Assessing the Impact of Landscape Development on Ecosystem Services Value in Tropical Watershed

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Assessing the Impact of Landscape Development on Ecosystem Services Value in Tropical Watershed

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Abstract. As development increases with demand, more forest lands are replaced with cropland, commercial plantation, and infrastructures for being able to accommodate the excessive growth in world's population. Environments were destroyed without considering their values in sustaining life on Earth.This phenomenon is still an ongoing scenario in most of the developing countries in the tropical region including Malaysia. Such unrestricted conversion may cause food or water crisis along with irreparable consequences to local and regional climate as the natural ecosystem is not only the main resources generator but also the climate stabilizer. Contrary to this, a study was conducted in Pahang Watershed, the largest watershed in Peninsular Malaysia with forest as the dominant land cover, to investigate the effect of landscape development on the ecosystem in terms of the erosion and ecosystem service value. Results of soil loss based on USLE indicated a direct relationship between development and total soil loss where total annual soil loss in year 2005 and 2010 showed a significant increase compare to year 2000. Meanwhile, developed and agricultural lands were discovered to be the main contributor whereas forest land produce the least soil loss (<10ton/ ha/yr).Apart from this, this study also reports a degrading trend in the overall ecological service value and goods (ESVG). Although oil palm had become the main commercial plantation in current years, the commercial profit brought by oil palm still insufficient to cover losses referring to overall estimated ESVG due to the forest clearance and soil degradation. In addition, for a destroyed ecosystem to be equilibrium again requires years. Therefore, ESVG of the tropical forest are expected to increase continuously in future which mean that the roles of the forest in conserving the environment stabilization and sustainability of life are getting more critical.

1. Introduction

Ecosystem function in providing food and services is the utmost key element to sustain life and motivate the entire operating system of earth itself [1]. Abiotic, consumer, producer and decomposer are the main components forming the ecosystem that linked to each other to maintain the equilibrium state of the whole ecosystem. However, continuos development conducted globally behalf of human civilization had become the biggest threat to nature conservation [2]. Landscape alteration due to development had substantially reduce total of forest land, largest producer and decomposer of the

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earth ecosystem globally. Thus, land development which altered the natural surface feature and produce excessive release of greenhouse gases is believed to be the root causing accelerate global warming since the rise of industrial revolution at late 1980's [16].

Applicable to watershed, ecosystem services provisions are highly dependent on the the land use, topography and local climate. Therefore, for country enrich with natural and water resources like Malaysia, proper land use and development management is essential to maximize the function of watershed [3][14]. Unfortunately, prompt development responding to industrial revolution in last few decades had caused land degradation resulting from deforestation and illegal logging even in reserved forest [12][13][17][18]. Evidence on the impact of landscape development such as drastic increase in annual soil loss, landslide and flood hazard in recent year. Though, most of the citizen are still lacking awareness regarding the needs in conserving the natural environment since it is difficult for them also the government policy maker in visualizing the exact value of the ecosystem and how to allocate public spending on conservation, prevention or restoration initiative [19]. In fact, the impacts of soil erosion affects not only food and water security but also local climate due to release of carbonium ions into the air during the erosion process [4]. In present paper, the destruction or degradation caused to the ecosystem due to landscape development was studied through the implementation of ecosystem services values to provide clearer view on the value and importance of ecosystem services to human well-being.

2. Materials and Methods

2.1. Study Area

Pahang watershed with a 440km main stream length is the largest watershed located at N2°48'45" - 3°40'24, E101°16'31" - 103°29'34 Peninsular Malaysia (Fig.1). Over the watershed, 2/3 of the surface are dominated by tropical rainforest. Since 1974, annual mean rainfall intensity received is at 2170mm. Presently, there are two main reservoir which are the Bera and Chini lake reservoir. Due to the large portion of tropical rainforest over the state, tropical timber trading had become the main economic pillar of the state throughout the decades.

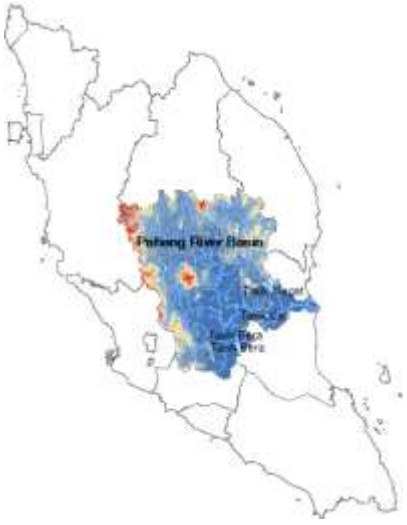

Figure 1: Pahang Watershed

2.2. Method

The methods implemented in present study include: (i) Observation on landscape development from 2000 to 2010 ; (ii) analysis on impact of landscape development to total annual soil loss produced

from 2000 to 2010; (iii) Evaluate the impact of landscape development to ecosystem value using ESVG (ecology service value and good) estimation.

2.2.1. Analysis of landscape development to total annual soil loss produced from 2000 to 2010

Land use mapping is performed based on MODIS 16-day 250m data for 2000, 2005 and 2010 using maximum likelihood technique (training sample from Peninsular Malaysia landuse map). To estimate annual soil loss over the watershed, remote sensing data and ancillary data are used as input in Universal Soil Loss Equation, USLE by MORGAN [9][20],

$$A=R.K.LS.C \quad (1)$$

Where A is the annual soil loss (ton/yr), R is the rainfall erosivity factor, K is the soil erodibility factor, LS is the slope-length factor, C is the crop management factor and P is the erosion control factor. Hence, equation 1 is implemented in MODIS NDVI data to map the soil loss pattern in 2000, 2005 and 2010. Meanwhile, ndvi from MODIS prduct data is transform into C-factor, and LS factor is generated from ASTERDEM using GIS application technique [3][15]. For R factor and K factor applied is provided by Department of Drainage and Irrigation Malaysia [10]. Thus, the soil loss estimated is used as the source in assessing the landscape risk resulted form landscape development.

