The Evaluations of Land Use, Land Cover Changes and the Impacts to Ecosystem Services Values in Northeast Thailand

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Abstract

Fluctuations in land use land cover (LULC) induces destruction of green cover, changes in nature, and pollution of water resources hence it disturbs ecosystem service values (ESVs). Objectives of the study were (1) to extract LULC status (from secondary data) and its change during the year 2008, 2013, 2018; (2) to assess LULC change impact on ecosystem service standards between 2008 and 2018. Therefore, to get status of LULC type, data of 2008, 2013, 2018 were classified from SERVIR-Mekong website under the Regional Land Cover Monitoring System (RLCMS). Ecosystem services (ESs) from the derived LULC data through simple benefit transfer method were then evaluated. Northeast Thailand was divided into three sections of big, medium and small provinces in terms of population density per area for a better comparison and analysis. Results revealed that cropland areas significantly decreased while forest land areas increased remarkably over the decade for all three sections. Whereas total ESVs increased for all sections from about 22837 million USD in 2008 to 23346 million USD in 2018 for the region. The impact that LULC changes had on ESVs remarkably fluctuated among the LULC categories according to the area and ESVs for individual LULC division over the decade. In conclusion, increase in ESV suggest that the region has great potential for land use and city planners to optimize the effect of LULC change on ESVs during the planning process.

Keyword: Land use land cover/ Ecosystem service values/ Ecosystem services/ Benefit transfer/ Northeast Thailand

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1. Introduction

The development of urban parts and the outcome of social actions on ecosystems have remained leading concerns of environmental attention. According to "World urbanisation prospects: The 2009 revision population database" by United Nations (2010), it is estimated that more than 50% of the worldwide populace are living in cities, and this fraction will reach to about 69.6% by end of 2050. Even though the total urban area resolves only a minor portion of the global surface (Grimm et al., 2000; Zhang et al., 2013), presently, urbanisation is informed to be the most authoritative influencer of climate change (Mccarthy et al., 2010). Exhaustive and accelerated urbanisation is an instance of human-induced land use/land cover (LULC) alteration, which has deteriorated the constant effects that affect the climate system (Jin et al., 2005).

The fluctuations in LULC induces destruction of green cover, changes in nature, and pollution of water resources (Billa et al., 2013). Escalating urban growth and LULC surges pressures on human welfare and the natural environment and have become a universal apprehension. Accelerated urban development typically occurs next to the expense of major cultivated land, with the forfeiture of open public space and natural landscape (Ongsomwang et al., 2019). The land use land cover (LULC) pattern of an area can be dependant by the socioeconomic and natural factors and their consumption by humans in space and time (Shiferaw & Singh, 2011; Showqi et al., 2014). The exterior of the ground has altered significantly over the last five decades by human activities particularly through intensive agricultural practices, desertification and urbanisation. Deviations in LULC are amid the utmost significant variations on the earth's surface (Showqi et al., 2014) The change of forest, woods and savannah into pasture and cropland through the previous decades has increased dramatically in the tropics (Lambin et al., 2003; Shiferaw & Singh, 2011). The dominant LULC change and quick urbanisation that are taking place in emergent nations such as Turkey, India, Thailand, Pakistan and other Latin American nations have been a growing consideration (Dewan & Yamaguchi, 2009; Geymen & Baz, 2008; Henríquez et al., 2006; Kumar et al., 2007; López et al., 2001).

The notion of ecosystem service can be well-defined as "the circumstances and procedures through which naturally occurring ecosystems, and the concurrent species that make them up, sustain and accomplish anthropoid life" (Luederitz et al., 2015; Ongsomwang et al., 2019). Ecosystem service is fatal to sustaining natural life and stable ecosystem. In recent years, ecosystem services research has become extremely significant. The number of researches focussing on ecosystem services is progressing exponentially and the consequence of the notion is perceived by the book of the Millennium Ecosystem Assessment (MEA), an outstanding work that comprises contribution of about 1300 researchers. One of the vital outcomes of the MEA was the discovery that universally 15 of the 24 ecosystem investigated are waning out, which will lead to a considerable and damaging effect on subsequent human well-being (Fisher et al., 2009; Millennium Ecosystem Assessment (MEA), 2005; Ongsomwang et al., 2019). MEA (2005) classified ecosystem facilities into four groups: (1) regulating services which are profits from the regulation of ecosystems such as flood control, purification of water, or readjustment of the climate through carbon sequestration; (2) provisioning amenities which are the product from the ecosystems like timber or food; (3) supporting services which are required for the manufacture of supplementary services for instance soil development and nutrient cycling; and (4) cultural services which help people from ecosystems through intellectual development, spiritual enrichment, aesthetic experiences, recreation and reflection (Ongsomwang et al., 2019).

Alternatively, the approach of ecosystem package valuation has been largely divided into three categories: economic, ecological and socio-cultural value (Ongsomwang et al., 2019). Ecosystem service values (ESVs) are specified evaluations of natural possessions and services, which show economic significance including the wellbeing and status of an ecosystem (Costanza, 2012; Johnston & Russell, 2011; Peng et al, 2015; Sannigrahi et al, 2018; Sannigrahi et al., 2020; Sannigrahi, Chakraborti, et al., 2019; Sannigrahi, Joshi, et al., 2019; Yan et al., 2016). Most of the studies on appraisal of ecosystems services is concentrated on assessing and monetizing definitive Ecosystem-Service Values (ESVs) at a particular juncture (Costanza et al., 1997; Li & Fang, 2014; Li et al., 2016).

Therefore, this research aims to apply geoinformatics technology and land us land cover change (LULCC) model to judge the impact of LULCC on ecosystem service standards in the North-eastern region of Thailand. Northeast Thailand was selected as the study region because it encompasses a total area of more than 170,000 square kilometres and is known for its vast agricultural growth potential for Thailand. The region covers one third of the country and for several years, North-eastern Thailand has had the major rural population growth (Ratanopad & Kainz, 2012).

The objectives of the study were (1) to extract LULC status (from secondary data) and its change during the year 2008, 2013, 2018; and (2) to assess LULC change impact on ecosystem service standards between 2008 and 2018. This research will focus on the years from 2008 to 2018 as the secondary data of LULC map is available only till the year 2018. Land cover map for 2019 and 2020 is still not available. This research also aims at a bigger picture by taking the entire region of Northeast Thailand instead of sticking to a particular province. This research can be a guideline for land use and city planners to give an optimum LULC scenario for balancing the economic development and ecosystem health in future for the entire region altogether.

2. Methodology

2.1 Study Area

Northeast Thailand (NET) (Figure 1) encompasses an overall area of more than 170,000 km^2 which inhabits one third of the country and is home to around 21 million people and it is the largest region in Thailand (Lacombe et al., 2017; Ratanopad & Kainz, 2012). The region is better known as Isan for the Thai people and it consists of 20 provinces. NET is situated on the Khorat Plateau, bounded by the border of the Sankamphaeng Range south of Nakhon Ratchasima, by Cambodia to the southeast and by Laos and Mekong River to the north and east. To the west it is divided from northern and central Thailand by the Phetchabun Mountains (“Isan”, n.d.). The region is primarily a sandstone plateau gently undulating between 100 and 500 m above sea level (Lacombe et al., 2017), tilting from the Phetchabun Mountains in the west down toward the Mekong River.

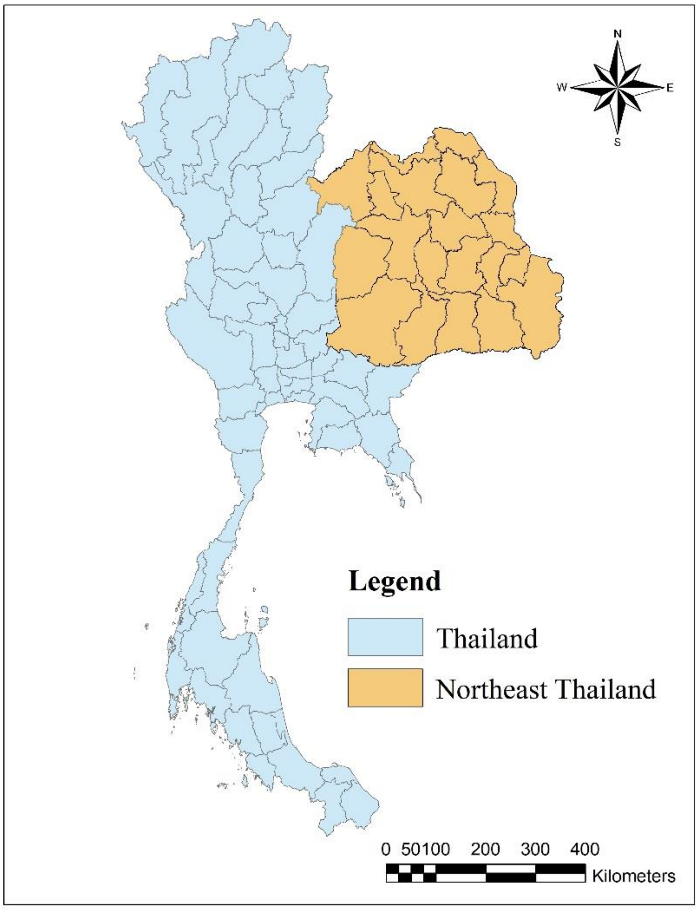


Figure 1. Map of Northeast Thailand

The region’s average temperature is from 19.6°C to 30.2°C. Typically, the region has unpredictable rainfall but is intense from May to October during the rainy season. Average annual precipitation ranges from 1,270 mm in the southwestern provinces of Buriram, Chaiyaphum, Nakhon Ratchasima, Maha Sarakham and Khon Kaen to 2,000 mm in some other areas. The hot season is generally from February to May with the highest temperatures in April and the cool season from October to February (“Isan”, n.d.). Approximately 80% of the population live in rural areas, mainly from agriculture and payments acknowledged from lots of permanent and seasonal migrants (Lacombe et al., 2017). The region also consists numerous national parks and possesses high biodiversity and several native species.

The development plans of Thailand don’t always cover regions in particular, it focusses on small sections of areas for example the Eastern Economic Corridor (EEC) or the lower Chao Phraya area and so on. As NET is a very big region, calculating the entire region's land use land cover values and the ecosystem services values altogether might result in giving a biased outcome; therefore, it is better to divide the region into different sections of big provinces, medium provinces and smaller provinces in terms of population density per area (Figure 2). The population density per area has been divided in a range from 200-150/km^2 for big provinces, 150-100/km^2 for medium sized provinces and 100-50/km^2 for small provinces.

