Science of the Total Environment xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Assessment of ecosystem productivity damage due to land use

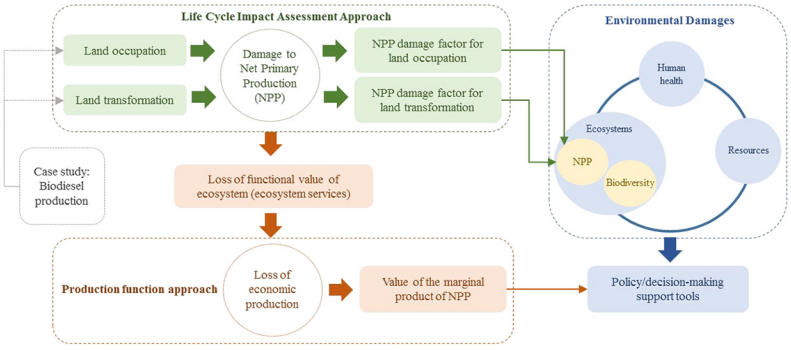
Piyanon Kaenchan [a,b], Jeroen Guinée [c], Shabbir H. Gheewala [a,b,*]

[a] The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Thailand
[b] Centre of Excellence on Energy Technology and Environment, PERDO, Bangkok, Thailand
[c] Institute of Environmental Sciences, Leiden University, The Netherlands

HIGHLIGHTS

- Method for assessing the damage of land use on ecosystem productivity is presented.
- Ecosystem productivity damage is expressed through net primary production (NPP).
- NPP damage factors for land use impacts are provided.
- Economic valuation of NPP yields a value of 10–15 THB per tonne dry weight biomass.
- Results are tested for effect of palm biodiesel promotion on land use in Thailand.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 16 May 2017
Received in revised form 10 October 2017
Accepted 10 October 2017
Available online xxxx

Editor: D. Barcelo

Keywords:
Land use
Net primary production
Valuation
Production function
Impact assessment

ABSTRACT

Land use can affect ecosystems on land and their services. Because land use has mainly local effects, damage to ecosystem productivity due to land use should be modelled spatially dependent. Unfortunately, even though land use of impacts are particular importance for countries whose economies are highly agriculture-based, ecosystem productivity damage due to land use has not yet been assessed in Thailand so far. This study presents the method for assessing the damage to ecosystem productivity due to land use (land occupation and land transformation) in Thailand. Ecosystem productivity damage is expressed through net primary production (NPP). To convert the damage into monetary units, this study performs an economic valuation of NPP using the production function approach. The results show that the value of marginal product of NPP is around 10–15 Thai baht (THB) (1 USD ≈ 36 THB), per tonne dry weight biomass. The results are applied to the case of biodiesel production. The method presented in this paper could be a guideline for future land use impact assessment research. In addition, converting the NPP damage results into monetary units facilitates integration of impact assessment and economic analysis results for supporting decision support tools such as cost benefit analysis.

1. Introduction

Land is known as the component of the ecosystem necessary for life in terms of being an input for food production and dwelling. Land is also considered significant for economic activities since it is used in manufacturing and service operations.

Because land is a limited resource, an increase in land use for one activity thus decreases the area available for others. To maximize profit, the landholder/producer generally determines the type of land use based on its potential income generation. However, determining land use based on only economic gain cannot sustain human well-being. Land utilization can also have an effect on terrestrial ecosystems that

* Corresponding author at: The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Thailand.
E-mail address: shabbir_g@jgsee.kmutt.ac.th (S.H. Gheewala).

https://doi.org/10.1016/j.scitotenv.2017.10.096
0048-9697/

in turn affects organisms including humans who use the services provided by the ecosystems. Therefore, land use should be managed in a way where not only economic gain is considered, but also the effect on ecosystems.

Life cycle assessment (LCA), a tool for assessing the potential environmental impacts generated from the whole life cycle of products, processes, and/or services (Goedkoop et al., 2009), can be used to estimate land use impacts. Under LCA approach, the impact of land use on ecosystems can be measured in the phase of life cycle impact assessment (LCIA) where the area of land use is converted into an indicator for ecosystem quality measurement. There have been several LCIA proposals assessing the potential damage to ecosystems due to land use. Most of them operationalize damage through the number of species lost (Goedkoop et al., 2009; de Baan et al., 2013a; Gabel et al., 2016). The number of species is, however, more related to intrinsic values of ecosystems; it does not directly represent the damage related to loss of functional values of ecosystems (European Commission, 2010; Callesen, 2016). For example, humans do not directly obtain economic benefit from having many types of plant species (they just feel good to know that those species still exist because it represents a good quality of ecosystem) rather than from using plants and their products in life support activities. In order to cover all ecosystem values, the potential loss related to the functional values of ecosystems should also be taken into account.

