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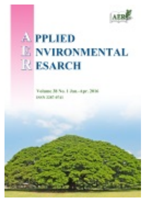

Ecosystem Service Value of the Mixed Land Use Pattern in Asia: Thailand's Experience

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Abstract

The rapid increase in economic development and urbanisation along the Eastern Economic Corridor (EEC) of Thailand has accelerated the change in its ecosystem service value (ESV), leading to the demand for related analysis to ensure sustainable growth in the area. The aim of this study is to: (1) evaluate the land use change in Chonburi Province; the most urbanised city in the EEC of Thailand between 2006 and 2016, and (2) assess the land use change impact on ESV. Secondary data from land use maps for 2006 and 2016 was used to evaluate land use change and its impact on ESV using the land use transition matrix, land use dynamic degree, and the benefit transfer method. Urban and built-up land use were found to dominate other use types. The top three highest annual rates of land use change were found in water bodies, rangeland, and urban and built-up land. The ESV in 2016 was found to be 1.31% higher than for 2006. The ecosystem service functions (ESFs) contributing to the increase in ESV were waste treatment, hydrological regulation, climate regulation and recreation and service culture. Future land use planning should focus on increasing wetlands and protecting agricultural land in the study area since these contribute to the highest ESV. In addition, it is essential to balance economic development with ecological enhancement.

Keywords: Land use change; Ecosystem service value; Thailand

Introduction

Mixed land use is a unique characteristic of urbanisation patterns in Asian countries. Generally, there are five major types of land use: commercial and industrial, residential, cropland and arable pasture, forest and grazing, and barren and waste [1]. In Western countries, there are clear, distinct boundaries for the various land use types and it is widely accepted that the best use of land resources is to maximise the return of the site [1–2]. Most land parcels are appropriate for a variety of uses and the best use for a

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particular site is often subject to change as a result of certain factors such as land resource location, technology, and public policies [3]. As a general rule, landowners tend to allocate their land resources in a way that provides them with the highest return [4–5]. However, Barlowe [1] stated that land resources can usually earn the highest returns when used for commercial or industrial purposes, followed by residential, cropland and arable pasture, forest and grazing, and barren and waste, respectively. As a result, commercial, residential, and industrial uses are often dominant in almost any site.

Most empirical research reveals that land use trends in Western countries are compliant with land resource economic theory; actually changing the way in which commercial, industrial, and residential land use types dominate other use types [6–7]. According to the European Environment Agency [8] from 2006–2012, built-up areas including capital cities such as London, Paris, Milan, as well as the Randstad conurbation in the Netherlands and the Rhine–Ruhr metropolitan area, showed the greatest increase among the land cover categories, in terms of both net area and percentage change. In the United States, Sleeter et al. [9] found a reduction of 24% in forest and agricultural area from 1973–2000, while built-up areas increased by 33%. In Australia, Bassett et al. [10] reported that from 1980–2004, the built-up area in New South Wales increased significantly, resulting in a decrease in the aerial extent of vegetation communities throughout the region. In Turkey, Reis [11] found that from 1976–2000, land use in North-East Turkey for urban activities increased by 117%, while agricultural land also increased by 36.2%, especially for tea gardens. In contrast, land use for pasture decreased by 72.8% and forestry by 12.8%.

Obviously, the conversion of land use into built-up urban areas in Western countries is estimated to have increased. Many researchers reveal that urban expansion has a negative impact on ecosystem service [12–16]. Daily [17] defined ecosystem service as conditions and processes through which natural ecosystems, and the species generating them, sustain and fulfil human life. There are four groups of ecosystem service: supporting, provisioning, regulating, and cultural [18]. Supporting services are those necessary for the operation of all other ecosystem services such as biomass production, nutrient cycling, water cycling, and soil formation. Provisioning services include all the material products obtained from ecosystems such as food, timber, or fresh water. Regulating services consist of the benefits obtained from the regulation of ecosystem processes, including the climate via carbon sequestration and water purification. Finally, the cultural services provided by ecosystems benefit people through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience [19]. Numerous relevant studies such as those by McKinney [20], McKinney [21], Chen et al. [22], Mamat et al. [23], and Sharma et al. [24] reveal that urban sprawl decreases the ESV. However, Czamanski et al. [25] and McDonald et al. [26] reviewed the relevant research regarding the benefit and effect of urbanisation on the ecological system, concluding that there appears to be no straightforward answer as to whether urban sprawl is good or bad for the environment. Therefore, the impact of urban sprawl on the ecosystem remains poorly understood.

