technique and test data for accuracy assessment (Table 1). This is to allow comparison with the previous studies in order to apply ecosystem

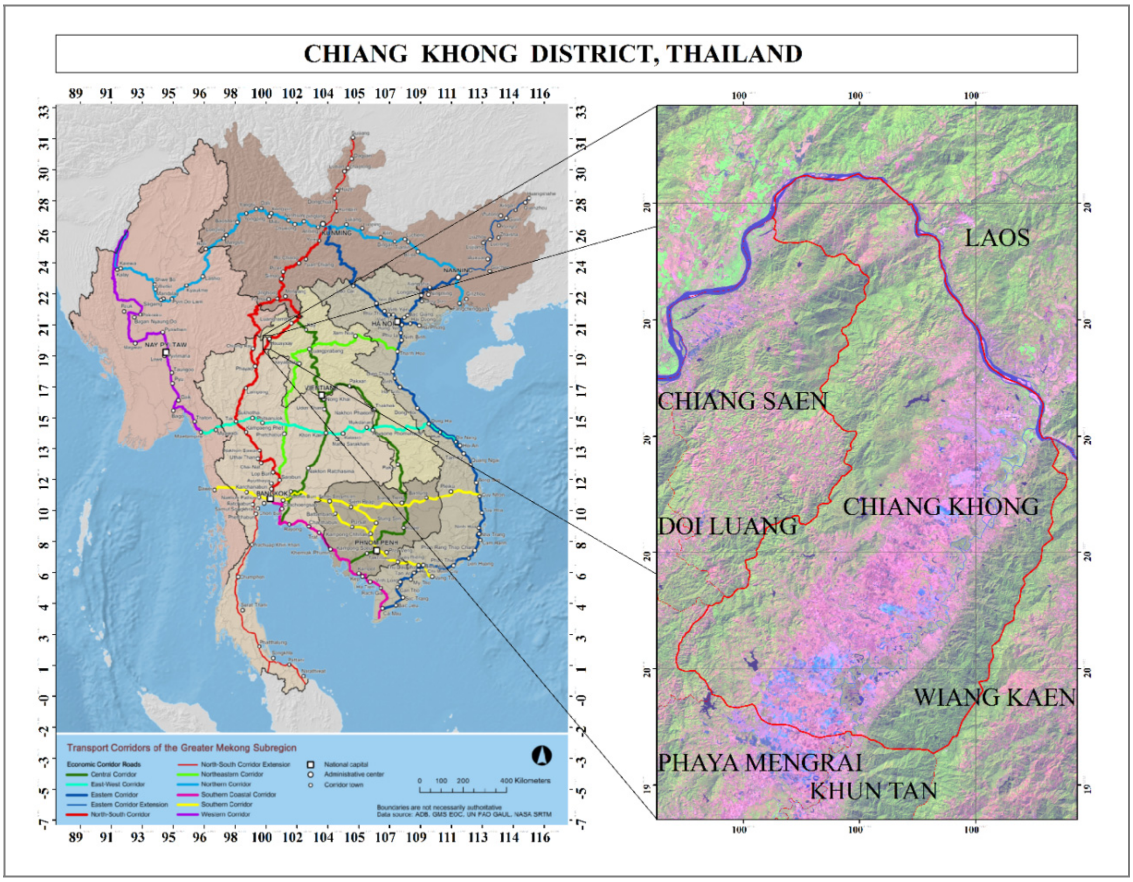

Figure 1. Location of Chiang Khong district, Thailand

service value transfer techniques (Tang *et al*., 2014; Wang *et al*., 2014; Zhang *et al*., 2015). The land use map was then edited and coded for further calculations of ecosystem service value and spatial analysis.

2.3. Ecosystem services valuation estimation

Ecosystems are complex systems; translation from quantities of goods and services derived from ecosystem structures and processes into monetary values is very difficult. However, to capture the loss of the ecological value in comparison to the gain of economic development in cost-benefit analyses is necessary. In many cases, market prices of these goods and services are lacking. In such case, an approach known as value transfer is used to generate baseline estimates of total ecosystem services values (TESV). Costanza *et al.* (2007) applied this technique to estimate the value of natural capital for the state of New Jersey, USA. Tianhong *et al*. (2010) investigated variations in ecosystem services in response to land use changes in Shenzhen, China. Zhao *et al*. (2004) found massive loss of ecosystem services (from US$316 to US$120 million dollars per year) between 1990 and 2000 due to the destruction of wetlands in Chongming Island, China. Troy and Wilson (2006) used the same technique to estimate the flow of ecosystem services for Massachusetts; Maury Island, Washington, and three counties in California.