Following the guidance of the European Commission (2010), the potential loss related to functional values of ecosystems can be presented through the biotic productivity loss of ecosystem using net primary production (NPP) as an indicator. NPP is the net amount of carbon assimilated in a given period by vegetation (Haberl et al., 2007; DAAC, 2016). It represents the total available energy for ecological trophic webs and reproduction of biological biomass stocks, i.e. the amount of plant biomass produced (Haberl et al., 2007; Haberl et al., 2012; Petrosillo et al., 2013; Pei et al., 2015). Because the amount of plant biomass could imply the capability of ecosystems in producing natural resources to serve economic production, NPP can be used to characterize the damage due to land use impacts on the functional value of ecosystems. Damage to NPP due to land use impacts has been considered in several LCIA methods, e.g. the LC-IMPACT (Life Cycle Impact assessment Methods for imProved sustAinability Characterisation of Technologies) and LIME2 methods (Lifecycle Impact Assessment Method based on Endpoint modeling) (de Baan et al., 2013b; Itsubo and Inaba, 2014). However, their damage models for land-use impacts are limited only to a few regions.

As land use is location-specific (Stranddorf et al., 2005), damage to ecosystem productivity caused by land use should be evaluated spatially-dependent and thus differently for different regions or countries. In Thailand, almost 50% of land is under agriculture (OAE, 2015), which can have a significant impact on land. The Thai agricultural sector is contributing up to 10.5% to Thailand's gross domestic product (GDP) (The World Bank Group, 2016). On the other hand, the support of biofuels in this country leads to an increase in the demand for biofuel feedstocks, i.e. cassava, sugarcane, and oil palm (DEDE, 2015), as well as the land required for this. Expansion of agricultural land is needed for cultivation of this biofuel feedstock that would in turn bring about the ecosystem damage due to the impacts of land occupation and land transformation. Therefore, to support decision-making on land use management in Thailand, this study aims to present the method for assessing damage of land use (land occupation and land transformation) to NPP in Thailand.

This damage is estimated by adjusting the procedures in LIME2. In addition, to convert the damage into monetary units, economic valuation of NPP is conducted using the production function approach which estimates how much a given ecosystem service contributes to the market value of economic goods/service (Pascual et al., 2010). Next, the results are applied to a case study on biodiesel. The method presented in this paper could contribute to future land use impact assessment research. Furthermore, expressing damage to NPP due to the effects on land use in monetary unit facilitates integration of land use impacts and other impact categories (which would lead to a single score of environmental externality). These could then be incorporated into economic analysis tools such as cost-benefit analysis (CBA) and system for economic and environmental accounting (SEEA) (Finnveden and Moberg, 2005; Höjer et al., 2008).

The method to assess the damage of land use to NPP as well as the economic valuation of NPP is explained below. Next, damage factors are calculated and discussed based on this method. These damage factors are then applied to a case study on biodiesel. Finally, conclusions are presented, followed by recommendations for future research.

2. Methods

To assess the damage to NPP caused by the effects of land use, NPP damage factors are needed. The cause-effect chain for land use impacts on ecosystems related to NPP is illustrated in Fig. 1. The methods for calculating NPP damage factors for land occupation and land transformation are described in Section 2.1. Moreover, to facilitate the integration and comparison among damage and impact categories, this study adds a monetary weighting method to the existing NPP damage approach for converting the damage to NPP into monetary units. The procedures to derive monetary weighting factor of the damage to NPP is based on the production function approach (Pascual et al., 2010), which is explained in Section 2.2.

2.1. NPP damage functions

Land use impacts are categorized into land occupation and land transformation (Goedkoop et al., 2009; Itsubo and Inaba, 2014). Land occupation refers to the damage caused by the continuous use of land;

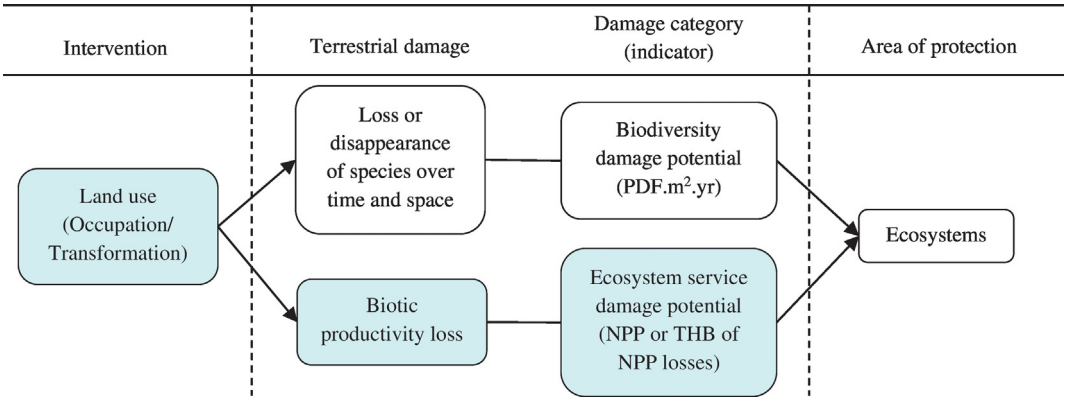


Fig. 1. Cause-effect chain for land use impacts on ecosystems (Margni et al., 2008; European Commission, 2010).