Journal of Cleaner Production 134 (2016) 532–538

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Greenhouse gas emissions from land use change due to oil palm expansion in Thailand for biodiesel production

Napapat Permpool [a, b], Sébastien Bonnet [a, b, *], Shabbir H. Gheewala [a, b]

[a] The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok, Thailand
[b] Centre for Energy Technology and Environment, Ministry of Education, Thailand

ARTICLE INFO

Article history:
Received 29 October 2014
Received in revised form
25 February 2015
Accepted 13 May 2015
Available online 21 May 2015

Keywords:
Oil palm
Thailand
Land expansion
GHG emissions
Feedstock security
Policy targets

ABSTRACT

Thailand depends heavily on importation of fossil oil to satisfy its energy demand. The transportation sector is an important contributor to energy demand; biofuels are therefore strongly promoted in Thailand, notably biodiesel from oil palm. According to the Renewable and Alternative Energy Development Plan (AEDP 2012–2021) a biodiesel target of 5.97 million litres per day is to be achieved by 2021. This research focuses on assessing the implication of this on oil palm plantation area requirement, regions most suitable for its expansion and related greenhouse gas (GHG) implications as well as feedstock security. The investigations revealed that about 91,200 ha of land would be required for oil palm expansion to achieve the biodiesel target while also meeting other requirements for palm oil including domestic consumption, export, stock and surplus. The Eastern and Southern regions were identified as the two most suitable for oil palm cultivation with respectively 29,772 ha and 61,427 ha of mainly grassland and abandoned land. Oil palm expansion in the East would lead to overall land use change related GHG savings amounting to 47,214 tonnes CO_2-eq per year. Oil palm expansion in the South would also bring GHG savings, 2.5 times higher than for the East.

1. Introduction

Thailand relies heavily on importation of fossil fuels to satisfy its energy demand. The importation of fossil oil translates in heavy financial cost and its use contributes to environmental impacts notably issues of climate change and air pollution, as well as risks to human health (Pleanjai et al., 2009).

At present, more than 70% of total energy consumption in Thailand is contributed in almost equal share by the industry and transport sectors (DEDE, 2012a). As Thailand is an agricultural country rich in biomass resources, the Thai government has made many efforts over the past 15 years in promoting renewable energy. The Renewable and Alternative Energy Development Plan (AEDP 2012–2021) is promoted by Thai government as a strategy to use such kind of energy to ensure greater self-reliance, improved energy stability and be able to meet the demand at both domestic and international levels. In this plan, a challenging target of 25% renewable energy has been set as a contribution to total energy consumption for 2021 with around 4% by biofuels (DEDE, 2011). The 2021 target of ethanol production has been set at 9 million litres per day (MLPD) while that of biodiesel around 6 MLPD. But with the growing demand for biofuels, issues of land use change and competition with food have surfaced (Kochaphum et al., 2013). Several studies have focused on investigating the sustainability of ethanol production in Thailand including environmental impacts, externalities and land use requirements (Nguyen and Gheewala, 2008; Silalertruksa and Gheewala, 2009; Silalertruksa et al., 2009; Nguyen et al., 2010; Papong and Malakul, 2010; Silalertruksa and Gheewala, 2010). Other studies have also focused on similar issues for biodiesel (Pleanjai and Gheewala, 2009; Pleanjai et al., 2009; Siangjaeo et al., 2011; Silalertruksa and Gheewala, 2012; Silalertruksa et al., 2012). However, this study focuses on detailed modelling of the annual expansion of oil palm plantation area over the past decades, including harvested area, oil yield, and oil palm production and consumption. The processing of such information is however important to model future requirement in oil palm plantation to meet specific policy targets and so implications in terms of land use expansion and associated greenhouse gas (GHG) emissions (Silalertruksa and Gheewala, 2010).

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

http://dx.doi.org/10.1016/j.jclepro.2015.05.048
0959-6526/

Biodiesel, also known as fatty acid methyl ester (FAME), is produced from the transesterification process of vegetable oils or animal fats with the addition of methanol (Meher et al., 2006). In Thailand, biodiesel is mainly produced from palm oil since oil palm plantations are well suited to tropical conditions and are characterized by the highest oil yield among oil yielding plants (Pleanjai and Gheewala, 2009). In 2012, biodiesel production capacity was around 1.72 MLPD (DEDE, 2012b). To achieve the 2021 policy target, the production of palm oil needs to be increased. This requires expanding oil palm plantations on to other land and also enhancing productivity.

Over the period 2001–2010, based on statistics from the Office of Agricultural Economics (OAE) the average annual increase in oil palm plantation area was about 9%. In 2012, there were about 660,000 ha of land occupied by oil palm plantation out of which 600,000 ha were harvested (OAE, 2012). Although oil palm production has been steadily increasing over the years, there are variations in the yield of fresh fruit bunch (FFB) from which crude palm oil (CPO) is extracted to produce refined oil products and biodiesel. These are due to various environmental factors including climate variability, flooding events, diseases, etc. But on average, OAE (2012) reports the yield of FFB for oil palm plantation in Thailand to be 18 tonnes per ha (OAE, 2012).