Thailand has the sixth largest area of urban land in the East Asian region as of 2010. Its urban area grew from about 2,400 to 2,700 km^2 between 2000 and 2010 with an average annual growth rate of 1.4% [27]. McGee [28] indicates that Asian countries have unique urbanisation characteristics and patterns. There are no distinct boundaries for various land use types in Asia, with the first floors of commercial buildings being used for shops, stores, and restaurants, while the second and third floors are utilised as warehouses and residential accommodation. Numerous studies on land use change trends and their impact on the ESV have been carried out in Asia and Thailand. For instance, Murakami et al. [29] found a highly complex mixture of land use during their study on Manila in the Philippines with the increase in residential land resulting in many environmental problems. In India, Rawat et al. [30] found that from 1990–2010, vegetation and built-up land increased by 3.51 and 3.55%, respectively while agriculture, barren land, and water bodies decreased by 1.52, 5.46, and 0.08%, respectively. These results are in line with the work of Shi et al. [31] in China, who found an increase in built-up areas and a decrease in arable land. However, the opposite result was found by Wijaya et al. [32], who studied land use change in Indonesia, reporting that agricultural areas in Indonesia showed the greatest increase among all land use types as a consequence of deforestation from 1990–2012. He et al. [33] also found an overall increase in the agricultural land area of China during the past 300 years. Hu et al. [34] studied the ESV of Anhui Province China in relation to land use change. They found that the built-up area increased while the water bodies decreased and the ESV of Anhui province decreased from $30{,}015.58\times10^{7}$ CNY in 2000 to $29{,}683.74\times10^{7}$ CNY in 2015. The relevant research in Thailand includes the work of Ongsomwang et al. [35], who assessed the impact of land use changes on the ESV of Khon Kaen Province, Northeastern Thailand. These researchers found that agricultural land use decreased while rangeland, urban, and built-up areas dramatically increased. The estimated total ESV of Khon Kaen in 2006 was 145 million USD, and this figure is projected to decrease to 132 million USD in 2026. The decrease in agricultural land use is the source of this estimated decrease in ESV. In Phitsanulok Province, Northern Thailand, Arunyawat and Rajendra [36] assessed the impact of land use on the ESVs in Wang Thong District from 1989–2013. They found an increase in agricultural land and urban and built-up areas as a result of deforestation, leading to a decrease in the ESV. Intralawan and Rueangkitwat [37] also estimated the impact of land use change on the ESV in the Chiang Khong District of Chiang Rai Province, Northern Thailand, finding an increase in agricultural land, which had been converted from wetland and forest. The ESV in 1976 was 1,896 million USD, declining to 1,455 million USD in 2015. In Songkhla Province, Southern Thailand, Srichaichana et al. [38] assessed land use change in the Khlong U-Tapao watershed during 2010–2017, finding an increase in rubber plantation and urban and built-up areas, but a decrease in forest and miscellaneous land use. They also identified the optimum land use scenario for providing the optimum water yield and sediment retention ecosystem services in the study area. Although numerous studies assess the land use change trend and its impact on the ESV in Thailand, no existing studies appear to exist on the assessment of such trend and its effect on the EEC, which the Thai government is aiming to develop into a leading economic zone in the ASEAN. The EEC faces extensive land use change resulting from dynamic economic development and urbanisation. The rapid development in the area has accelerated the ESV, leading to the demand for ESV analysis to ensure sustainable growth. This study aims to fill this gap by evaluating and examining Chonburi Province; the most urbanised city in the EEC.

Materials and methods

1) Study site

Chonburi Province is located in Eastern Thailand (Figure 1), consisting of 11 districts. In 1982, the Thai government approved a law for trade and investment in the Eastern Seaboard, now known as the EEC with plans to develop it into a technological manufacturing hub, connecting Thailand to its ASEAN neighbours by sea, air, and land. Chonburi is one of the three eastern provinces in Thailand (Chonburi, Rayong, and Chachoengsao), located in the EEC. It also represents an important industrial hub in Thailand since there are 15 industrial estates in Chonburi Province while the total number in Thailand is 59, equating to 25.42% of the total national industrial estates. Chonburi is also home to Laem Chabang—the largest seaport in Thailand. In addition, U-Tapao Airport is also located on the boundary between Chonburi and Rayong Province. A total of 1,483,049 people reside in Chonburi Province, excluding the non-registered population of 583,356 [39].

The city centre of Chonburi Province is situated in the Mueang Chonburi District. Most of the industrial estates are located in the Sri Racha and Bang Lamung Districts while Ko Chan, Nong Yai, Ban Bueng, Panusnikom, Phan Thong, and Bo Thong Districts are regarded as the food production sources or agricultural areas of the province. Ko Sichang and Sattahip Districts are tourist beach destinations.

2) Data

Secondary data is used in this study. The land use map and administrative district boundaries for the years 2006 and 2016 were obtained from the Land Development Department of Thailand (LDD) in digital format (ArcGIS shapefile). According to the land use map, there were 108 land use types in 2006 and 185 in 2016. The land use types in these two periods were re-classified based on their ESV, into six classes: agricultural land, forest land, marsh and swamp, rangeland, urban and built-up areas, and water bodies. Descriptions of these land use classes are presented in Table 1.