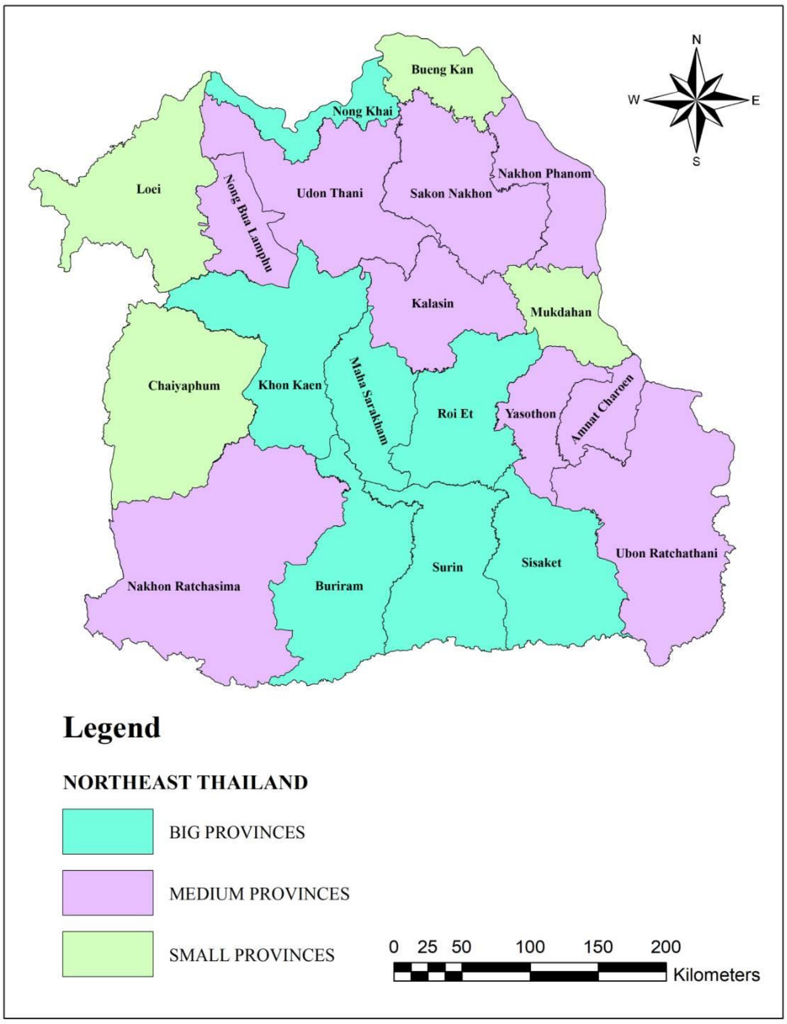


Figure 2. Big, Medium and Small Provinces of NET

2.2 Data Collection and Analysis

2.2.1 LULC Assessment

In order to get the area as well as the change of the LULC type, first, the old and recent LULC in 2008, 2013, 2018 was classified from the SERVIR-Mekong website (SERVIR Mekong, n.d.) under the Regional Land Cover Monitoring System (RLCMS). SEVIR-Mekong is a geospatial data-for-development program that responds to the needs of Lower Mekong countries. SERVIR-Mekong is mobilizing space technology and open data to help focus on challenges related to a changing climate, through a unique partnership between the U.S. Agency for International Development (USAID) and the U.S. National Aeronautics and Space Agency (NASA). It works in partnership with these leading organizations to assist the five countries in the Lower Mekong Region (Myanmar, Lao PDR, Cambodia, Vietnam and Thailand) to use information provided by geospatial technologies and Earth observing satellites to manage climate risks.

Under this program is the Regional Land Cover Monitoring System (RLCMS) which produces high-quality regional land cover maps and identifies annual land cover changes in the Lower Mekong region. It uses well documented, transparent open-source technique. It also consists of quality assurance/ quality control approaches that combines information from multiple sources (Regional Land Cover Monitoring System Methodology, n.d.). The process in which the land cover map was produced is the following: once the map of Northeast Thailand (NET) was downloaded, LULC classification was done by using the typology values from RLCMS. In this study, the LULC classification system comprised of (1) Barren Land (bare land, abandoned land, landfills and pits); (2) Cropland; (3) Forest Land; (4) Marsh and Swamp; (5) Rangeland; (6) Surface Water; and (7) Urban and Built-up Area which was altered from the standard land use classification system in Thailand by the Land Development Department. Once the classification was done, the area of each LULC type was calculated using the ArcGIS software.

2.2.2 Ecosystem Service Evaluation (240 words)

Once the LULC status assessment data is created, the next phase of the research consists of evaluating the ecosystem services. ESVs were quantified using a simple benefit transfer method, which is used to calculate economic values for ecosystem services by substituting existing data from the previous study of Ongsomwang et al. (2019) to the present study region, since this technique is an instantaneous and a lower cost approach to assessing ecosystem valuation. Moreover, benefit values of separate LULC types with regard to ecosystem service was inaccessible. The LULC data that was derived between 2008, 2013 and 2018 was used to calculate ESVs determined from the simple benefit transfer method (Costanza et al., 1997) as:

$$ESV=\sum (VC_k \times A_k) \quad (1)$$

Where, ESV signifies the entire value of ecosystem service, while VC_k and A_k represent the coefficient value in USD/ha/year (Table 1) (which were assigned to each LULC type according to the value used by Ongsomwang et al., (2019)) and the area in ha for LULC type 'k', respectively. Proceeding, ESV change was evaluated by comparing the results of one dataset with the equivalent result of the second dataset in each time period. Therefore, the ESV changes were calculated (Kindu, Schneider, Teketay, & Knoke, 2016) as:

$$\text{ESV change} = \text{ESV final year} - \text{ESV initial year} \quad (2)$$

To calculate the percentage ESV changes the following equation was used (Kindu et al., 2016):

$$\%\ \text{ESV change} = [(\text{ESV final year} - \text{ESV initial year}) / (\text{ESV initial year})] \times 100 \quad (3)$$

Furthermore, to calculate estimated values of services provided by each ecosystem functions within the study area, the following equation was taken:

$$ESV_f = \sum (VC_{fk} \times A_k) \quad (4)$$

Where, ESV_f signifies calculated ecosystem service value of function 'f'', VC_{fk} is the value coefficient of function 'f' (USD/ha/year) for LULC type 'k' and A_k is the area (ha).

3. Results and Discussion

3.1 LULC Status

In 2008, 2013 and 2018, the top three dominant LULC types for all three sections of Isan were cropland, forest-land and surface water. For big provinces the three dominant LULC types covered 83.86% (cropland), 12.78% (forest-land), and 1.51% (surface water) of the total area; for medium provinces they covered 76.15% (cropland), 20.45% (forest-land), and 1.86% (surface water) of the total area; for small provinces they covered 53.30% (cropland), 44.39% (forest-land), and 0.96% (surface water) of the total area (Figures 3 (a)-(c), Figures 4 (a)-(c), Figures 5 (a)-(c)). In these periods, forest-land areas notably increased from 6190.17 km^2 in 2008 to 7808.05 km^2 in 2018 for big provinces; from 15384.21 km^2 in 2008 to 17528.37 km^2 in 2018 for medium provinces and from 12837.80 km^2 in 2008 to 14847.13 km^2 in 2018 for small provinces. However, cropland and surface water exceptionally decreased from 48107.85 km^2 in 2008 to 46398.47 km^2 in 2018 for big provinces; from 64515.42 km^2 in 2008 to 62236.57 km^2 in 2018 for medium provinces and from 18186.82 km^2 in 2008 to 16131.92 km^2 in 2018 for small provinces (Figure 3 (d), Figure 4 (d), Figure 5 (d)). Among the three divisions in the region, medium provinces have the highest area of LULC covering 243231.15 km^2.

Table 1. Coefficient value for different LULC types for ESV estimation

Ecosystem services category	Ecosystem services function	Ecosystem service value of each LULC type (USD/ha/year)						
		Urban and Built-up Area	Cropland	Forest Land	Surface Water	Marsh and Swamp	Range Land	Barren Land
Regulating services	1) Gas regulation	0	74.7	299.4	0	268.9	104	4.2
	2) Climate regulation	0	133	282.1	68.7	2,554.7	108	9.0
	3) Waste Treatment	0	245	119.2	2,719.0	2,716.0	91.5	18.0
Supporting services	1) Soil formation	0	218.1	278.6	1.5	255.5	155	11.8
	2) Biodiversity protection	0	106.1	312.6	372	373.5	130	27.7
Provision Services	1) Water supply	0	89.6	283.5	3047.7	2 315.6	105	4.8
	2) Food production	0	149.4	22.9	14.9	44.8	29.8	1.4
	3) Raw materials	0	14.9	206.5	1.5	10.5	25	2.8
Cultural services	1) Recreation and culture	12.7	1.5	144.2	648.4	829.2	60.3	16.6
Total		12.7	1,032.30	1,949.00	6,873.70	9,368.70	808.6	96.3

Source: Modified from (Mamat et al., 2018; Ongsomwang et al., 2019)

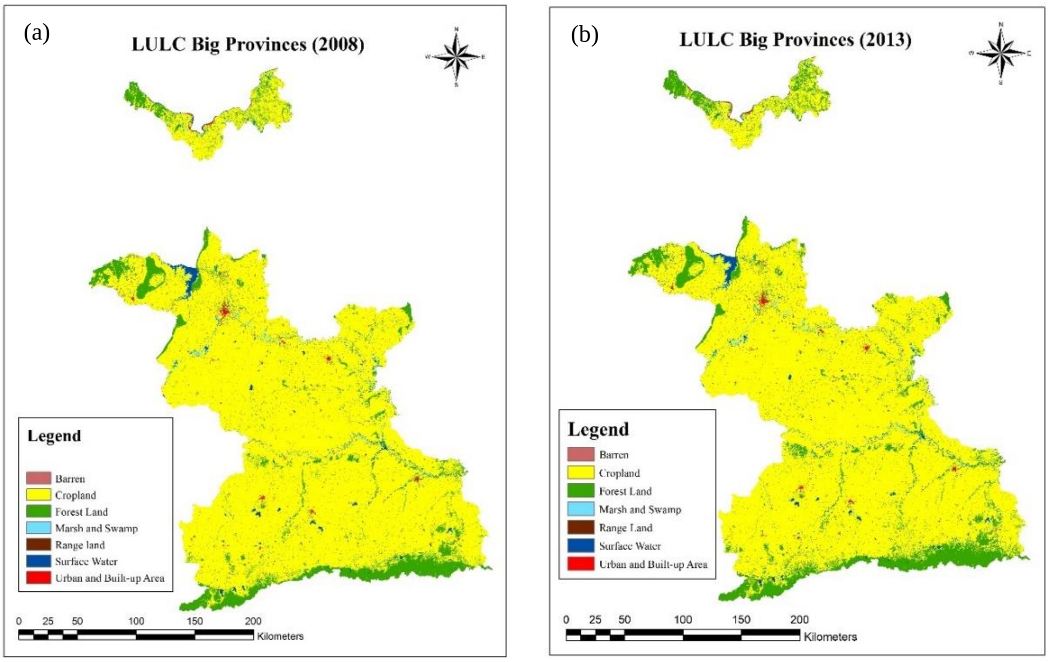
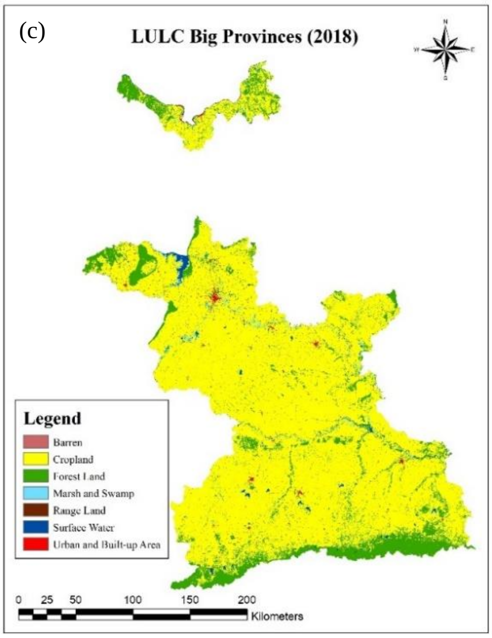
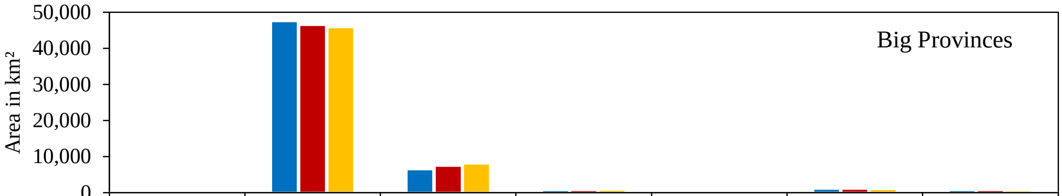