2.4. Calculation of ecosystem services

Following the work of Costanza *et al*. (1997), Xie extrapolated the equivalent weight factors of terrestrial ecosystem services per hectare based on Chinese context (Xie *et al*., 2003; Xie *et al*., 2010). Coefficients were calibrated and modified by 200 experts as following (Table 2).

The value transfer method using coefficients based on the Chinese situation used by previous studies by Xie *et al*. (2010) and Tianhong *et al*. (2010) is also appropriate for our Chiang Khong study. This is because the institutional settings, geographic locations and socio-cultural attitudes toward the environment are similar for both Thailand and China. The countries share similar economic situations, popular culture and attitudes toward environmental conservation. Furthermore, the Gross Domestic Product (GDP) per capita is approximately the same-US$ 6,229 for Thailand and US$ 6,991 for China in 2013. For the

Table 1. Definition of land use type in Chiang Khong sub-district, Thailand

Type of Land Use	Definition
Forest	Evergreen forest, deciduous forest, degraded forest, plantation forest.
Grassland	Shrub, brush, pasture and rangeland.
Farmland	Irrigable land, crop field including paddy, rice field, and other cash crop, rubber trees and fruit.
Wetland	Swamp, marsh, riverine, seasonal inundated forest.
Water body	Rivers, ponds, reservoir, lakes.
Unused land	Bare soil, barren, land unsuitable for crop cultivation.

Chiang Khong District, food crop production (mainly rice) is about 600 kilogram per rai[1] or 3.75 ton per hectare per year. The average farm price for grain (rice) in 2015 was Baht 9,100/ton (Office of Agricultural Economics, 2014).

In general, Chiang Khong farmers plant one crop of rice which results in an ecosystem service value for Chiang Khong District of Baht 34,125 or US$ 1,137 per hectare per year (in 2015). Table 3 shows the ecosystem service valuation per hectare per year in US dollars for each land use category.

2.5. Total ecosystem value valuation

After each mapping unit is assigned a value for its ecosystem services, the total ecosystem services can be calculated. The total value for a locality can be obtained by multiplying the area of each land category by the value coefficient of each biome using the following formula.

$$TESV = \Sigma (A_i \times VC_i),$$

TESV = Total Value of Ecosystem Services for each biome
A_i = area of each land category in hectare
VC_i = value efficiency in dollar per hectare per year

3. Results and Discussion

3.1. Change in Land Use

Chiang Khong District has experienced enormous changes with respect to wetland conversion, deforestation and farmland expansion. The land use land cover change statistics are summarized in Table 4. The overall accuracy of image classification for all dates is in the acceptable range between 80-85%.

In 1976, the dominant land covers were forest (41.8 % of total area) and farmland (29.7% of total area). By 2015, farmland had almost doubled in area, from 22,530 ha (29.7 %) to 36,220 ha (47.8 %) of the total area (Fig. 2).

The cross-tabulation matrix (Table 5) illustrates the change of different land cover classes. Out of 31,674 hectare of forest land in 1976, only 24,123 hectare remains the forest land in 2015. The majority of the forest land has been converted into farmland (6,609 ha). Also, out of 8,364 hectare of wetland in 1976, only 249 remains the wetland in 2015. Most of the wetland area has also been converted into farmland (7,208 ha). Clearly, the expansion of agriculture area has occurred at the expense of wetlands and deforestation