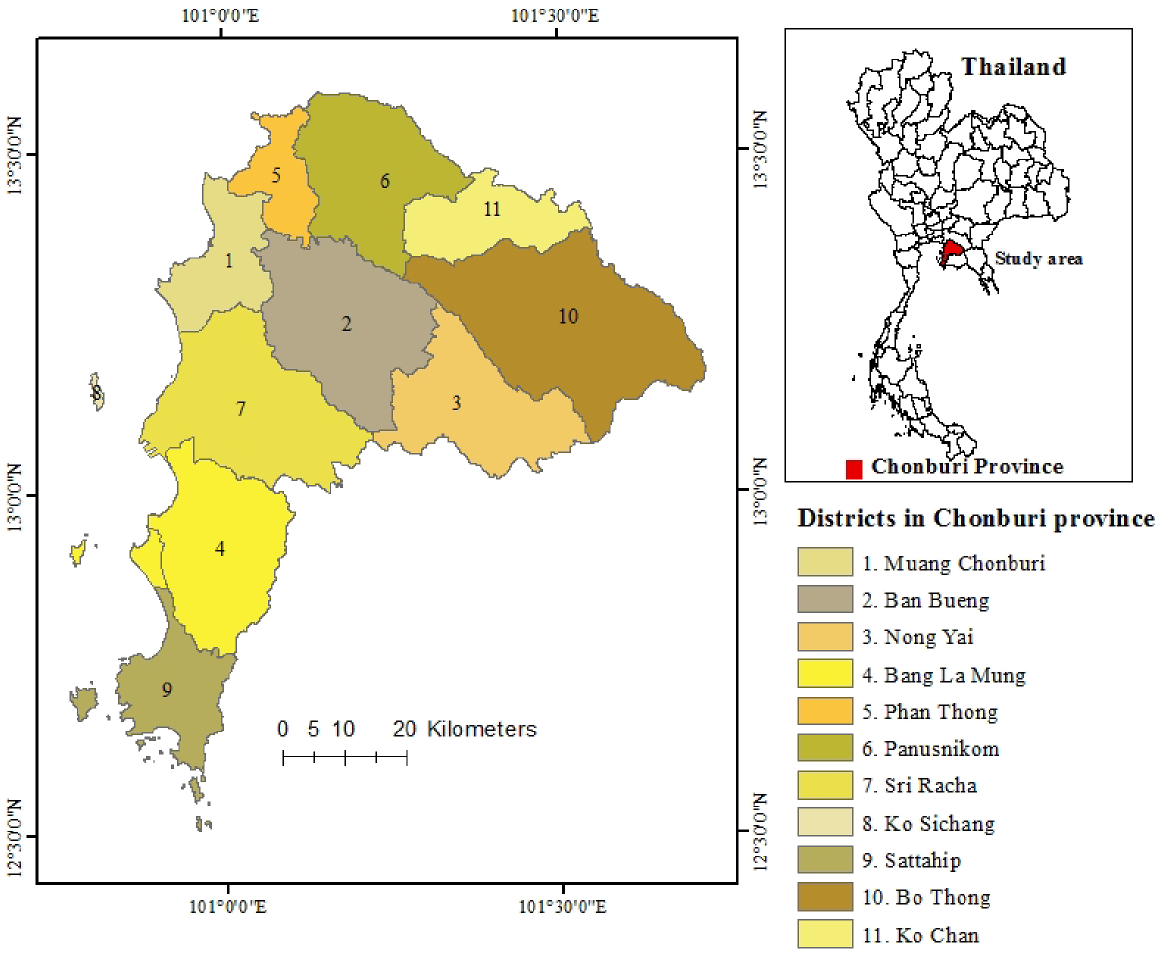

Figure 1 Location of Chonburi Province, Thailand.

Table 1 Land use classification

Land use classes	Description
Urban and built-up areas (UB)	Industrial estates, factories, cities, towns, commercial areas, villages, institutional land, transportation, communication and utility, recreational areas, golf course, cemeteries, refugee camps
Agricultural land (AG)	Paddy field, field crops, perennials, orchards, horticulture, swidden cultivation, farmhouses, aquatic plants, aquaculture, integrated farms, diversified farms
Forest land (FR)	Evergreen forest, deciduous forest, mangrove forest, swamp forest, forest plantation, agro-forestry
Water bodies (WB)	Natural water bodies, reservoirs
Marsh and swamp (MS)	Marsh and swamp, pits
Rangeland (RL)	Rangeland, pasture, abandoned fields

3) Methods

The land use change trend was evaluated using the land use transition matrix and land use dynamic degree models, while the ESV was assessed using the benefit transfer method as follows.

3.1) Land use transition matrix

The land use transition matrix was used to describe the changes in land use type between the two study periods [40] and detect the decrease and increase in each land use type including "from-to change" information among land use types. The formula for the land use transition matrix used in this study is shown in Eq. 1

$$Lij = \begin{vmatrix} L_{11} & L_{12} & \dots & L_{1n} \\ . & . & & . \\ L_{n1} & L_{n2} & \dots & L_{nn} \end{vmatrix}, i \text{ and } j = 1, 2, 3, \dots, n \quad \text{(Eq. 1)}$$

Where L is the area, i and j are the land use types before and after transition, respectively.

3.2) Land use dynamic degree model

The dynamic degree of land use refers to the type of land use during certain time periods. The model shows the annual rate of land use change, expressed as a percentage of the spatial extent. Values above zero indicate gains while below zero values show the loss situation [41]. The formula is shown in Eq. 2.

$$D = ((U_1-U_2)/U_2) \times (1/T)\times 100\% \quad \text{(Eq. 2)}$$

Where D is the dynamic degree of land use or the annual rate of change in land use type during a certain period, U_1 is the number of land use changes at the beginning of the study period, U_2 is the number of land use changes at the end of the study period, and T is the duration of the research period.