Figure 3. Spatial distribution of LULC data for big provinces in three years (a), (b), (c) and (d) comparison of LULC area in 2008, 2013, and 2018



(d)



	Barren	Cropland	Forest Land	Marsh and Swamp	Range Land	Surface Water	Urban and Built-up Area
2008	33.42	47233.80	6190.17	455.50	14.20	874.05	473.24
2013	29.42	46218.12	7199.62	490.31	21.61	838.67	476.50
2018	35.51	45613.64	7808.05	576.69	35.92	784.83	420.01

Figure 3. Spatial distribution of LULC data for big provinces in three years (a), (b), (c) and (d) comparison of LULC area in 2008, 2013, and 2018 (cont.)

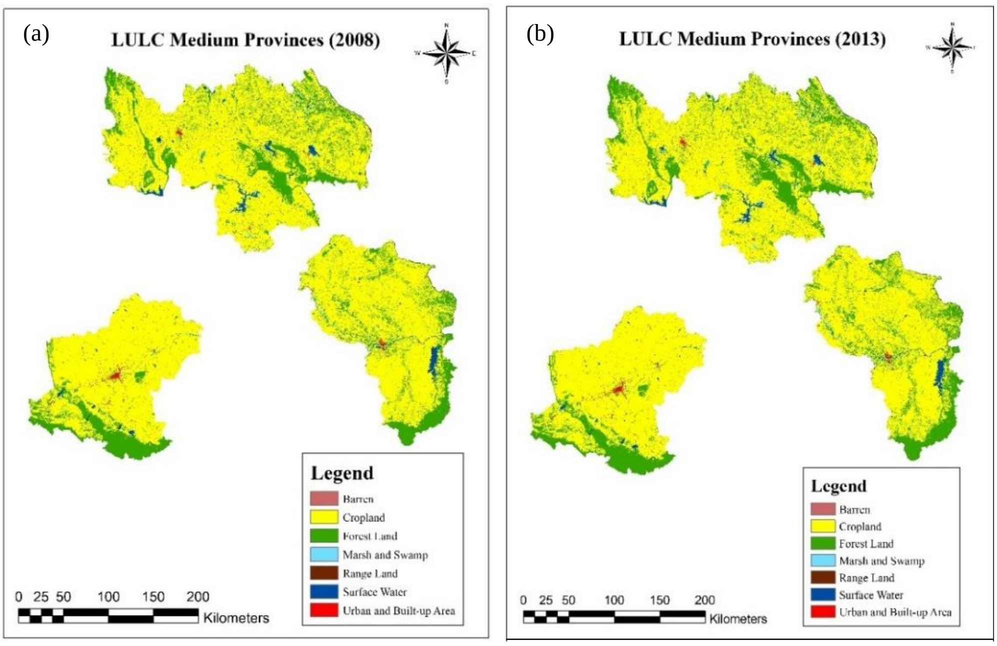
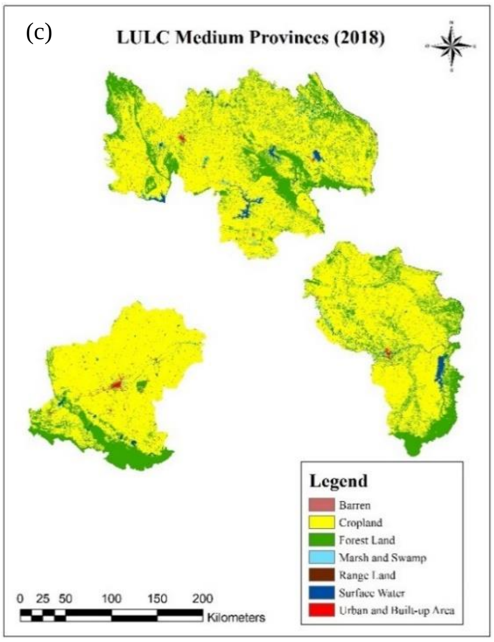


Figure 4. Spatial distribution of LULC data for medium provinces in three years (a), (b), (c) and (d) comparison of LULC area in 2008, 2013, and 2018



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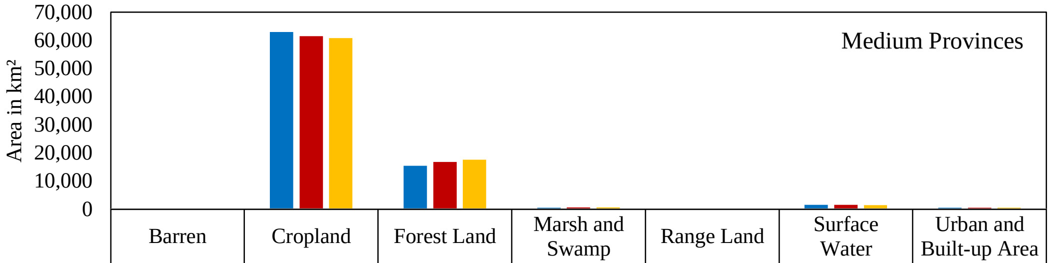


	Barren	Cropland	Forest Land	Marsh and Swamp	Range Land	Surface Water	Urban and Built-up Area
2008	50.37	62964.92	15384.21	535.68	33.73	1550.50	557.67
2013	53.60	61499.01	16827.62	590.35	47.13	1496.30	562.93
2018	63.83	60764.16	17528.37	661.47	79.22	1472.41	507.68

Figure 4. Spatial distribution of LULC data for medium provinces in three years (a), (b), (c) and (d) comparison of LULC area in 2008, 2013, and 2018 (cont.)

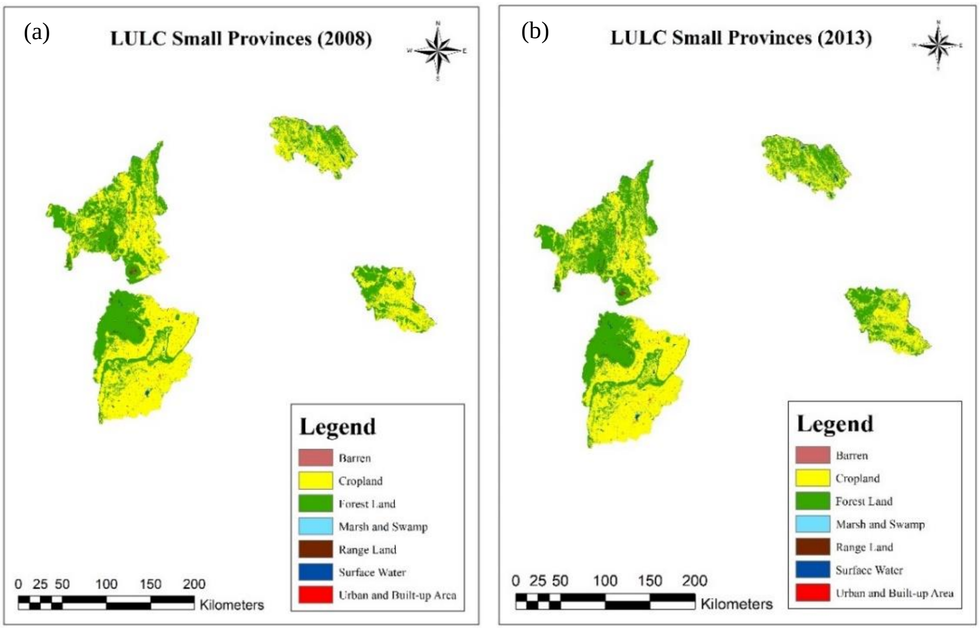
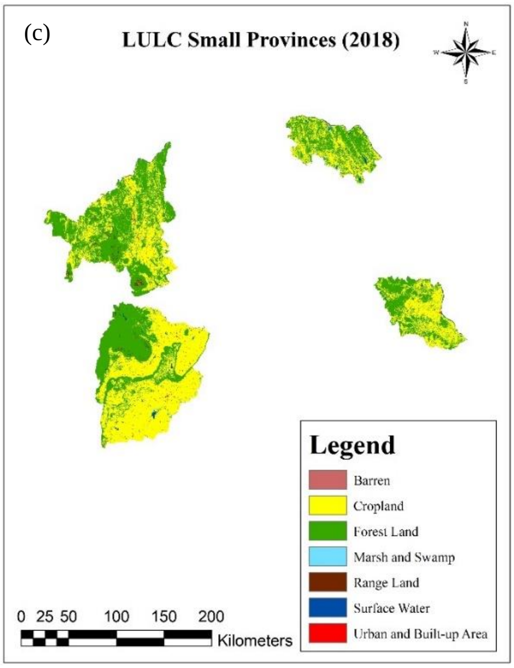
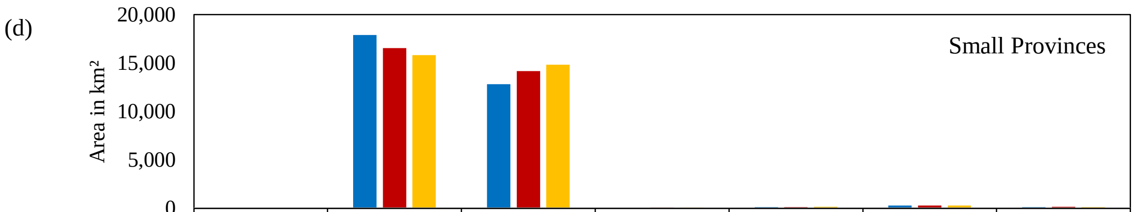


Figure 5. Spatial distribution of LULC data for small provinces in three years (a), (b), (c) and (d) comparison of LULC area in 2008, 2013, and 2018





	Barren	Cropland	Forest Land	Marsh and Swamp	Range Land	Surface Water	Urban and Built-up Area
2008	7.45	17881.76	12837.80	91.47	148.06	305.07	158.19
2013	9.08	16538.55	14168.46	96.18	156.45	300.76	160.29
2018	12.09	15834.31	14847.13	110.47	184.30	297.62	144.04

Figure 5. Spatial distribution of LULC data for small provinces in three years (a), (b), (c) and (d) comparison of LULC area in 2008, 2013, and 2018 (cont.)