Table 2. Equivalent weight factor of ecosystem services per hectare per year

Land Use Categories	Ecosystem Services (US$/ha/yr.)									Total
	GR	CR	WS	SFT	WT	BP	FD	RM	RC	
Forest	4.32	4.07	4.09	4.02	1.72	4.51	0.33	2.98	2.08	28.12
Grassland	1.50	1.56	1.52	2.24	1.32	1.87	0.43	0.36	0.87	11.67
Farmland	0.72	0.97	0.77	1.47	1.39	1.02	1.00	0.39	0.17	7.90
Wetland	2.41	13.55	13.44	1.99	14.40	3.69	0.36	0.24	4.69	54.77
Water body	0.51	2.06	18.77	0.41	14.85	3.43	0.53	0.35	4.44	45.35
Unused land	0.06	0.13	0.07	0.17	0.26	0.40	0.02	0.04	0.24	1.39
Note: GR = Gas Regulation, CR = Climate Regulation, WS = Water Supply, SFT = Soil Formation and Retention, WT = Waste Treatment, BP = Biodiversity Protection, FD = Food, RM = Raw Material, RC = Recreation and Culture										

[1]Rai is a Thai unit land area equally to 1600 square meters (40m x 40m). 1 Rai is equivalent to 0.16 Hectare.

Table 3. Ecosystem service valuation for each land use category

Land Use Categories	Ecosystem Services ($/ha/yr.)									Total
	GR	CR	WS	SFT	WT	BP	FD	RM	RC	
Forest	4,911.84	4,627.59	4,650.33	4,570.74	1,655.64	5,127.87	375.21	3,388.26	2,364.96	31,972.44
Grassland	1,705.50	1,773.72	1,728.24	2,546.88	1,500.84	2,126.19	488.91	409.32	989.19	13,268.79
Farmland	818.64	1,102.89	875.49	1,671.39	1,580.43	1,159.74	1,137.00	443.43	193.29	8,982.30
Wetland	2,740.17	15,406.35	15,281.28	2,262.63	16,372.80	4,195.53	409.32	272.88	5,332.53	62,273.49
Water body	579.87	2,342.22	21,341.49	466.17	16,884.45	3,899.91	602.61	397.95	5,048.28	51,562.95
Unused land	68.22	147.81	79.59	193.29	295.62	454.80	22.74	45.48	272.88	1,580.43

Note: GR = Gas Regulation, CR = Climate Regulation, WS = Water Supply, SFT = Soil Formation and Retention, WT= Waste Treatment, BP = Biodiversity Protection, FD = Food, RM = Raw Material, RC = Recreation and Culture US$ 1 = 30 Baht

Table 4. Land use land cover statistics for 1976, 1985, 1995, and 2015

Land use type	1976		1985		1995		2005		2015		1976-2015
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Net area change (%)
Forest land	31,674	41.80	30,361	40.07	28,964	38.22	28,105	37.09	27,845	36.75	-5.05
Grassland	8,592	11.34	10,167	13.42	10,342	13.65	8,363	11.04	4,758	6.28	-5.06
Farmland	22,530	29.73	22,078	29.14	26,664	35.19	28,539	37.66	36,220	47.80	18.07
Wetland	8,364	11.04	8,966	11.83	5,791	7.64	4,665	6.16	2,200	2.90	-8.14
Water body	784	1.03	794	1.05	695	0.92	567	0.75	639	0.84	-0.19
Unused land	3,830	5.05	3,408	4.50	3,318	4.38	5,535	7.30	4,112	5.43	0.37

