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Impacts of Thai bio-ethanol policy target on land use and greenhouse gas emissions

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ABSTRACT

The growing demand for biofuels has led to an increased demand for feedstocks which in turn is anticipated to induce changes in the cropping systems or land requirement for agriculture use. This study used consequential life cycle assessment (LCA) to evaluate the environmental consequences of possible (future) changes in agricultural production systems and determine their effects on land use change (LUC) and greenhouse gas (GHG) implications when cassava demand in Thailand increases. Six different cropping systems to increase cassava production including converting unoccupied land to cropland, yield improvement, displacement of area currently under sugarcane cultivation and the other potential changes in cropping systems in Viet Nam and Australia are modeled and assessed. The comparative results show that LUC is an important factor in overall GHG emissions of the first generation biofuels especially change in soil carbon stock contributing about 58–60% of the net GHG emissions. Increased cassava production by expanding cultivation area has a significantly larger effect on GHG emissions than increased productivity. The analysis shows that increasing productivity of both sugarcane and cassava are important ways to maximize benefits in using of certain area of Thailand to serve both the food and fuel industries.

1. Introduction

Consequential impacts from increased energy crop demand have raised concerns about the sustainability of the first generation biofuels. One of the reasons is that land use and management can influence a variety of ecosystem processes such as photosynthesis, decomposition, nitrification/de-nitrification and combustion which affect greenhouse gas fluxes [1]. Increasing of biofuels demand leads to an increasing of crop production which can only be satisfied by cultivation of land and/or increasing of the existing crop productivity. Increase in cultivated land and changing of land management can induce both direct and indirect land use change. Direct land use change occurs when energy crops for biofuels displace a prior land use (e.g. forest, grassland, other crops) and indirect land use change is the ripple effect that results from using land currently used for food for fuel production [2]. These displacements could adversely affect the net GHG emissions due to change of above-ground and below-ground biomass and soil carbon stock [3–5].

Bioethanol from local energy crops such as cassava and sugarcane is one of the alternative fuels encouraged by the Government of Thailand to prevent energy risks when crude oil prices fluctuate greatly or increase rapidly. In Thailand, bioethanol has been used for vehicle in various types of ethanol blends with gasoline (called gasohol) i.e. E10, E20 and E85. E10, a 10% blend of bioethanol with 90% gasoline, was introduced in the market in 2004. E20, a 20% ethanol blend, was introduced in 2008 after E10 had penetrated the market. Moreover, E85 gasohol has been launched 3 years ahead of schedule; it was introduced in the local market in August 2008. Due to government promotion strategies, the total gasohol consumption in Thailand has increased from 0.16 M l day^{-1} in 2004 to 10.48 M l day^{-1} in 2008 [6]. Moreover, about 30.7 M l bioethanol have been exported to other countries such as Singapore, EU, Australia and the Philippines (as of October 2008) [7].

The Thai renewable energy policy has set the target to increase the use of ethanol up to 3 M l day^{-1} by 2011 [8]. To achieve the target, ten cassava ethanol producers are expected to operate by the year 2009 with a total capacity 2.32 M l day^{-1} [8]. About 6.36 M ton yr^{-1} of cassava are needed to serve ethanol industry (based on 133.2 l ethanol produced per ton cassava roots [9]). This demand of bioethanol will induce changes in cropping systems and land requirement for agriculture use in Thailand and may result in other impacts on ecosystems, e.g. deforestation, biodiversity loss and increase in the net GHG emissions. This study aims to assess the consequential impacts of increased cassava ethanol demand in Thailand on land use and greenhouse gas emissions. The Thai biofuels policy target by 2011 was used as the milestone. Different possible cassava production systems including yield improvement, transformation of unoccupied land to cropland and displacement of other cultivated areas for growing energy crops are modeled and assessed.

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2. Methodology

2.1. LCA approach

A consequential life cycle assessment (LCA), referred to as prospective LCA, is one of the methodologies for evaluating the environmental consequences of possible (future) changes between alternative product systems [10–13]. It has been effectively used to analyse the agricultural production system changes when there are changes in demand of agricultural products in the market [14–16]. Nielsen and co-workers identified the marginal suppliers of various crops by using economic modeling of the responses to change in demand for different agricultural products [17]. The basic principle of using consequential approach is that the technologies (or processes) actually affected by a change in demand must be modeled through realistic cause–effect relation. For example, increase in demand of biodiesel in EU may be satisfied by increasing rapeseed plantation in the EU itself or importing feedstock, e.g. crude palm oil, or biodiesel from Thailand. These options have different production chains that need to be analysed for each specific chain.