3.2 Ecosystem Service Values Estimation

The ESV estimations according to LULC types (Tables 2 (a)-(c)) revealed that the top four predominant LULC types for all three divisions were cropland, forest land, surface water, and marsh and swamp. They contributed ESVs in 2008, 2013, and 2018 around 99.97%, 99.96% and 99.95% of total ESVs for big provinces, about 99.96%, 99.96% and 99.93% of total ESVs for medium provinces, and approximately 99.74%, 99.73% and 99.66% of total ESVs for small provinces, respectively.

Table 2. Ecosystem Service values estimation according to LULC type for big (a), medium (b), and small (c) provinces

(a) Big Provinces

LULC type	ESVs in Million USD					
	2008		2013		2018	
	ESV	%	ESV	%	ESV	%
Barren	0.32	0.005	0.28	0.004	0.34	0.005
Cropland	4875.94	68.559	4771.10	66.148	4708.70	64.379
Forest Land	1206.46	16.964	1403.21	19.454	1521.79	20.806
Marsh and Swamp	426.74	6.000	459.35	6.369	540.29	7.387
Range Land	1.15	0.016	1.75	0.024	2.90	0.040

Table 2. Ecosystem Service values estimation according to LULC type for big (a), medium (b), and small (c) provinces (cont.)

	ESVs in Million USD					
LULC type	2008		2013		2018	
	ESV	%	ESV	%	ESV	%
Surface Water	600.80	8.448	576.48	7.992	539.47	7.376
Urban and Built-up Area	0.60	0.008	0.61	0.008	0.53	0.007
Total	7112.02	100.000	7212.77	100.000	7314.02	100.000

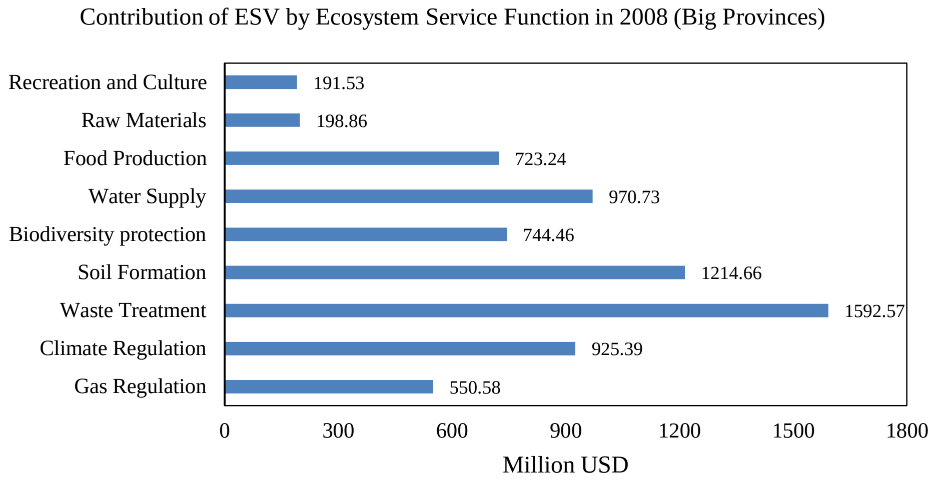
(b) Medium Provinces

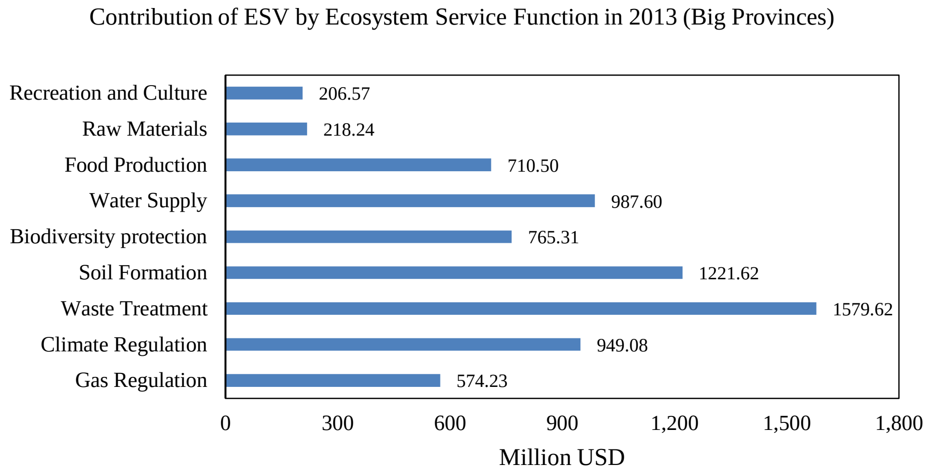
	ESVs in Million USD					
LULC type	2008		2013		2018	
	ESV	%	ESV	%	ESV	%
Barren	0.49	0.004	0.52	0.005	0.61	0.005
Cropland	6499.87	58.717	6348.54	56.608	6272.68	56.108
Forest Land	2998.38	27.086	3279.70	29.244	3416.28	30.558
Marsh and Swamp	501.86	4.534	553.08	4.932	470.97	4.213
Range Land	2.73	0.025	3.81	0.034	6.41	0.057
Surface Water	1065.77	9.628	1028.51	9.171	1012.09	9.053
Urban and Built-up Area	0.71	0.006	0.71	0.006	0.64	0.006
Total	11069.80	100.000	11214.88	100.000	11179.69	100.000

(c) Small Provinces

	ESVs in Million USD					
LULC type	2008		2013		2018	
	ESV	%	ESV	%	ESV	%
Barren	0.07	0.002	0.09	0.002	0.12	0.002
Cropland	1845.93	39.649	1707.27	35.735	1634.58	33.683
Forest Land	2502.09	53.743	2761.43	57.800	2893.71	59.630
Marsh and Swamp	85.69	1.841	90.11	1.886	103.49	2.133
Range Land	11.97	0.257	12.65	0.265	16.13	0.332
Surface Water	209.69	4.504	205.77	4.307	204.57	4.216
Urban and Built-up Area	0.20	0.004	0.20	0.004	0.18	0.004
Total	4655.65	100.000	4777.53	100.000	4852.77	100.000

Furthermore, the input of ESVs by ecosystem service functions (ESFs) throughout the study period affirmed that the top four principle ESFs were waste treatment, soil formation, water supply, and climate regulation for all three parts. Amongst these four functions, ESV of waste treatment declined, whereas surprisingly, ESV of both soil formation and water supply improved over the decade (Figures 6 (a)-(c), Figures 7 (a)-(c), Figures 8 (a)-(c)). For example, ESVs of waste treatment dropped from 1592.57 million USD in 2008 to 1581.02 million USD in 2018 for big provinces, from 2293.49 million USD in 2008 to 2278.51 million USD in 2018 for medium provinces, and from 700.29 million USD in 2008 to 677.55 million USD in 2018 for small provinces. Contrarily, ESVs of soil formation increased from 1214.66 million USD in 2008 to 1227.82 million USD in 2018 for big provinces, from 1816.37 million USD in 2008 to 1832.03 million USD in 2018 for medium provinces, from 752.35 million USD in 2008 to 764.73 million USD in 2018 for small provinces. In the same way, ESVs of water supply rose from 970.73 million USD in 2008 to 1003.18 million USD in 2018 for big provinces, from 1597.27 million USD in 2008 to 1644.16 million USD in 2018 for medium provinces, from 639.89 million USD in 2008 to 681.02 million USD in 2018 for small provinces.





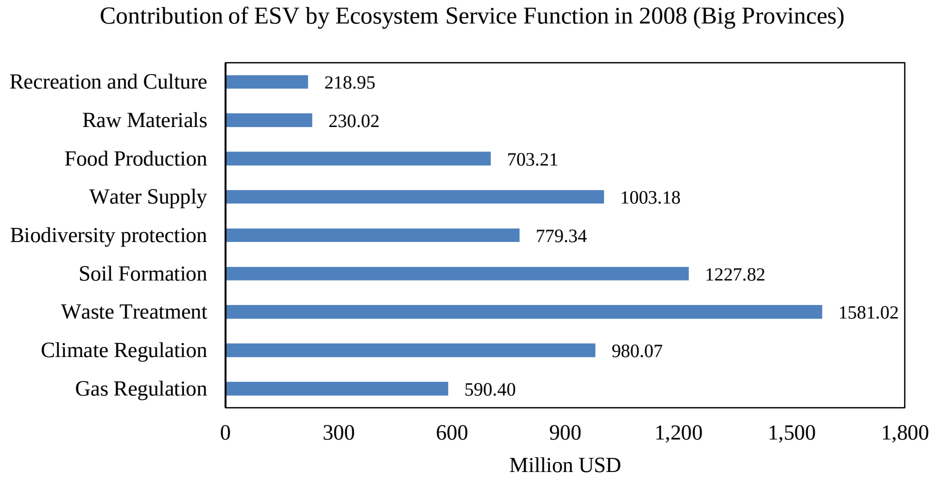
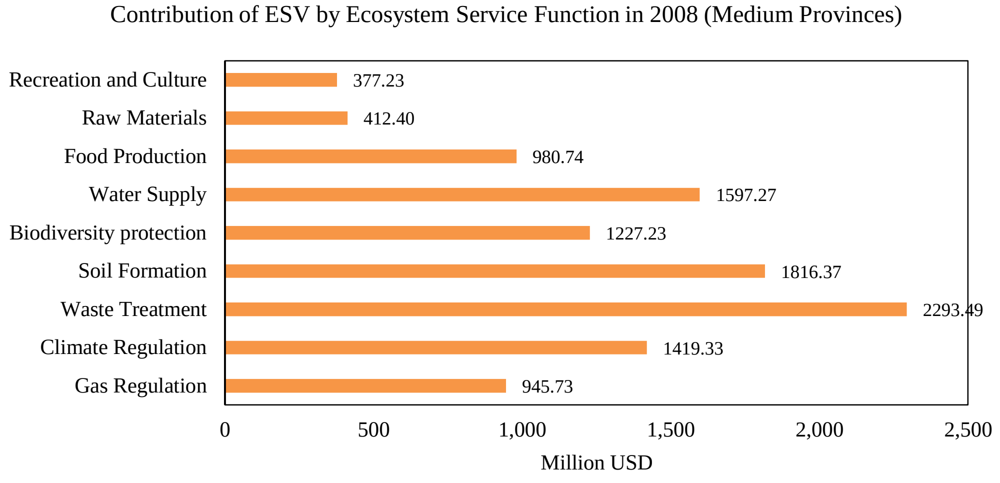
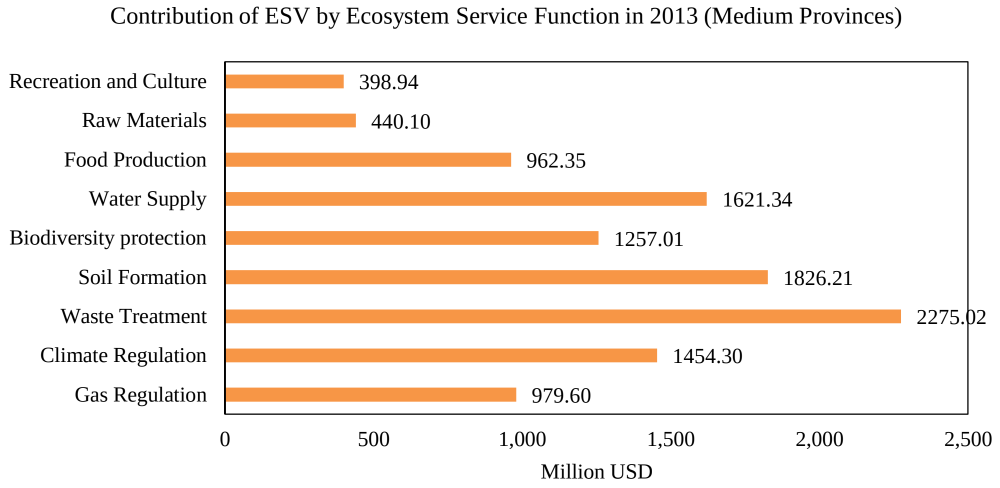