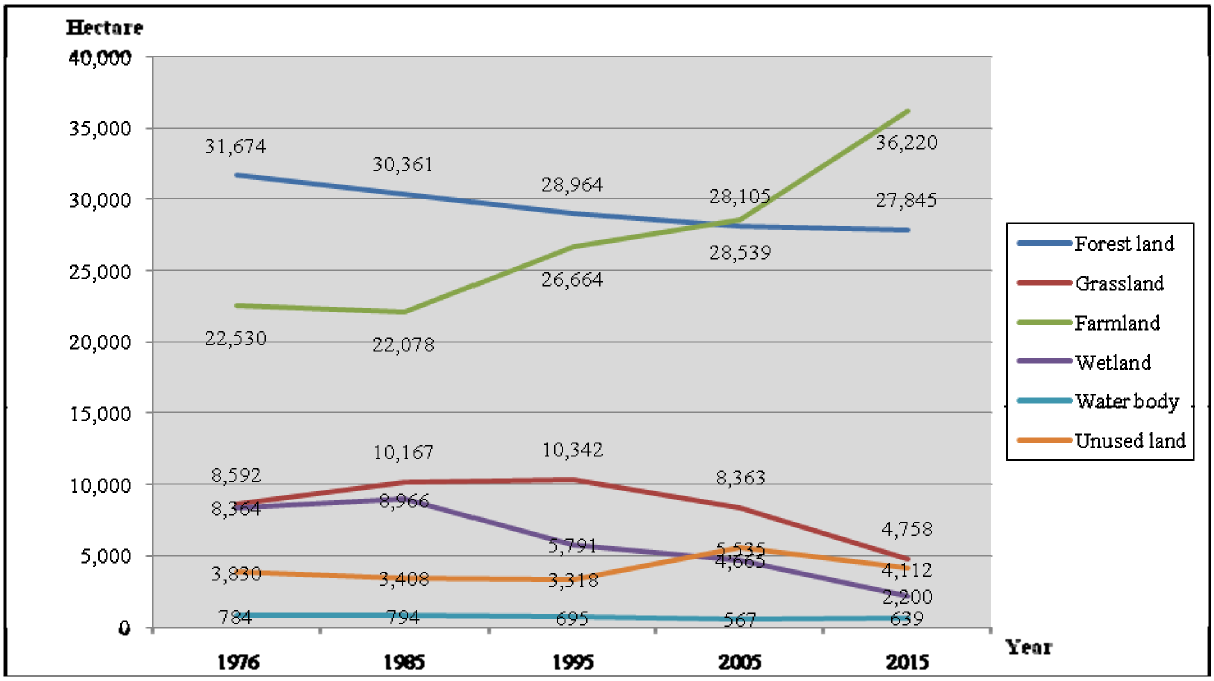

Figure 2. Trends of Land Use Land Cover Change from 1976-2015

Table 5. Cross-tabulation of land cover classes between 1976 and 2015 (area in ha)

Type 1976	2015 Farmland	Forest	Grassland	Unused land	Water body	Wetland	Grand Total
Farmland	13,823	2,407	2,695	2,245	132	1,228	22,530
Forest	6,609	24,123	116	741	67	18	31,674
Grassland	5,455	1,282	735	657	104	359	8,592
Unused land	2,871	2	594	138	28	198	3,830
Water body	254	3	40	38	301	148	784
Wetland	7,208	28	578	293	8	249	8,364
Grand Total	36,220	27,845	4,758	4,112	639	2,200	75,774

3.2. Change in ecosystem services

Fig. 3 presents the results of spatial distribution of each land use land cover class based on GIS mapping of its ecosystem service flow values. For each year, Total Ecosystem Service Valuation (TESV) for each LULC is illustrated in Table 6.

The value of total ecosystem services was US$ 1,896.41, US$ 1,908.58, US$ 1,704.47, US$ 1,594.40 and US$ 1,455.17 million per year for each of the four periods. The largest loss in ecosystem services of 204 million dollar, from 1985 to 1995, is explained mostly by a significant decline of services provided by wetlands. The benefits of wetland to society were estimated to be US$ 520 million/year in 1976. By the year 2015, it had declined to US$ 136 million /year. Although there was an increase in farmland ecosystem services, the net decline in the all estimated ecosystem services from 1976 to 2015 was about US$ 302 million. The changes in TESV between different periods are illustrated in below (Fig. 3).

4. Conclusions

Ecosystem services include provisioning services (fisheries, aquatic animals and plants, fresh water for cleaning, bathing, and irrigation), regulating (erosion control, riverbank stabilization), supporting (soil formation, nutrient cycling, provisioning of habitat), and cultural services (sense of place, income generation for cultural events, etc.). Among different biomes, wetlands provide the highest ecosystem services value. However, many of these services are undervalued as a result of their characteristics of indirect uses and non-marketed resources. Conversion of wetlands and forest land into farmland has affected ecological structures and processes. Therefore, ecosystem services need to be evaluated and explicitly defined in order to reach a socially optimal balance and an efficient allocation of public goods.

The results from this study show a significant ecosystem value decline of US$ 441.24 million over the past four decades despite the increased household

Table 6. Total Ecosystem Services from 1976 to 2015

Land use type	TESV* 1976	1985	1995	2005	2015
Forest land	1,012.70	970.73	926.05	898.58	890.29
Grassland	114.00	134.90	137.23	110.96	63.13
Farmland	202.37	198.31	239.50	256.35	325.34
Wetland	520.86	558.34	360.61	290.52	136.98
Water body	40.43	40.92	35.84	29.25	32.92
Unused land	6.05	5.39	5.24	8.75	6.50
Total	1,896.41	1,908.58	1,704.47	1,594.40	1,455.17

*TESV = Total Ecosystem Services in million dollar (10^6) unit per year.