3.3) Ecosystem service evaluation

The benefit transfer method was used to calculate the ESVs between 2006 and 2016, based on the coefficient value used by Li et al. [42] and Xie et al. [43]. Xie et al. [43] estimated the equivalent weight factor of ecosystem service per km^2 in China by interviewing 700 ecologists (Table 2). Based on the equivalent weight factor of ecosystem service per km^2 proposed by Xie et al. [43], Li et al. [42] estimated the ESV in response to land use changes in Shenzhen, where the climate, institutional setting, and socio-economics are similar to those in Chonburi Province, Thailand. Shenzhen is located in the Guangdong Province, in Southern China which has a tropical climate like Thailand. Shenzhen is a coastal city with a famous beach and rich natural attractions including a mangrove nature reserve and island; similar to Chonburi Province. The Shenzhen Special Economic Zone was established in 1980, about the same time as Chonburi's economic zone. Shenzhen was also designed to be a transportation hub, accessible by land, sea, and air, like Chonburi Province. It also represents an important industrial hub in China with a GDP growth between 2006–2016 of 9.97% which is quite close to the 7.80% GDP growth rate of Chonburi during the same period [39, 44]. Since there is a strong match and similarities between Shenzhen and Chonburi in terms of economic development and natural conditions, Shenzhen was selected as a reference region. The simple benefit transfer equation of Costanza et al. [45] was applied as shown in Eq. 3.

$$ESV = \sum_{k=1}^{n} A_k \times VC_k \qquad \text{(Eq. 3)}$$

Where ESV is the total value of the ecosystem service. A_k is the area (km^2) for land use type k, and VC_k is the coefficient value (USD km^{-2} a^{-1}) for land use type k.

The main food crop produced in Chonburi Province is rice. The average value of rice production in Chonburi for 2016 was 123,571 USD km^{-2} [46]. Li et al. [42] stated that generally, natural food production should represent 1/7 of the overall food produced, and therefore, the ESV for Chonburi is equivalent to 17,653 USD km^{-2}. The ESV per km^2 for each land use category in Chonburi Province is shown in Table 3.

The ESV for urban and built-up land is assumed to be zero. Although many researchers have found positive values for urban green space [47–49], the works of Van Oudenhoven et al. [12]; Metzger et al. [13]; McIntyre et al. [14]; Mendoza-Gonzalez et al. [15]; Bihamta et al. [16] reveal that urban sprawl is the cause of ecological degradation and ecosystem service reduction. In addition, Xie et al. [50] report a negative ESV for built-up areas. Therefore, the assumption of a zero ESV for urban and built-up areas can help to reduce analysis bias, although a lack of consensus remains.

Table 2 Equivalent weight factors for annual ecosystem service per km^2 in China

Ecosystem service category	Ecosystem service function	Ecosystem service value (USD km^{-2} a^{-1})					
		Urban and built-up land	Agri-cultural land	Forest land	Water bodies	Marsh and swamp	Range land
Regulating services	1) Gas regulation	N/A	72	432	51	241	150
	2) Climatic regulatioı	N/A	97	407	206	1,355	156
	3) Hydrological regulation	N/A	77	409	1,877	1,344	152
	4) Waste treatment	N/A	139	172	1,485	1,440	132
Supporting services	1) Soil formation	N/A	147	402	041	199	224
	2) Biodiversity protection	N/A	102	451	343	369	187
Provisioning services	1) Food production	N/A	100	33	53	36	43
	2) Raw materials	N/A	39	298	35	24	36
Cultural services	1) Recreation and culture	N/A	17	208	444	469	87
Total		N/A	790	2,812	4,535	5,477	1,167

Source: [42]

Table 3 Ecosystem service value of different land use categories in Chonburi

Ecosystem service category	Ecosystem service function	Ecosystem service value of each LULC type (USD km^{-2} a^{-1})					
		Urban and built-up land	Agri-cultural land	Forest land	Water bodies	Marsh and swamp	Range land
Regulating services	1) Gas regulation	0.00	12,710	76,261	9,003	42,544	26,480
	2) Climatic regulation	0.00	17, 123	71,848	36,365	239,198	27,539
	3) Hydrological regulation	0.00	13,593	72,201	331,347	237,256	26,833
	4) Waste treatment	0.00	24,538	30,363	262,147	254,203	23,302
Supporting services	1) Soil formation	0.00	25,950	70,965	7,238	35,129	39,543
	2) Biodiversity protection	0.00	18,006	79,615	60,550	65,140	33,011
Provisioning services	1) Food production	0.00	17,653	5,825	9,356	6,355	7,591
	2) Raw material	0.00	6,885	52,606	6,179	4,237	6,355
Cultural services	1) Recreation and culture	0.00	3,001	36,718	78,379	82,793	15,358
Total		0.00	139,459	496,402	800,564	966,855	206,011

3.4) Ecosystem service sensitivity analysis

Since the biomes used as proxies for each land use categories are not perfectly matched, Kreuter et al. [51] suggest the use of coefficient sensitivity (CS) to calibrate the applied valuation coefficient based on the concept of elasticity. The formula applied is shown in Eq. 4.

$$CS = ((ESV_j - ESV_i)/ESV_i)/((VC_{jk} - VC_{ik})/VC_{ik}) \quad \text{(Eq. 4)}$$

Where ESV is the estimated ecosystem service value, VC is the value coefficient, i and j are the initial and adjusted values, respectively and k is the land use category. In the event that the ratio of the percentage change in the estimated total ecosystem value (ESV) and the percentage change in the adjusted valuation coefficient (VC) is greater than unity, the estimated ecosystem value is then elastic with respect to that coefficient, but if the ratio is less than one, then the estimated ecosystem value is considered to be inelastic.