Figure 6. Ecosystem service value contribution by its function from 2008 to 2018 for big provinces





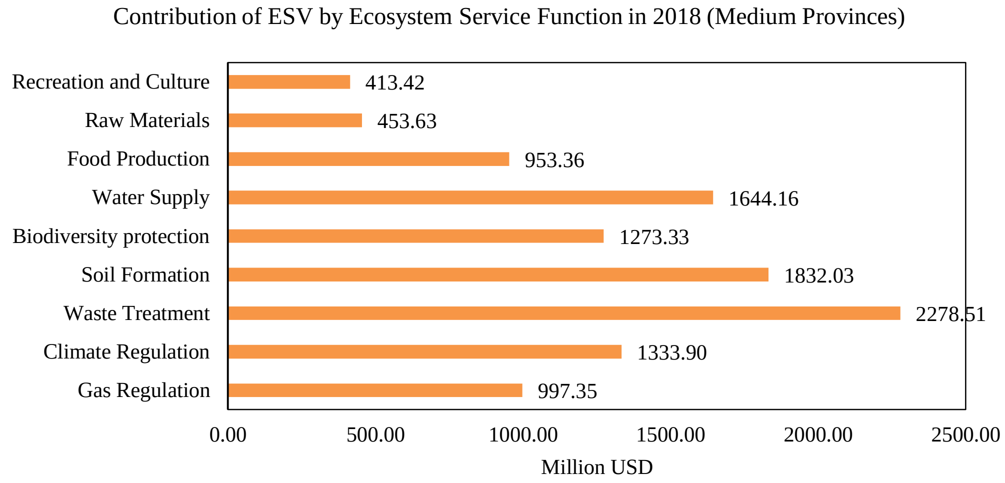
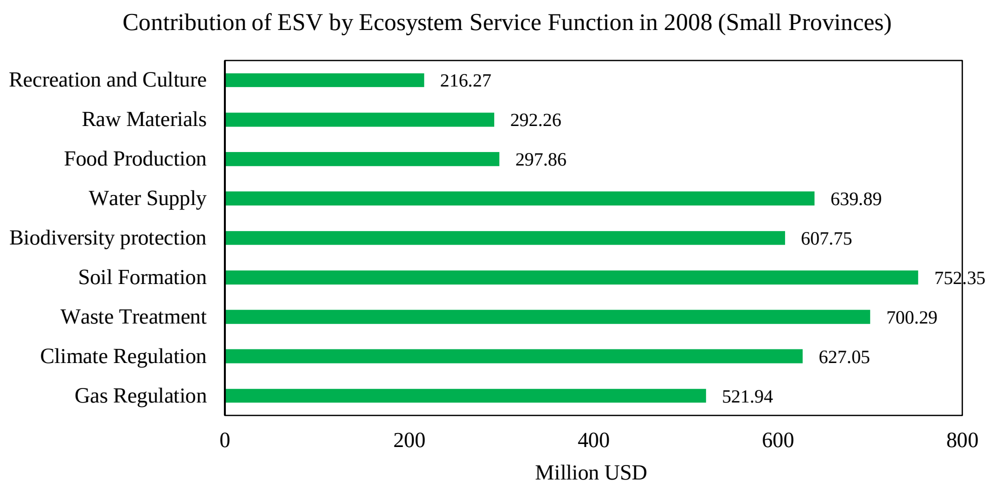
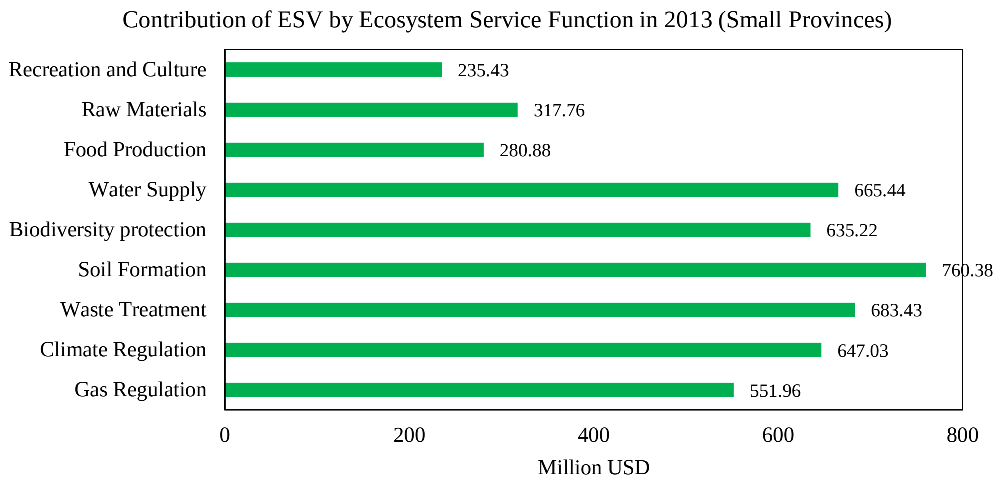


Figure 7. Ecosystem service value contribution by its function from 2008 to 2018 for medium provinces





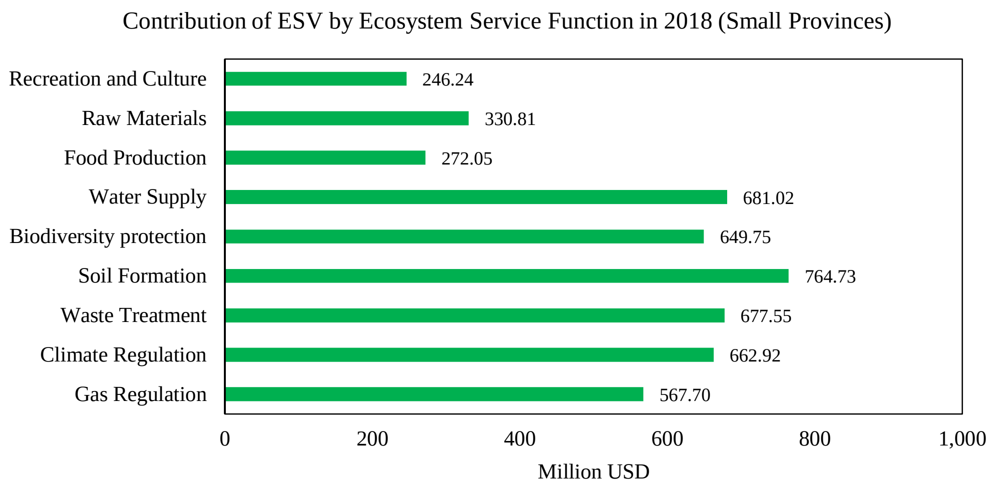


Figure 8. Ecosystem service value contribution by its function from 2008 to 2018 for small provinces

3.3 Changes in Ecosystem Service Values

The changes in ESVs revealed a noteworthy increase in the total ESVs over the study period (Tables 3 (a)-(c)). The overall ESVs fluctuations for big provinces from 2008 to 2013 was 100.75 million USD or 58.68% of the entire price in 2008 and it further increased from 2013 to 2018 with an amount of 101.25 million USD or 93.44% of the total value in 2013. Meanwhile, for medium provinces the summation number of changes of ESVs from 2008 to 2013 was 145.08 million USD or 60.85% of the over-all amount in 2008 and from 2013 to 2018 the ESV change was of 35.19 million USD or 63.83% of the total value in 2013. This entails that the change in ESV from 2013 to 2018 was smaller than during the year 2008 to 2013. In a similar manner, for small provinces the total variation in ESVs from 2008 to 2013 was 121.88 million USD or 34.90% of the sum value in 2008. From 2013 to 2018, for small provinces, the entire ESV change was of 75.24 million USD or 65.31% of the entire value in 2013. This finding indicates that the change in ESV from 2013 to 2018 was smaller than during the year 2008 to 2013 just like for medium provinces.

Table 3. Ecosystem services values changes for big (a), medium (b), and small (c) provinces

(a) Big Provinces

LULC type	2008-2013		2013-2018	
	Million USD	Proportion (%)	Million USD	Proportion (%)
Barren	-0.04	-11.97	0.06	20.69
Cropland	-104.85	-2.15	-62.40	-1.31
Forest Land	196.74	16.31	118.58	8.45
Marsh and Swamp	32.61	7.64	80.93	17.62
Range Land	0.60	52.21	1.16	66.26
Surface Water	-24.32	-4.05	-37.00	-6.42
Urban and Built-up Area	0.00	0.69	-0.07	-11.85
Total	100.75	58.68	101.25	93.44

(b) Medium Provinces

LULC type	2008-2013		2013-2018	
	Million USD	Proportion (%)	Million USD	Proportion (%)
Barren	0.03	6.41	0.10	19.09
Cropland	-151.33	-2.33	-75.86	-1.19
Forest Land	281.32	9.38	136.58	4.16
Marsh and Swamp	51.22	10.21	-82.11	-14.85
Range Land	1.08	39.73	2.59	68.07
Surface Water	-37.25	-3.50	-16.42	-1.60
Urban and Built-up Area	0.01	0.94	-0.07	-9.82
Total	145.08	60.85	-35.19	63.86

(c) Small Provinces

LULC type	2008-2013		2013-2018	
	Million USD	Proportion (%)	Million USD	Proportion (%)
Barren	0.02	21.76	0.03	33.17
Cropland	-138.66	-7.51	-72.70	-4.26
Forest Land	259.35	10.37	132.27	4.79
Marsh and Swamp	4.42	5.16	13.38	14.85
Range Land	0.68	5.66	3.48	27.48
Surface Water	-3.92	-1.87	-1.20	-0.58
Urban and Built-up Area	0.00	1.33	-0.02	-10.14
Total	121.88	34.90	75.24	65.31

Additionally, the changes in ESVs revealed a significant increase or decrease in ESVs from varied LULC types in different periods for all three sections of provinces (see Table 3). As shown, for big provinces, the increment of ESVs between 2008 and 2013 was mainly characterized by forest land, marsh and swamp and rangeland that calculated to be 229.95 million USD, while the decrease of ESVs in the same period signified by cropland and surface water summed up to be 129.17 million USD. Likewise, between 2013 and 2018, the increase and decrease of ESVs was represented by the same LULC types, i.e., forest land, marsh and swamp and rangeland, and cropland and surface water respectively. Meanwhile for medium provinces, the surge in ESVs between 2008 and 2013 was represented by forest land, marsh and swamp and rangeland that accounted for 333.62 million USD, while the decline of ESVs in the same period characterised by cropland and surface water summed up to be 188.58 million USD. But surprisingly, between 2013 and 2018, the increase of ESVs was characterised by forest land and rangeland, whereas the decrease was represented by cropland, marsh and swamp and surface water. Moving onto the small provinces, the increase of ESVs between 2008 and 2013 was mostly represented by forest land, marsh and swamp and rangeland that summed to be 264.44 million USD, while the decrease of ESVs in the same period signified by cropland and surface water accounted for 142.58 million USD. Similarly, between 2013 and 2018, the increase of ESVs was represented by the same LULC types and also for the decrease of ESVs, the same LULC types were defined that is cropland and surface water.