The expansion of oil palm plantation can induce land use change (LUC) issues and competition with other cash crops. LUC has raised considerable concerns over the last decade as it frequently goes along with environmental impacts including, deforestation, animal extinction and peatland destruction (FAO, 2013). LUC can also be associated with GHG emissions that may challenge the global warming performance of biofuels depending on the vegetation replaced (Siangjaeo et al., 2011). For instance, the conversion of tropical grassland to oil palm has been reported to contribute removing 135 tonnes CO_2-eq per ha while forest conversion to oil palm plantation contributes emissions of around 650 tonnes CO_2-eq per ha (Germer and Sauerborn, 2008). Such issues need therefore to be carefully considered when energy feedstocks such oil palm plantations are to be expanded, avoiding to replace high carbon stock vegetation such as forests. In addition to land use type, soil quality needs also to be carefully considered so that it is adequate for oil palm production and productivity is attractive enough for farmers to consider growing such a feedstock.

This study aims therefore at assessing the area requirement for oil palm expansion in suitable regions of Thailand based on the biodiesel target and the land use change related GHG emissions of such expansion.

2. Methodology

2.1. Background information about oil palm plantation and assumptions of this study

To assess the area of oil palm plantation required by 2021 to satisfy the overall demand in CPO including that for biodiesel production, two main factors need to be investigated, the area of oil palm plantation harvested in each year and the potential yield of fresh fruit bunch (FFB) per area. The area of oil palm plantation harvested is based on the assumption that the area of new planting in each year will be harvested in the third year after being planted (DOA, 2011). The yield of FFB varies with the age of an oil palm tree. However, its productive lifetime is considered to be 25 years as it corresponds to the period during which yields of FFB are still within competitive range and it is not too hard to harvest (Akesamatramate et al., 2005; ACFS, 2008).

Yearly information about area of oil palm plantation since 1982 up to 2012 and yield of FFB per age of tree were obtained from OAE (2012). This information was combined to calculate past production of FFB up to 2012. In 2012, oil palm plantations covered an area of 0.7 million ha out of which 0.62 million ha were harvested and 11.33 million tonnes of FFB were produced. This information was used in order to forecast future production up to 2021.

2.2. Parameters to estimate the amount of CPO required for biodiesel production

The two major aspects to consider when planning for oil palm plantation are the supply and demand side for all sectors consuming CPO. In terms of supply, in addition to plantation area and yield of FFB, oil extraction rate (OER) needs to be considered (about 17%) (OAE, 2012). Although the AEDP policy target for biodiesel production is used as the basis to assess the requirement in CPO by 2021, all sectors contributing to CPO demand are considered. Aside from biodiesel (B100), these include: domestic consumption, Bio-Hydrogenated Diesel (BHD) production, safety stocks and export. The assumptions and data used to estimate the future demand of those sectors for CPO are detailed below.

2.2.1. Domestic consumption

This sector provides refined oil products derived from CPO for food and cosmetic industries. In Thailand, domestic oil palm consumption has been increasing over the years at a stable rate and is directly proportional to the population growth rate. According to data from DIT (2010), this rate is in the range 3–5%. It is therefore assumed in this study that the future increase in domestic oil consumption will follow a 3% annual increase as per population growth rate (DLT, 2012; NSO, 2012).

2.2.2. Biodiesel consumption

Biodiesel consumption in the transport sector is encouraged by the central government to reduce dependency on imported fossil fuel diesel, reduce energy cost, and improve environmental performance. The actual consumption of diesel referred to as high-speed diesel (HSD) and B100 for the years 2011 and 2012 are reported in Table 1. As mentioned earlier, the B100 production target of 2021 is set at 5.97 million litres per day. Thus, to assess the requirement in CPO to satisfy the target, two factors need to be assessed, the HSD consumption and the fraction of B100 to be blended with HSD to produce the required blend of biodiesel for transport. With regard to HSD, as recommended by DEDE (personal communication), a 3% annual increase in the population growth rate was used instead to forecast the future demand in HSD (DLT, 2012; NSO, 2012). In terms of blending, the level is based on the forecasted consumption of HSD over the next decade and the AEDP policy target set for B100. Based on information from DEDE (2012c), the blending level of biodiesel should reach 7% (B7) in 2015 and 9% in 2019 (B9).

When assessing the amount of CPO required for producing a certain amount of B100, two major aspects need to be taken into consideration (1) the regulation from DEDE regarding blending

Table 1
Actual blending of biodiesel during 2011–2012.

Year	[a]HSD consumption (MLPD)	[b]B100 production (MLPD)	[c]Actual blending (%)
2011	51.4	1.72	3.35
2012	54.7	2.42	4.43

Notice: MLPD stands for million litres per day.
[a] Source: DOEB, 2012a.
[b] Source: DOEB, 2012b.
[c] Source: EPPO 2012.