Results

The spatial and temporal characteristics of land use between 2006 and 2016 were compared using a geographic information system (GIS) with an overlay and union technique. As shown in Figure 2, the clear variation in land use type is due to the expansion of urban and built-up areas along the Laem Chabang industrial estate, located in Sri Racha and Bang La Mung Districts, and the expansion of water bodies in the Ko Chan District as a result of the Khlong Luang Rachalothorn reservoir construction project which started in 2009 and was completed in 2016. The objective of the project is to solve the flood problems in Ko Chan, Phan Thong, Panusnikom, and Bo Thong Districts: areas of food production in the province. Agricultural land use appears to change into urban and built-up areas during this period with most of these changes occurring in the districts of Muang Chonburi, Sri Racha, Bang La Mung, Phan Thong, and Ko Chan.

1) Land use transition matrix from 2006–2016

The transitional change matrix for land use was applied to analyse the "from-to change" information in Chonburi Province. Table 4 shows that over the ten-year period, the most significant feature of land use in Chonburi Province was the reduction of agricultural to other land use types. The main pattern involved the transformation of agricultural land use into urban and built-up areas. From 2006–2016, the decrease in agricultural land was 325.20 km^2, of which 194.29 km^2 (59.72%) changed into urban and built-up areas. The second highest transitional trend occurred with urban and built-up areas changing into agricultural land use. There was a reduction in urban and built-up areas of 133.13 km^2 during this period, of which 106.04 km^2 (79.65%) changed into agricultural use. Another significant change occurred in range-land with 41.98% (57.28 km^2) of the total 136.46 km^2 reduction transforming into agricultural land with another 33.81% (46.14 km^2) being converted into urban and built-up areas. Most of the conversion of forest land (53.23% or 16.48 km^2) also changed into agricultural land.

2) Degree of dynamic land use

The land use transition matrix was used to calculate the degree of dynamic land use in Chonburi Province from 2006–2016 as presented in Table 5. The result shows that water bodies exhibit the highest degree of dynamic land use (6.11%), followed by rangeland (-3.68%), and urban and built-up areas (1.89%), respectively. The degree of variation in dynamic land use for Chonburi Province from 2006–2016 was 4.67%.

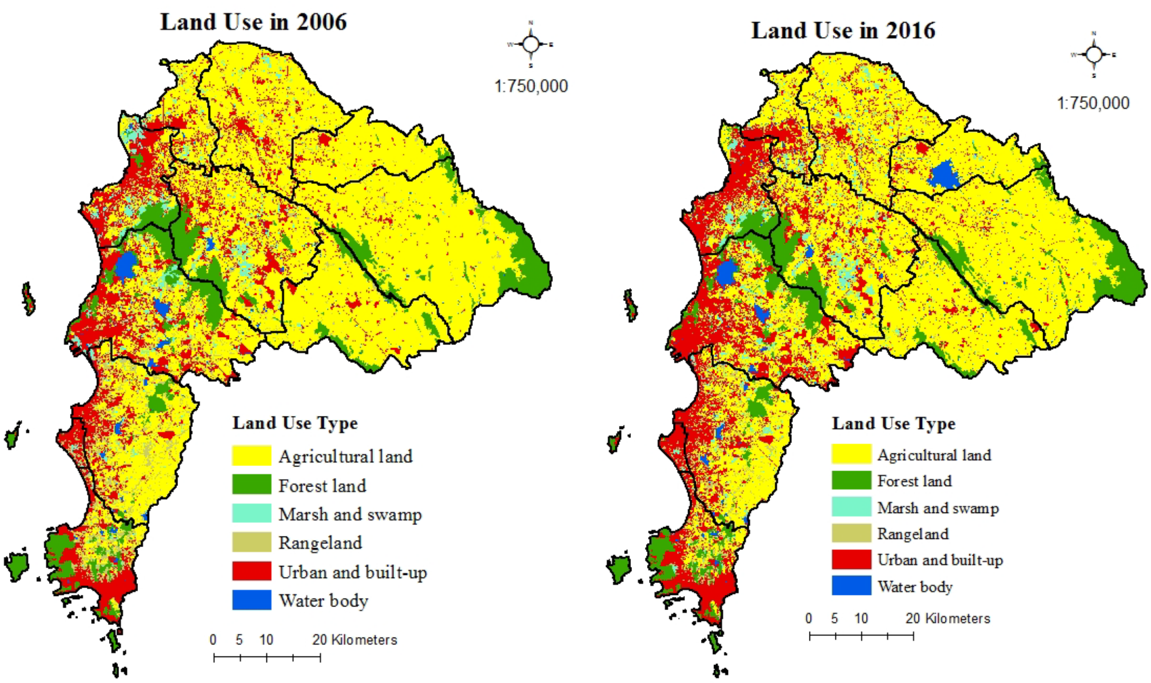

Figure 2 Land use maps of Chonburi Province for 2006 and 2016.

Table 4 Transition matrix of land use in Chonburi from 2006–2016 (km^2)

Land type	2016						Total
2006	AG	FR	MS	RL	UB	WB	
AG	2,488.78	15.16	49.90	30.72	194.29	35.13	2,813.99
FR	16.48	464.63	0.83	2.01	11.17	0.47	495.60
MS	18.91	5.96	69.43	8.21	23.89	4.37	130.77
RL	57.28	11.61	11.50	84.86	46.14	9.93	221.32
UB	106.04	4.73	6.02	13.28	644.08	3.07	777.21
WB	3.68	0.29	1.52	0.87	4.45	58.12	68.93
Total	2,691.18	502.37	139.19	139.97	924.01	111.08	4,507.81

Table 5 Degree of dynamic land use in Chonburi from 2006–2016

Land use type	Year 2006–2016	
	Change area (km^2)	Dynamic degree
Agricultural area	-122.80	-0.44
Forest area	6.78	0.14
Marsh and swamp	8.43	0.64
Rangeland	-81.35	-3.68
Urban and built-up areas	146.80	1.89
Water bodies	42.15	6.11
Total		4.67

3) Estimation of ecosystem service value

The ESV analysis in Table 6 shows a slightly higher value for 2016 than 2006. The total ESV increased by 11.37 million USD or 1.31% from 2006 to 2016. The change in ESV is dominated by the increase in water bodies (61.15%) and decrease in rangeland (-36.76%). Obviously, water bodies make a significant contribution to the total increase in ESV during this period.