Moreover, the fluctuations in ESVs by ESFs revealed a considerable increase of nearly all functions except waste treatment under regulating services and food production under provision services in all periods for all three sections of provinces (Tables 4 (a)-(c)), with the exception of climate regulation under regulating services for medium provinces. As an outcome, for big provinces, climate regulation under regulating services had considerably increased from 23.69 million USD in the 2008-2013 time period to 30.98 million USD in the 2013-2018 time period. While soil formation under supporting services increased from 6.97 million USD in the 2008-2013 timeframe to 6.20 million USD in the 2013-2018 timeframe, describing that the changes during 2013-2018 was less than during 2008-2013. Likewise, water supply under provision services increased from 16.87 million USD in the period of 2008-2013 to 15.58 million USD in the period of 2013-2018 and recreation and culture under culture services boosted from 15.04 million USD between 2008 and 2013 to 12.38 million USD between 2013 and 2018. Both these functions show that the changes during 2013-2018 was less than during 2008-2013. Further, waste treatment under regulating services declined from 12.96 million USD in the 2008-2013 time period to 1.41 million USD in the 2013-2018 time period and food production under provision services deteriorated from 12.74 million USD in the timeframe of 2008-2013 to 7.29 million USD in the timeframe of 2013-2018.

In the meantime, for medium provinces, climate regulation under regulating services, saw an increase between the years 2008-2013 with an amount of 34.96 million USD, whereas it decreased significantly between the years 2013-2018 with an amount of 120.39 million USD. While soil formation under supporting services surged from 9.84 million USD in the 2008-2013 time period to 5.82 million USD in the 2013-2018 time period, suggesting that the changes during 2013-2018 was less than during 2008-2013. Similarly, water supply under provision services rose from 24.07 million USD in the timeframe of 2008-2013 to 22.81 million USD in the timeframe of 2013-2018 and recreation and culture under culture services increased from 21.71 million USD between 2008 and 2013 to 14.48 million USD between 2013 and 2018. Both these functions indicate that the 2013-2018 changes were less than the 2008-2013 changes. To the contrary, waste treatment under regulating services saw a decrease between the years 2008-2013 with an amount of 18.47 million USD, whereas it increased slightly between the years 2013-2018 with an amount of 3.48 million USD; and food production under provision services deteriorated from 18.39 million USD in the period of 2008-2013 to 8.99 million USD in the period of 2013-2018.

Table 4. Ecosystem services values changes by ecosystem service function for big (a), medium (b), and small (c) provinces

(a) Big Provinces

Ecosystem services function	2008	2013	2018	2008-2013		2008-2013	
	Million USD	Million USD	Million USD	Million USD	%	Million USD	%
Regulating services							
Gas Regulation	550.58	574.23	590.40	23.65	4.29	16.18	2.82
Climate Regulation	925.39	949.08	980.07	23.69	2.56	30.98	3.26
Waste Treatment	1592.57	1579.62	1581.02	-12.96	-0.81	1.41	0.09
Supporting services							
Soil Formation	1214.66	1221.62	1227.82	6.97	0.57	6.20	0.51
Biodiversity protection	744.46	765.31	779.34	20.85	2.80	14.03	1.83
Provision services							
Water Supply	970.73	987.60	1003.18	16.87	1.74	15.58	1.58
Food Production	723.24	710.50	703.21	-12.74	-1.76	-7.29	-1.03
Raw Materials	198.86	218.24	230.02	19.38	9.75	11.78	5.40
Cultural services							
Recreation and Culture	191.53	206.57	218.95	15.04	7.85	12.38	5.99
Total	7112.02	7212.77	7314.02	100.75	26.99	101.25	20.46

(b) Medium Provinces

Ecosystem services function	2008	2013	2018	2008-2013		2008-2013	
	Million USD	Million USD	Million USD	Million USD	%	Million USD	%
Regulating services							
Gas Regulation	945.73	979.60	997.35	33.88	3.58	17.74	1.81
Climate Regulation	1419.33	1454.30	1333.90	34.96	2.46	-120.39	-8.28
Waste Treatment	2293.49	2275.02	2278.51	-18.47	-0.81	3.48	0.15
Supporting services							
Soil Formation	1816.37	1826.21	1832.03	9.84	0.54	5.82	0.32
Biodiversity protection	1227.23	1257.01	1273.33	29.78	2.43	16.32	1.30
Provision services							
Water Supply	1597.27	1621.34	1644.16	24.07	1.51	22.81	1.41
Food Production	980.74	962.35	953.36	-18.39	-1.88	-8.99	-0.93
Raw Materials	412.40	440.10	453.63	27.71	6.72	13.53	3.07
Cultural services							
Recreation and Culture	377.23	398.94	413.42	21.71	5.75	14.48	3.63
Total	11069.80	11214.88	11179.69	145.08	20.31	-35.19	2.48

Table 4. Ecosystem services values changes by ecosystem service function for big (a), medium (b), and small (c) provinces (cont**.**)

(c) Small Provinces

Ecosystem services function	2008	2013	2018	2008-2013		2008-2013	
	Million USD	Million USD	Million USD	Million USD	%	Million USD	%
Regulating services							
Gas Regulation	521.94	551.96	567.70	30.02	5.75	15.73	2.85
Climate Regulation	627.05	647.03	662.92	19.98	3.19	15.90	2.46
Waste Treatment	700.29	683.43	677.55	-16.86	-2.41	-5.88	-0.86
Supporting services							
Soil Formation	752.35	760.38	764.73	8.03	1.07	4.35	0.57
Biodiversity protection	607.75	635.22	649.75	27.47	4.52	14.53	2.29
Provision services							
Water Supply	639.89	665.44	681.02	25.56	3.99	15.57	2.34
Food Production	297.86	280.88	272.05	-16.98	-5.70	-8.82	-3.14
Raw Materials	292.26	317.76	330.81	25.50	8.73	13.05	4.11
Cultural services							
Recreation and Culture	216.27	235.43	246.24	19.15	8.86	10.81	4.59
Total	4655.65	4777.53	4852.77	121.88	27.99	75.24	15.20

Proceeding to small provinces, climate regulation under regulating services rose from 19.98 million USD in the period of 2008-2013 to 15.90 million USD in the period of 2013-2018. This data indicates that the changes during 2013-2018 was less than the changes during 2008-2013. While soil formation under supporting services increased from 8.03 million USD in the 2008-2013 timeframe to 4.35 million USD in the 2013-2018 timeframe, signifying that the fluctuations during 2013-2018 was less than the fluctuations during 2008-2013. Similarly, water supply under provision services upscaled from 25.56 million USD in the period of 2008-2013 to 15.57 million USD in the period of 2013-2018 and recreation and culture under culture services increased from 19.15 million USD between 2008 and 2013 to 10.81 million USD between 2013 and 2018. Both these functions point to the fact that 2013-2018 changes were less than 2008-2013 changes. Besides, waste treatment under regulating services declined from 16.86 million USD in the 2008-2013 time period to 5.88 million USD in the 2013-2018 time period and food production under provision services deteriorated from 16.98 million USD in the timeframe of 2008-2013 to 8.82 million USD in the timeframe of 2013-2018.

3.4 LULC change impact on ecosystem service values

The effect of LULC change on ESVs clearly had a fluctuation between the LULC categories as noticed in the inputs of the area and ESV for specific LULC group over the time periods for all three groups of provinces (Figures 9 (a)-(c)). Especially, for big provinces, the forest land increased about 6190.17 km^2 (11.19%) in 2008 to 7808.05 km^2 (14.12%) in 2018 and marsh and swamp increased from about 455.50 km^2 (0.82%) in 2008 to 576.69 km^2 (1.04%) in 2018. (See Figure 3 (d)). And because of this increase, the total ESVs essentially increased over the decade. The ESV of forest land significantly increased from 196.74 million USD in 2008 to 118.58 million USD in 2018. Likewise, the ESV of marsh and swamp increased from 32.61 million USD in 2008 to 80.93 million USD in 2018. For big provinces, mainly the changes in these two LULC type (forest land and marsh and swamp) suggestively affected the changes in the total ESVs throughout the decade. Herein, the total ESVs of these two LULC increased by 199.52 million USD from 2013-2018 while the total ESVs in the study area increased by 101.25 million USD (Table 3 (a)). Contrarily, cropland areas repetitively decreased over the time period. It deteriorated from around 47233.80 km^2 (85.45%) in 2008 to 45613.64 km^2 (82.52%) in 2018, and its corresponding ESV showed a decrease from 104.85 million USD in 2008 to 62.4 million USD in 2018.

Meanwhile for medium provinces, the forest land increased about 15384.21 km^2 (18.97%) in 2008 to 17528.37 km^2 (21.62%) in 2018 and marsh and swamp increased from about 535.68 km^2 (0.66%) in 2008 to 661.47 km^2 (0.81%) in 2018. (See Figure 4 (d)). And because of this increase, the total ESVs essentially increased as well. The ESV of forest land significantly increased from 281.32 million USD in 2008 to 136.58 million USD in 2018. Whereas, the ESV of marsh and swamp increased in 2008 by 51.22 million USD but surprisingly decreased to 82.11 million USD in 2018. For medium provinces, mainly the changes in forest land significantly affected the changes in the total ESVs throughout the decade. Herein, the total ESVs of forest land increased by 136.58 million USD from 2013-2018 while the total ESVs in the study area from 2013-2018 became 35.19 million USD (Table 3 (b)). This data is mainly suggesting that the change from 2008-2013 was way higher than the change from 2013-2018, even-though the total ESV of medium provinces increased (Table 2 (b)). Furthermore, cropland areas constantly decreased over the time period. It reduced from approximately 62964.92 km^2 (77.66%) in 2008 to 60764.16 km^2 (74.95%) in 2018, and its corresponding ESV showed a decrease from 151.33 million USD in 2008 to 75.86 million USD in 2018.