2.2.2. Evaluate the impact of landscape development to ecosystem value using ESVG (ecology service value and good) estimation from 2000 to 2010

Environment conservation is crucial in slowing down speed of the global warming. But, the uncertainty and invisible commercial market of the ecosystem function and services bring difficulties to policy maker in allocating investment in protecting the environment. So, absolute ecosystem services values are derived as ecological service values and goods for a given area [1][19]. Guideline based on paper by FAO and TEEB on ESVG is used in present study [4, 5, 6, 7, 8, 11, 21]. Out of 17 indicators, 11 indicators directly linked to landscape feature are adopted as shown in table 2.

3. Results and Analysis

From 2000 to 2010, various development had been conducted in Pahang Watershed where there is increase in the commercial plantation and built-up area coverage as shows in Table 1. For development purpose, forest is being replace by other plantation that have higher commercial values such as oil palm and rubber. Or else, construction to broaden residential and industrial area which produce more visible economic income to the country. But, in term of gaining profit, the country is actually getting negative profit. It is so since the environment losses due to landscape development is being ignored. Simultaneous to development, occurrence of erosion and the amount of soil loss had been increased excessively through the years from 3mil ton/yr in 2000 to 12mil ton/yr in 2010. Among the land use features, forest produced least amount of soil loss (<10ton/ha/yr) while oil palm and rubber landscape are highly potential in producing large amount of soil loss depending on the state of maturity of the plantation.

Table 1: Land Use Changes from 2000 to 2010

Genaral Land use	2000	2005		2010	
	Area(ha)	Area(ha)	changes	Area(ha)	changes
Forest	2505801	2298612	-207189	2235976	-62636
Secondary Forest	55864	105177	49313	100885	-4292
Oil Palm	230365	392341	161976	425381	33040
Rubber	22776	27199	4423	47386	20187
Built-Up Area	15971	9019	-6952	18128	9109
Wetland	2339	811	-1528	5224	4413

Mix cultivation	35	68	32	302	235
Total (Area)	2833151	2833227		2833281	
Annual soil loss(ton/yr)	2,993,061	2,478,559		14,211,170	

Estimated ESVG for each landscape features is shown in Table 2. Amongst the features, the ESVG for oil palm is the highest that is 1202 USD/ha/yr followed by forest and secondary forest. Sum of the features ESVG for each year show increament in overall ESVG from 2000 to 2010. Conversely, overall ESVG began to show losses for about 26mil USD/yr in 2010 as in Table 3 when environment element, soil loss is included. On this study, ESVG estimated are partially represent the ecosystem services value since only 11 indicator used. Consequently, further implementation of ESVG using full indicators will indicate much higher ESVG assets. Moreover, most of the ecological services values adaopted is being generalized to global scale and valueing the ecosystem services at local scale may be more comphrehensive for precise ESVG mapping and provide real environmental benefits to policy maker to prioritize environment conservation project.

Table 2: Ecology Service Values and Good in Watershed for 2000, 2005 and 2010

Ecology Service Values And Goods												
	Ecological Services							Ecological Goods				
Landscape Features	water supply #	Erosion Contol #	Waste Trestment #	Carbon Stock *	Carbon Sequestration *	Recreation #	Cultural and Artistic info #	Food Production #	Raw Materials #	Medical Resources *	Ornamental Resources *	Total Rate (USD/ha)
tropical primary forest	8	245		8	8	112	2	108.24	330	50	250	1121.4
tropical secondary forest	8	245		6	6	112		32	330		250	989
oilpalms	2								1200			1202
rubber	2								77			79
wetland		96.7						204				300.71
Built-up area												0
Mix cultivation								54				54
soil loss due to erosion(ton / year)												6
#ESVG based on Costanza; *ESVG based on FAO, ∞ based on TEEB valuation database [1][11][5]												

Table 3: ESVG for Pahang Watershed in 2000, 2005 and 2010

Ecology Service values and goods (ESVG)			
	Total Cost (USD/yr)		
Landscape Features	**2000**	**2005**	**2010**
tropical primary forest	2809603939	2577295662	2507065216
tropical secondary forest	55249480.29	104020282.5	99775067.2
oilpalms	276899247.9	471594115.6	511307642.3
rubber	1799281.565	2148721.563	3743459.295
wetland	703238.8113	243869.3986	1570858.792
Built-up area			
Mix cultivation	1916.04096	3646.13994	16316.83062
soil loss due to erosion(ton / year)	17,958,366	14,871,354	85,267,020
Total ecology Services and Goods (USD/yr)	3126,298,738	3140,434,943	3114,951,858

4. Conclusion

Replacement of forest with other land features leaving earth surface less protected thus causing more soil detachment. From 2000 and 2010, reduction in overall forest cover due to landscape development had worsen the erosion occurred where the annual soil loss had achieved 12mil ton/yr in 2010 compare to 3mil ton/yr in 2000. The accelerate increase in soil loss is linked with the landscape development that conducted in the watershed. Among all, forest produced least soil loss which is less than 10ton/ha/yr. Although oil palm has the highest commercial values compare to others in present study, the commercial profit brought by oil palm still insufficient to cover losses referring to overall estimated ESVG due to the forest clearance and soil degradation. However, regional or local ecosystem services valuation should be carry out to provided more precise and accurate values for every 17 parameter used in order to draft and practice a better environment conservation, preservation and restoration policy. Lastly, well-planned landscape development is essential to minimise the destruction towards the natural environment to ensure well-being of human itself and a sustainable living environment in the future.

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