Details of the ESV changes in 2006 and 2016 according to function and category are presented in Supplementary Materials 1 and 2, respectively. The top three dominant ecosystem service functions (ESFs) over the study period were waste treatment, hydrological, and climatic regulation. The ESV of these functions increased in accordance with the rise in water body land use which played a significant role during this period.

The ESV proportions in 11 districts are presented in Table 7. Seven districts showed an increased ESV, namely Ko Chan, Panusnikom, Ban Bueng, Nong Yai, Bo Thong, Bang La Mung, and Ko Sichang. From 2006–2016, Ko Chan District exhibited the largest increase with 17.56 million USD, followed by Panusnikom (15.59 million USD) and Ban Bueng (8.90 million USD), respectively. The other four districts showed a decreased in ESV, namely Sri Racha, Muang Chonburi, Sattahip, and Phan Thong. The Sri Racha District has the largest decrease with 17.26 million USD, followed by Muang Chonburi (14.78 million USD) and Sattahip (1.28 million USD), respectively. The top three contributors to the ESV of the province in 2006 were Bo Thong, Sri Racha, and Ban Bueng, respectively while in 2016 they were Bo Thong, Ban Bueng, and Sri Racha, respectively.

4) Ecosystem service sensitivity analysis

The percentage change in the estimated total ESV and the 50% adjustment for the coefficient of sensitivity are presented in Table 8. The coefficient of sensitivity (CS) for agricultural land was the highest (±0.45) due to the large area involved, despite the low service value coefficient. The CS for agricultural land and rangeland decreased slightly in 2016 compared to 2006, while forest land, marsh and swamp, and water bodies increased slightly. The highest variation in the estimated ESV is exhibited by the water bodies. When increasing or decreasing the coefficient by 50%, the ESV was affected by 3.19% in 2006 and 5.07% in 2016. In these analyses, the CS values were less than unity in all cases. This indicates that the total ecosystem values estimated for the study area are relatively inelastic with respect to the ecosystem service coefficients, implying that the estimates in this study are robust.

Discussion

This study evaluates the land use change trend and its impact on ESV in the EEC, which has a high degree of economic development activity and an increasing urban sprawl. The results and implications are detailed below.

Land use transition matrix: The results for the transition from rangeland and urban and built-up areas to agricultural land indicates that the decrease in agricultural land use is actually quite small since it is offset by the conversion of urban built-up areas and rangeland into agricultural land. One possible explanation for the back and forth land use behaviour between rangeland and agricultural land is the construction of the Khlong Luang Rachalothorn Reservoir, making the agricultural land use choice appear more competitive. In relation to the conversion of urban and built-up areas into agricultural land, this study examines in detail the transformation of urban and built-up areas and agricultural land, finding that the majority of conversions occur in abandoned village/lowland villages and road areas. Out of 106.04 km^2 of urban and built-up areas which have changed to agricultural use, abandoned village/lowland villages account for 73.48% (77.92 km^2) while road areas account for 15.34% (16.27 km^2), representing around 90% of the total change. Abandoned village/lowland villages have mainly been converted into paddy field, cassava, and sugarcane, with most road areas converted into cassava and sugarcane. Lowland villages in Thailand are not structurally strong. The walls of the houses are often made of wood or bamboo and the roofs are made from leaves. Although the dwellings are permanent, they are easy to move when relocation is required. This finding justifies the phenomenon of converting urban and built-up areas into agricultural land. In relation to the results for road conversion, the findings indicate an increasing trend of agricultural encroachment on roads in the study area. This trend occurs mostly in Ban Bueng, and Panusnikom Districts which are agricultural areas in the province (52% of the total road area has been encroached). The results for the 53.23% conversion of forest land to agricultural land also indicates an increasing trend of land encroachment for agriculture in the study area.

Table 6 Ecosystem service values according to land use type for Chonburi Province in 2006 and 2016 (million USD)

Land use type	2006		2016		Net value change	% change
	ESV	%	ESV	%		
Agricultural area	392.43	45.33	375.31	42.79	-17.13	-4.36
Forest area	246.01	28.42	249.38	28.43	3.36	1.37
Marsh and swamp	126.43	14.61	134.58	15.34	8.15	6.44
Rangeland	45.59	5.27	28.83	3.29	-16.76	-36.76
Urban and built-up areas	0.00	0.00	0.00	0.00	0.00	0.00
Water bodies	55.19	6.37	88.93	10.14	33.74	61.15
Total	865.66	100.00	877.03	100.00	11.37	1.31

Table 7 District ecosystem service values and percentage proportional contributions to Chonburi's total ecosystem service value (USD)