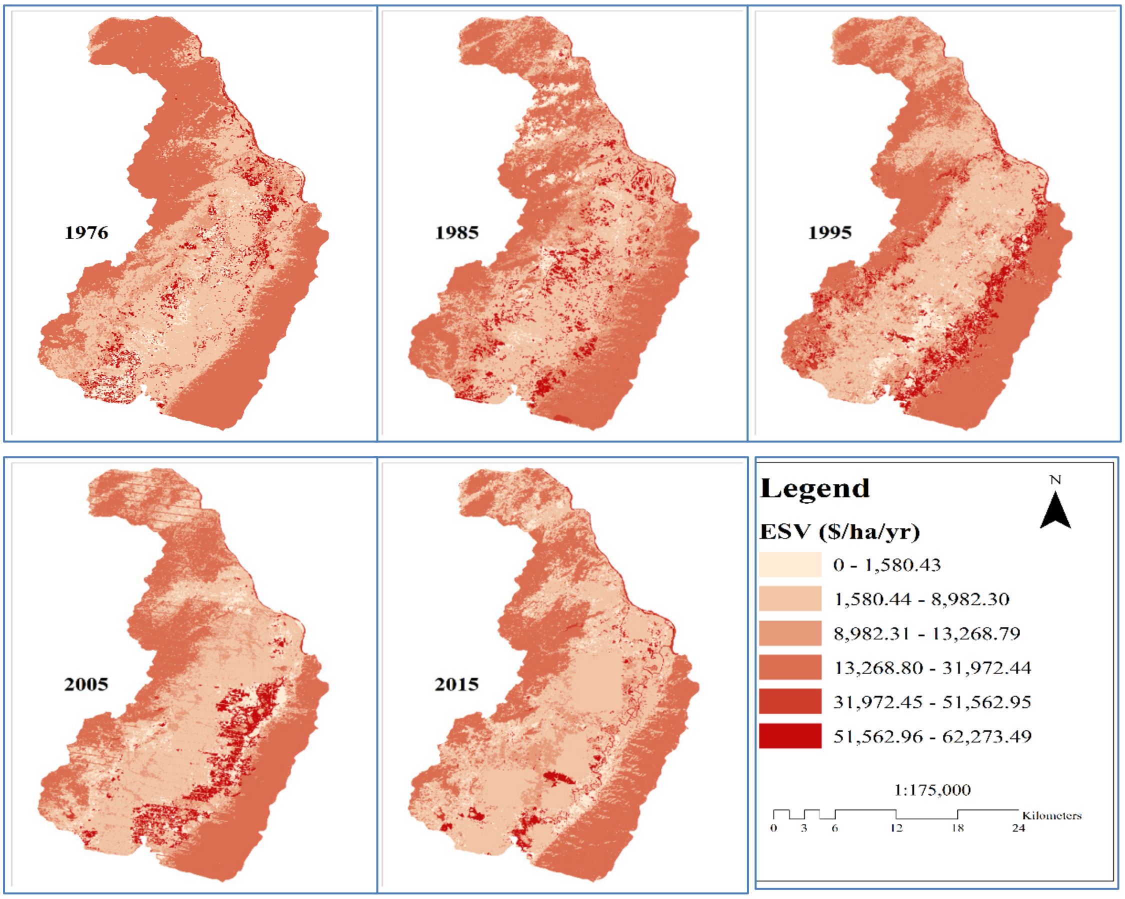

Figure 3. Mapping of Ecosystem Services

income from agricultural production in Chiang Khong, Chiang Rai Province, Thailand. These findings will be used to raise awareness about conservation of natural capital. Also, this research justifies the sustainable use of natural capital and the protection and restoration of forest land and wetlands for continued benefits to society.

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Correspondence to
Dr.Apisom Intralawan
Natural Resources and Environmental Management Research and Training Center,
School of Science,
Mae Fah Luang University,
Chiang Rai, 57100
Thailand
E-mail: intraa@mfu.ac.th