To achieve the objective of this study, the consequential LCA was used as a tool to track possible changes in agricultural production systems and determine their effects on land use change and GHG implications when cassava demand in Thailand increases. A framework for increased agricultural crops production in a certain region and certain area as proposed by Schmidt [15] was applied to model different ways to satisfy the increasing demand of cassava in Thailand. Fig. 1 shows six scenarios including converting unoccupied land to cropland (scenario 1), increasing productivity (scenario 2), fulfilling the increased demand by importing feedstock which brings about an agricultural processes change abroad (scenarios 3 and 4), displacement of other cultivated areas which lead to indirect land use change (scenarios 5 and 6). These scenarios, however, are extreme cases to satisfy increasing demand. This study did not focus on combination of various other scenarios which have a greater likelihood for occurring in reality. For example, the increased demand of cassava in Thailand may cause both the Thai farmers and/or farmers in another country to produce more for export to Thailand. The relocation of displacements will also depend on the market prices of the displaced commodities.

2.2. System boundary

Scope of the study involves land areas required, resources used and greenhouse gas emissions related to the change of cropping systems in the different scenarios described above. Fig. 2 shows the mechanism in changing of agricultural cropping systems and relevant inputs–outputs. The GHG emissions were estimated by considering (1) clearance of land before the establishment of new cassava plantation; (2) changes in soil carbon stock due to land use change and/or a change in the land management practices; (3) emissions from fossil fuel consumption for agricultural operations; (4) production of synthetic fertilizers; (5) N_2O emission from land management during cultivation; and (6) production of agrochemicals used.

2.3. Modeling of scenarios

Scenarios as shown in Fig. 1 were modeled by using the following background information and assumptions.

- For the scenarios considering increase in cultivated area, long-term energy crop plantation (20 years) was assumed. This factor will directly affect the amount of carbon-stock change from clearance of land prior to the establishment of biomass plantation per unit products of energy crop.
- For the scenarios considering increase in yield, this study focused on increased yield in terms of additional N-fertilizers input. This is because the yield of both cassava and sugarcane respond well to N-fertilizer [18,19]. Too much nitrogen, however, may result in adverse effects such as excessive vegetation growth at the expense of tuber yield in cassava or decreasing of sugar content and effect on juice quality [18,19]. However, the

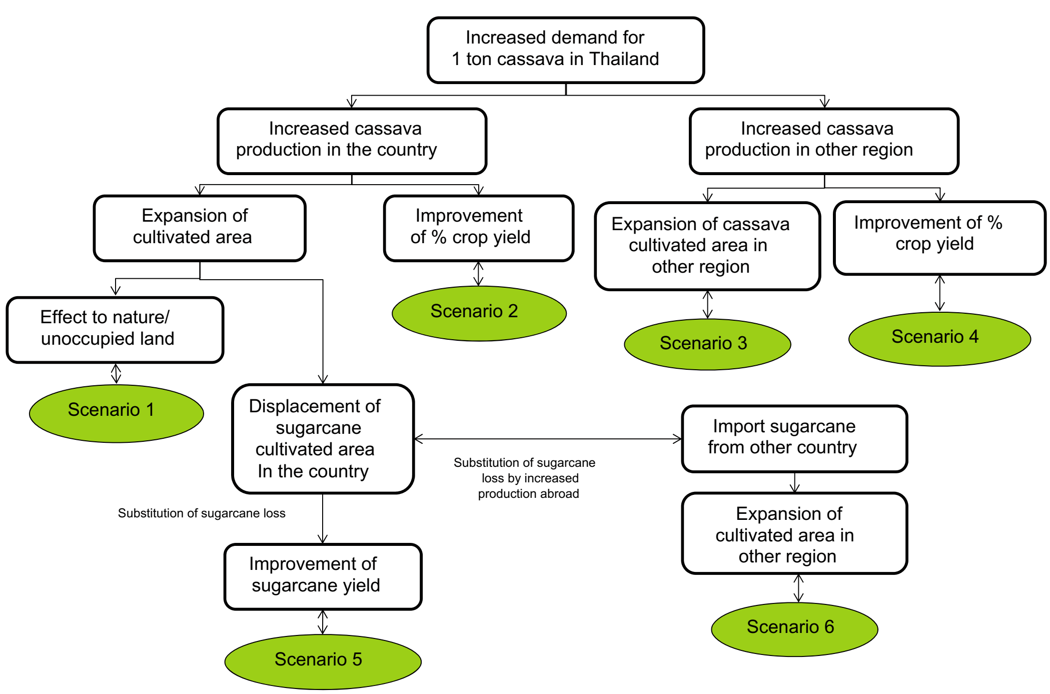

Fig. 1. Modeling of changes in agricultural systems to satisfy increased demand of a ton cassava in Thailand.