Additionally, for small provinces, the forest land rose from about 12837.80 km^2 (40.85%) in 2008 to 14847.13 km^2 (47.24%) in 2018 and marsh and swamp increased from about 91.47 km^2 (0.29%) in 2008 to 110.47 km^2 (0.35%) in 2018. (See Figure 5 (d)). And because of this increase, the total ESVs significantly increased over the decade. The ESV of forest land significantly increased from 259.35 million USD in 2008 to 132.27 million USD in 2018. Likewise, the ESV of marsh and swamp increased from 4.42 million USD in 2008 to 13.38 million USD in 2018. For small provinces, mainly the changes in these two LULC type (forest land and marsh and swamp) prominently affected the changes in the total ESVs throughout the study period. Herein, the total ESVs of these two LULC increased by 145.65 million USD from 2013-2018 while the total ESVs in the study area increased by 75.24 million USD (Table 3 (c)). While, cropland areas continually decreased over the time period. It worsened from around 17881.76 km^2 (56.89%) in 2008 to 15834.31 km^2 (50.38%) in 2018, and its corresponding ESV showed a decrease from 138.66 million USD in 2008 to 72.7 million USD in 2018.

Therefore, depending on the simple benefit transfer method of Costanza et al. (1997) with the altered coefficient of ESVs from Ongsomwang et al. (2019), the general tendency of ESVs as an outcome of changes in LULC were similar (Figures 9 (a)-(c)).

3.5 Discussion

Ecosystem services are encountering extensive pressure due to climate change and mainly human activities as chief contributors who are changing the ecosystem services through LULC changes, and it is likely to continue to rise (Wang at al., 2014). LULC changes are the essential motive of deviations in the ecosystem function assessment, the land-use formation, and the compelling developments of landscapes around the world and they disturb ecosystem services by animal husbandry, agricultural actions, mining, developed areas and human settlements (Mamat et al., 2018). Ecosystem services are not given too much importance in policy decisions because they are not entirely 'occupied' in profitable markets or sufficiently calculated in terms similar with manufactured capital (Costanza et al., 1997). This indifference will eventually weaken the sustainability of individuals in the environment. The savings of the Earth would come to a standstill without the facilities of ecological life-support structures (Costanza et al., 1997); in other words one can tell that their overall worth to the economy is endless. Human beings along with other organisms profit directly as well as indirectly in several aspects from the environment's ecosystems, for instance by the arrangement of food and resources, air purification, storing carbon, pharmaceuticals, the regulation of local climates and biodiversity protection; and understanding the various benefits contributed by these ecosystems is becoming gradually critical (Chuai et al., 2016; R-Q. Li et al., 2007; Mamat et al., 2018; Sawut et al., 2013).

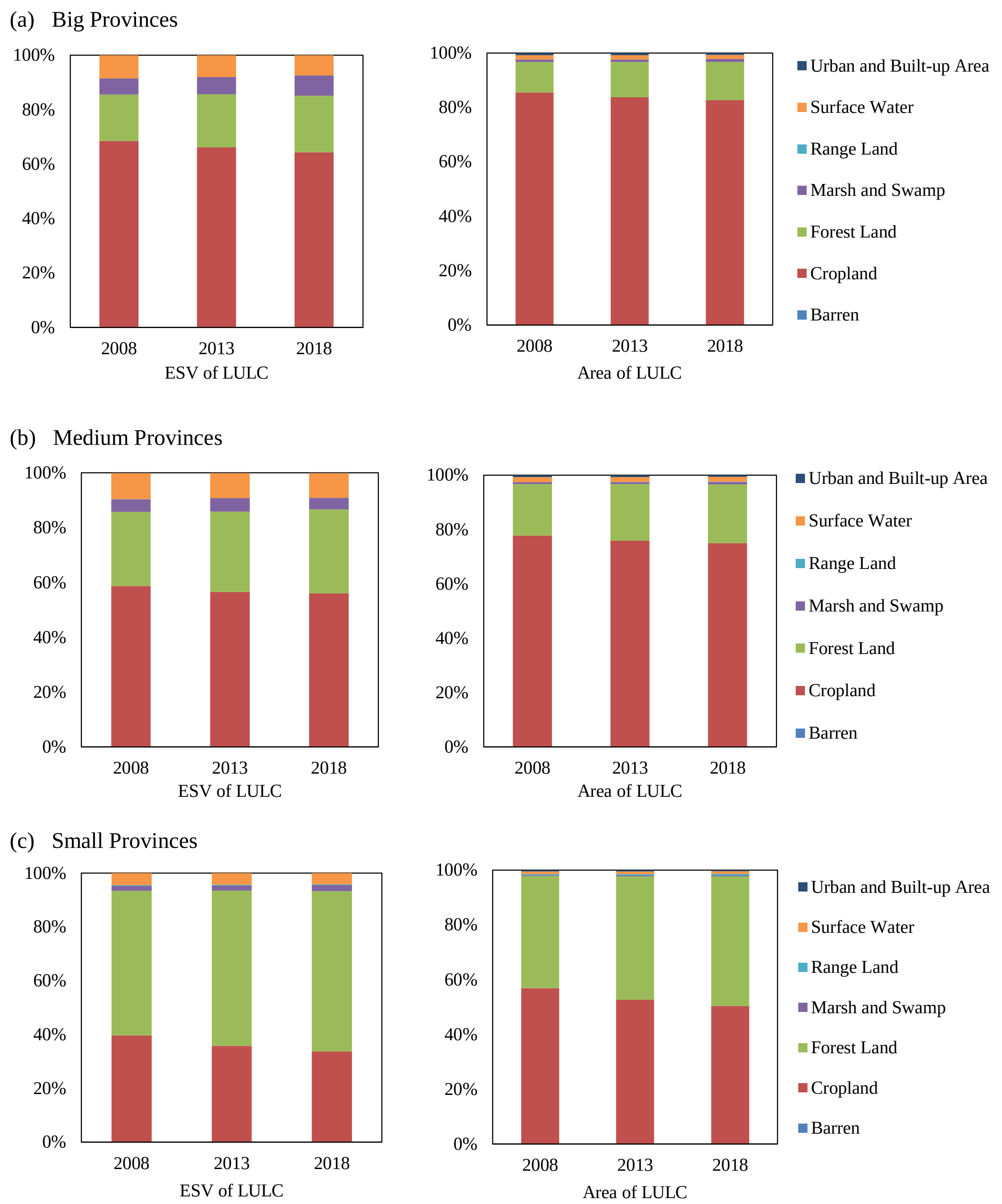


Figure 9. Ecosystem services value and area contribution of LULC categories in different years for big (a), medium (b), and small (c) provinces

Most of the studies on valuation of ecosystems services is concentrated on assessing and monetizing definitive ESVs at any particular stage (Costanza et al., 1997; G. Li & Fang, 2014;

G. Li et al., 2016). Even though time-based fluctuations in ESVs are equally important, observing alterations over an extended time period has hardly ever been done on regional, nationwide or global scales; still, this subject has fascinated intellectual consideration recently (Costanza et al., 2014; G. Li et al., 2016). Perhaps, Costanza et al. calculated that the worldwide damage of ESV since 1997 to 2011 triggered by land-use changes was US$4.3–20.2 trillion/year (Costanza et al., 2014). Su et al. (2012) researched that significant urban development caused a forfeiture of 8.5 billion RMB Yuan ecosystem-service amount per year since 1994 and 2003 in the Hang-Jia-Hu part of China (Su et al., 2012). Kreuter et al. (2001) testified a 4% total drop in the assessed yearly cost of ecosystem services amid 1976 and 1991 in San Antonio, the USA (Kreuter et al., 2001). Additionally, the amount of research based on this subject has increased quickly (Hu et al., 2008; G. Li et al., 2016; R.-Q. Li et al., 2007; Mamat et al., 2018; Ongsomwang et al., 2019; Sannigrahi et al., 2020; Zhao et al., 2004).

Northeast Thailand consists numerous national parks and possesses high biodiversity and native species (Lacombe et al., 2017). According to the LULC data gathered, it was found that areas of forest land increased in the ten years of the study period for all three sections, which mainly suggests that the entire region of Northeast Thailand saw an increase in forest land. Whereas in the study of Ratanopad and Kainz (2012) results showed that forest land had decreased. It can be argued that this study only focused on one province of the entire region of NET, making the results quite specific. While this study looked at a larger picture and therefore giving results that are slightly dissimilar. Additionally, from the LULC data, it was reported that cropland areas decreased overall for all three groups, suggesting that NET's cropland fell over the decade. Approximately 80% of the population of NET live in rural areas, mainly from agriculture and payments acknowledged from lots of permanent and seasonal migrants (Lacombe et al., 2017). This indicates that as majority of the population depend on agricultural land, and cropland being one of the main sources, it is quite likely that cropland areas might be exploited.

Moreover, the changes in ESVs of the land use categories varied according to their fluctuations in area. As the forest land area increased, its corresponding ESV value increased and similarly as cropland area decreased, its corresponding ESV value decreased. According to the data calculated the total ESV for all three sections increased from 2008 to 2018, meaning that ESV increased for entire NET. It was observed that the main LULCs that were responsible for the increase in ESVs were forest land and marsh and swamp. This was because of their high coefficient value in the region. Even though, cropland area was bigger than the area of forest land and marsh and swamp combined, its coefficient value was dramatically less than the other two LULC types combined (forest land and marsh and swamp). Since the coefficient value for forest land and marsh and swamp was high and their area as well increased over the study period, they eventually contributed more to the overall ESV.

A limitation from this study was the LULC information as it was derived from secondary data. The information given were restricted in terms of LULC classification, if they were given in more details, perhaps the data calculated could have been even more precise. In this study, ESV that were calculated surprisingly increased over the time period but it should be noted that the timeframe was only of ten years. Most of the other studies had a longer timeframe, therefore resulting in a decreasing ESV. Further studies can potentially elaborate on the year factor and then calculate ESVs to compare from this study. Additionally, the coefficient value of ecosystem services was taken from secondary data as well leading for the ESV data to have rough estimations. The coefficient value of ecosystem services for the particular region should be surveyed with more specification for individual LULC category when ESVs were calculated depending on the simple benefit transfer method.

Even with these limitations, according to the results found from this study, the increase in ESV suggest that the entire region has a great potential for land use and city planners to optimize the effect of LULC change on ESVs during the planning process. If needed, they can divide the region into smaller sections so that planning process can be made easier with smaller areas. The planning should maintain a stability between ecosystem health and economic development so that ESVs should not decrease.