District	2006		2016	
	ESV	%	ESV	%
Ban Bueng	121,946,469.15	14.09	130,850,306.99	14.92
Bang La Mung	88,537,042.12	10.23	89,408,093.98	10.19
Bo Thong	165,704,765.41	19.14	167,623,324.48	19.11
Ko Chan	38,120,936.90	4.40	55,683,999.98	6.35
Ko Sichang	2,493,452.98	0.29	2,549,025.54	0.29
Muang Chonburi	65,217,079.41	7.53	50,441,304.63	5.75
Nong Yai	79,460,610.73	9.18	81,818,440.55	9.33
Phan Thong	28,436,739.58	3.28	27,854,230.01	3.18
Panusnikom	67,415,295.22	7.79	81,012,410.30	9.24
Sattahip	65,372,452.70	7.55	64,089,319.18	7.31
Sri Racha	142,958,126.67	16.51	125,701,535.33	14.33
Total	865,662,970.88	100.00	877,031,990.97	100.00

Table 8 Estimated total ecosystem service values in Chonburi after the 50% adjustment in the ecosystem service valuation coefficient (million USD)

Change in value coefficient	Total ESV after adjusting coefficients		2006		2016	
	2006	2016	%	CS	%	CS
Agricultural land VC+50%	1,061.88	1,064.69	22.67	0.4533	21.40	0.4279
Agricultural land VC-50%	669.44	689.38	-22.67	-0.4533	-21.40	-0.4279
Forest land VC+50%	988.67	1,001.72	14.21	0.2842	14.22	0.2843
Forest land VC-50%	742.65	752.34	-14.21	-0.2842	-14.22	-0.28 43
Marsh and swamp VC+50%	928.88	944.32	7.30	0.1461	7.67	0.1534
Marsh and swamp VC-50%	802.45	809.74	-7.30	-0.1461	-7.67	-0.1534
Rangeland VC+50%	888.46	891.45	2.63	0.0527	1.64	0.0329
Rangeland VC-50%	842.87	862.61	-2.63	-0.0527	-1.64	-0.0329
Urban and built-up areas VC+50%	865.66	877.03	0	0.0000	0	0.0000
Urban and built-up areasVC-50%	865.66	877.03	0	0.0000	0	0.0000
Water bodies VC+50%	893.25	921.50	3.19	0.0637	5.07	0.1014
Water bodies VC-50%	838.07	832.57	-3.19	-0.0637	-5.07	-0.1014

Degree of dynamic land use: In general, during the ten-year period under study, the active land use change situation in Chonburi Province is due to rapid urbanisation with water bodies and urban and built-up areas showing the largest increase, and rangeland use in rapid decline.

Ecosystem Service Value: the GDP of Chonburi was 13,808.21 million USD in 2006 and 25,733.67 million USD in 2016, representing an increase of 86.37%, and an annual average growth rate of 7.80% during this ten-year period [52]. The total ESV of Chonburi Province was about 6.27% of its GDP in 2006, declining to 3.41% in 2016. Although the analysis detects a higher total ESV, this declines in comparison to its respective GDP. The economic growth appears to be in contrast to ecological enhancement. In 2013, the World Wide Fund for Nature (WWF) attempted to estimate the ESV in the Mekong Basin using meta-analysis. Although the results rely heavily on the accuracy of pre-existing research and the work includes only four land use types (natural forests, freshwater wetlands, mangroves, and coral reefs), it is the first and only attempt to value and model the region's total ESV. The WWF reported that the ESV of Thailand was about 27.13 billion USD, equating to 10.52% of Thailand's GDP in 2013 of 257.82 billion USD, while the ESV of Vietnam was about 28.87 billion USD in 2013, equating to 16.86% of Vietnam's GDP of 171.20 billion USD. The ESV for Cambodia was about 16.87 billion USD in 2013 equating to 110.77% of Cambodia's GDP of 15.23 billion USD. Furthermore, the ESV of Lao was about 38.88 billion USD in 2013, equating to 283.75% of its GDP of 11.94 billion USD. [53]. The figures reported by the WWF also support the findings of this study, in that economic growth contrasts with ecological development; the higher the GDP, the lower the ESV. The results of this study have been compared with those of Li et al. [42], who reported that the total ESV for Shenzhen in 1996 was 388.64 million USD (2.9% of Shenzhen's GDP in 1996), declining to 356.26 million USD (0.74% of Shenzhen's GDP in 2004). The ESV for Chonburi is twice that of Shenzhen (865.66 million USD in 2006 and 877.03 million USD in 2016). The ESV of Chonburi was compared with that of Khon Kaen relying on the work of Ongsomwang et al. [35]. The estimated total ESV of Khon Kaen in 2006 was 145 million USD, and projected to decrease to 132 million USD in 2026. The figure represented 3.54% of Khon Kaen's GDP in 2006 (4,093 million USD) which is relatively close to Chonburi's figure. However, the popular international work by Costanza et al. [44], indicated that the global ESV was about 1.8 times the global GNP. Although his work receives some strong critique on the methodology used, the figure obtained means that the Chonburi ESV is significantly less than the global average. Furthermore, the work of Intralawan and Rueangkitwat [37] reported the ESV of Chiang Khong District in Chiang Rai Province, Thailand as 1,896 million USD in 1976 and 1,455 million USD in 2015. Since the GDP of Chiang Khong District is not available, the ESV of Chiang Khong District is compared with that of Chiang Rai instead. The only data available on the GDP of Chiang Rai was for 2015 which equated to 2,756 million USD. Thus, the ESV of Chiang Kong represents 52.79% of Chiang Rai's GDP in 2015. This extreme gap in the ESV indicates that greater analysis accuracy is required in this field for effective quantification. Although the comparison between ESV and GDP suggests that balancing economic development and ecological enhancement is crucial in this area, the 1.31% rise in total ecosystem value from 2006–2016 must be recognised. The increase in the total ESV also suggests that urban expansion may not necessarily lead to a decline in the ecosystem service if there is a rise in other land use types, thus providing a greater level of ecosystem services to offset the negative impacts caused by urban development. This is an important point, since the results of this study also indicate that the land use trend is changing, with urban and built-up areas increasing. Therefore, other land use types will continue to decline over time since land resources are fixed and cannot increase or decrease like other resources. As long as the returns on land use are the top priority for landowners when making decisions on their land allocation, the conversion of land into built-up areas is to be expected since this land use type produces the highest return. Therefore, land use planning in the study area should focus on increasing wetlands, since this land use type makes the greatest contribution to ESV in urban areas. Furthermore, agricultural land must be protected since it covers a large area and is an important source of food security in Chonburi Province.

The greatest contribution to Chonburi's ESV (around 19%) was made by Bo Thong District in both 2006 and 2016. Bo Thong has the largest agricultural and forest land, and therefore, the largest ESV proportion in Chonburi Province. The next highest contributors to Chonburi's ESV in 2006 were Sri Racha and Ban Bueng Districts with 16.51% and 14.09%, respectively. The ESV contribution ranking in 2006 changed from Sri Racha being the second largest contributor to the third largest in 2016 with 14.33%, with its second place ranking taken by Ban Bueng (14.92%). When examining Sri Racha District in detail, a decrease in all land use types was found in 2016 except for urban and built-up areas which increased by 42.93 km^2. Obviously, other land use types were converted into urban and built-up areas in Sri Racha District. The results indicate that urban and built-up areas are the key land use types determining the reduction in the total ESV for Sri Racha District. In relation to the increased ESV in Ban Bueng District, there is a comparatively high rise in marsh and swamp as well as water bodies. Since the ESV per unit for marsh and swamp and water bodies is much higher than that of other land use types [32], increases in these land use types are key to the shift in the ranking contribution in ESV of Ban Bueng District.

The results of the change in ESV according to function indicate that urban development increases the dependency of cities on water services for the population. The extent of the water bodies affects evapotranspiration rates, thereby contributing to changes in temperature and climate. Water is necessary for human life and urban areas are associated with large populations. People living in urban areas need water for their daily activities such as drinking, cooking, cleaning, and the disposal of human waste. Moreover, industrial activities also require water in the production process such as for cooling systems and cleaning activities. Therefore, a large amount of water is essential in urban areas. In addition, recreation and culture also play a significant role in the increased ESV between 2006 and 2016. Chonburi Province has recently attracted many eco-tourists and agri-tourists. Apart from the beautiful beach, the Khlong Luang Rachalothorn Reservoir and Bang Pra Reservoir, located in the Ko Chan and Sri Racha Districts, respectively, are popular camping destinations.

Conclusion

This study investigates the trend in land use change for Chonburi Province, Thailand, and the effect of such change on the ESV. The key findings are summarised as follows:

The largest land use type in Chonburi Province is agricultural, followed by urban and built-up areas, and forest. The rapid urbanisation development is the main driving factor for the conversion in land use type. An increase in water bodies and urban and built-up areas, and a decrease in rangeland are mainly responsible for the changing land use trend in Chonburi. The majority of urban and built-up areas have been converted from agricultural land, while agricultural land has mainly been converted from urban and built-up areas (abandoned village/ lowland villages and roads) and rangeland.

Road encroachment by agriculture shows an increasing trend in Ban Bueng and Panusnikom Districts (agricultural areas of the province). Forest land has mainly been converted into agricultural land in the study area, indicating encroachment.

From 2006 to 2016, the total ESV of Chonburi Province increased by 11.37 million USD (1.31%). Approximately 47% of the total ESV is due to the function of waste treatment, hydrological and climate regulation. All ecosystem service functions were found to have a negative effect on ESV except hydrological regulation, waste treatment, and recreation and culture, all of which relate to the rise in water bodies. Among 11 districts, the ESV of Sri Racha and Muang

Chonburi Districts has been greatly affected by the high urbanisation rate. Since the gap between economic and ecological development is wider when comparing the ESV with its respective GDP, the authority in Chonburi Province should shift its efforts towards balancing economic development with ecological enhancement instead of focusing merely on economic growth.

The expansion of water bodies has led to an increase in the ESV of Chonburi Province, indicating that land use planning in the study area should focus on increasing the wetlands and protecting agricultural land since these make the highest contribution to the ESV.

There are some limitations in the biomes used in this study for each land use category due to the different climate conditions and uncertainties in the representation, although the figures were robust-checked by sensitivity analysis based on the economic elasticity concept. In addition, the method used did not consider other factors apart from land use type and its corresponding ESV per unit of area. Factors such as the inflation rate, government policy, and market price may have an effect on the estimated ESV, especially when incorporating dynamic time and space analysis, and these should be addressed in future studies. The study analysis also detected two research gaps that would benefit from further investigation. Firstly, the need for the urban ESV to be examined in Asia, since the negative and positive values found in previous research reveals a wide analysis bias gap when attempting to estimate the total economic value (TEV) of land use change. Secondly, a more accurate methodology is required to robustly capture the benefit and cost of land use change.

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