4. Conclusions

This study used the technology of geoinformatics to classify LULC data for calculating the LULC variation impact on ESVs in the entire region of Northeast Thailand. The impact that LULC changes had on ESVs remarkably fluctuated among the LULC categories according to the area and ESVs for individual LULC division over the decade from 2008 to 2018 for all three groups: big provinces, medium provinces and small provinces. It reported that for all three sections, areas of forest land increased remarkably: for big provinces from 6190.17 km^2 (11.19%) in 2008 to 7808.05 km^2 (14.12%) in 2018, for medium provinces from 15384.21 km^2 (18.97%) in 2008 to 17528.37 km^2 (21.62%) in 2018, and for small provinces from 12837.80 km^2 (40.85%) in 2008 to 14847.13 km^2 (47.24%) in 2018. Whereas, areas of cropland significantly reduced for all three groups: for big provinces from 47233.80 km^2 (85.45%) in 2008 to 45613.64 km^2 (82.52%) in 2018, for medium provinces from 62964.92 km^2 (77.66%) in 2008 to 60764.16 km^2 (74.95%) in 2018, and for small provinces from 17881.76 km^2 (56.89%) in 2008 to 15834.31 km^2 (50.38%) in 2018.

The total ESVs measurably increased over the decade for all three sections. For big and small provinces, the change in forest land and marsh and swamp greatly influenced the changes in the total ESVs in the study region. Their ESVs increased significantly: for big provinces, by approximately 200 million USD, while the overall ESVs increased by 101 million USD; for small provinces, by approximately 146 million USD, while the overall ESVs increased by 75 million USD. Whereas for medium provinces, the change in forest land alone greatly influenced the changes in the total ESVs in the study region. To conclude, the increase in ESV suggest that the entire region has a great potential for land use and city planners to optimize the effect of LULC change on ESVs during the planning process. Further studies would be suggested to discover future opportunities and include involvement strategies for a bigger study period.

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References

Al-Shalabi, M., Billa, L., Pradhan, B., Mansor, S., & Al-Sharif, A. A. A. (2013). Modelling urban growth evolution and land-use changes using GIS based cellular automata and SLEUTH models: the case of Sana'a metropolitan city, Yemen. *Environmental Earth Sciences*, *70*(1), 425-437.

Chuai, X., Huang, X., Wu, C., Li, J., Lu, Q., Qi, X., … Lu, J. (2016). Land use and ecosystems services value changes and ecological land management in coastal Jiangsu, China. *Habitat International, 57*, 164–174.

Costanza, R. (2012). Ecosystem health and ecological engineering. *Ecological Engineering*, *45*, 24-29.

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*(6630), 253-260.

Costanza, R., De Groot, R., Sutton, P., Van Der Ploeg, S., Anderson, S. J., Kubiszewski, I., … Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, *26*, 152–158.

Dewan, A. M., & Yamaguchi, Y. (2009). Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization. *Applied Geography*, *29*(3), 390-401.

Fisher, B., Turner, R. K., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics*, *68*(3), 643-653.

Geymen, A., & Baz, I. (2008). Monitoring urban growth and detecting land-cover changes on the Istanbul metropolitan area. *Environmental Monitoring and Assessment*, *136*(1–3), 449-459.

Grimm, N. B., Morgan Grove, J., Pickett, S. T. A., & Redman, C. L. (2000). Integrated Approaches to Long-TermStudies of Urban Ecological Systems. *BioScience, 50*(7), 571.

Henríquez, C., Azócar, G., & Romero, H. (2006). Monitoring and modeling the urban growth of two midsized Chilean cities. *Habitat International*, *30*(4), 945-964.

Hu, H., Liu, W., & Cao, M. (2008). Impact of land use and land cover changes on ecosystem services in Menglun, Xishuangbanna, Southwest China. *Environmental Monitoring and Assessment*, *146*(1–3), 147–156.

Isan. (n.d.). In *Wikipedia*. Retrieved from https://en.wikipedia.org/wiki/Isan

Jin, M., Dickinson, R. E., & Zhang, D. L. (2005). The footprint of urban areas on global climate as characterized by MODIS. *Journal of Climate*, *18*(10), 1551–1565.

Johnston, R. J., & Russell, M. (2011). An operational structure for clarity in ecosystem service values. *Ecological Economics*, *70*(12), 2243-2249.

Kindu, M., Schneider, T., Teketay, D., & Knoke, T. (2016). Changes of ecosystem service values in response to land use/land cover dynamics in Munessa–Shashemene landscape of the Ethiopian highlands. *Science of The Total Environment*, *547*, 137-147.

Kreuter, U. P., Harris, H. G., Matlock, M. D., & Lacey, R. E. (2001). Change in ecosystem service values in the San Antonio area, Texas. *Ecological Economics, 39*(3), 333–346.

Kumar, J. A. V., Pathan, S. K., & Bhanderi, R. J. (2007). *Spatio-temporal analysis for monitoring urban growth – a case study of Indore City*. *35*(1), 11-20.

Lacombe, G., Polthanee, A., & Trébuil, G. (2017). Long-term change in rainfall distribution in Northeast Thailand: Will cropping systems be able to adapt? *Cahiers Agricultures*, *26*(2).

Lambin, E. F., Geist, H. J., & Lepers, E. (2003). DYNAMICS OFLAND-USE ANDLAND-COVERCHANGE INTROPICALREGIONS. *Annual Review of Environment and Resources*, *28*(1), 205-241.

Li, G., & Fang, C. (2014). Global mapping and estimation of ecosystem services values and gross domestic product: A spatially explicit integration of national 'green GDP' accounting. *Ecological Indicators*, *46*, 293–314.

Li, G., Fang, C., & Wang, S. (2016). Exploring spatiotemporal changes in ecosystem-service values and hotspots in China. *Science of The Total Environment*, *545–546*, 609-620.

Li, R.-Q., Dong, M., Cui, J.-Y., Zhang, L.-L., Cui, Q.-G., & He, W.-M. (2007). Quantification of the Impact of Land-Use Changes on Ecosystem Services: A Case Study in Pingbian County, China. *Environmental Monitoring and Assessment*, *128*(1–3), 503–510.

López, E., Bocco, G., Mendoza, M., & Duhau, E. (2001). Predicting land-cover and land-use change in the urban fringe. *Landscape and Urban Planning*, *55*(4), 271-285.

Luederitz, C., Brink, E., Gralla, F., Hermelingmeier, V., Meyer, M., Niven, L., … Von Wehrden, H. (2015). A review of urban ecosystem services: six key challenges for future research. *Ecosystem Services*, *14*, 98-112.

Mamat, A., Halik, Ü., & Rouzi, A. (2018). Variations of Ecosystem Service Value in Response to Land-Use Change in the Kashgar Region, Northwest China. *Sustainability*, *10*(1), 200.

Mccarthy, M. P., Best, M. J., & Betts, R. A. (2010). Climate change in cities due to global warming and urban effects. *Geophysical Research Letters*, *37*(9), n/a-n/a.

Millennium Ecosystem Assessment (MA). (2005). *Ecosystem and Human Well-being: Synthesis*. Washington DC: Island Press.

Ongsomwang, S., Pattanakiat, S., & Srisuwan, A. (2019). Impact of Land Use and Land Cover Change on Ecosystem Service Values: A Case Study of Khon Kaen City, Thailand. *Environment and Natural Resources Journal*, *17*(4), 43-58.

Peng, J., Liu, Y., Wu, J., Lv, H., & Hu, X. (2015). Linking ecosystem services and landscape patterns to assess urban ecosystem health: A case study in Shenzhen City, China. *Landscape and Urban Planning*, *143*, 56-68.

Ratanopad, S., & Kainz, W. (2012). Land Cover Classification and Monitoring in Northeast Thailand Using Landsat 5 Tm Data. *International Archives of Photogrammetry, Remote Sensing, and Spatial Information Sciences*, *36*(2), 137–144.

Regional Land Cover Monitoring System Methodology [Online]. (n.d.). Retrieved from https://rlcms-servir.adpc.net/en/method/

Sannigrahi, S., Bhatt, S., Rahmat, S., Paul, S. K., & Sen, S. (2018). Estimating global ecosystem service values and its response to land surface dynamics during 1995–2015. *Journal of Environmental Management*, *223*, 115-131.

Sannigrahi, S., Chakraborti, S., Joshi, P. K., Keesstra, S., Sen, S., Paul, S. K., … Dang, K. B. (2019). Ecosystem service value assessment of a natural reserve region for strengthening protection and conservation. *Journal of Environmental Management*, *244*, 208-227.

Sannigrahi, S., Joshi, P. K., Keesstra, S., Paul, S. K., Sen, S., Roy, P. S., … Bhatt, S. (2019). Evaluating landscape capacity to provide spatially explicit valued ecosystem services for sustainable coastal resource management. *Ocean and Coastal Management*, *182*(February), 104918.

Sannigrahi, S., Zhang, Q., Joshi, P. K., Sutton, P. C., Keesstra, S., Roy, P. S., … Sen, S. (2020). Examining effects of climate change and land use dynamic on biophysical and economic values of ecosystem services of a natural reserve region. *Journal of Cleaner Production*, *257*, 120424.

Sawut, M., Eziz, M., & Tiyip, T. (2013). The effects of land-use change on ecosystem service value of desert oasis: a case study in Ugan-Kuqa River Delta Oasis, China. *Canadian Journal of Soil Science, 93*(1), 99–108.

SERVIR Mekong. (n.d.). *Connecting Space to Village in the Lower Mekong Region* [Online]. Retrieved from https://servir.adpc.net/

Shiferaw, A., & Singh, K. . (2011). Evaluating The Land Use And Land Cover Dynamics In Borena Woreda South Wollo Highlands, Ethiopia. *Journal of Sustainable Development in Africa*, *2*(1).

Showqi, I., Rashid, I., & Romshoo, S. A. (2014). Land use land cover dynamics as a function of changing demography and hydrology. *GeoJournal*, *79*(3), 297–307.

Su, S., Xiao, R., Jiang, Z., & Zhang, Y. (2012). Characterizing landscape pattern and ecosystem service value changes for urbanization impacts at an eco-regional scale. *Applied Geography, 34,* 295–305.

United Nations. (2010). *World urbanization prospects: The 2009 revision population database.* http://esa.un.org/unpd/wup/index.htm.

Wang, S., Wu, B., & Yang, P. (2014). Assessing the changes in land use and ecosystem services in an oasis agricultural region of Yanqi Basin, Northwest China. *Environmental Monitoring and Assessment*, *186*(12), 8343-8357.

Yan, Y., Zhao, C., Wang, C., Shan, P., Zhang, Y., & Wu, G. (2016). Ecosystem health assessment of the Liao River Basin upstream region based on ecosystem services. *Acta Ecologica Sinica*, *36*(4), 294-300.

Zhang, H., Qi, Z. fang, Ye, X. yue, Cai, Y. bin, Ma, W. chun, & Chen, M. nan. (2013). Analysis of land use/land cover change, population shift, and their effects on spatiotemporal patterns of urban heat islands in metropolitan Shanghai, China. *Applied Geography*, *44*, 121-133.

Zhao, B., Kreuter, U., Li, B., Ma, Z., Chen, J., & Nakagoshi, N. (2004). An ecosystem service value assessment of land-use change on Chongming Island, China. *Land Use Policy, 21*(2), 139–148.