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Sustainability of sugarcane cultivation: case study of selected sites in north-eastern Thailand

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ABSTRACT

This paper aims to assess sustainability of different sugarcane cultivation practices in selected sites in North-eastern Thailand; and to provide recommendations to improve sustainability of sugarcane cultivation in the areas studied. This study evaluates the environmental and socio-economic impacts of sugarcane cultivation in different stages at detailed level. The indicators assessed are the impacts on global warming, human toxicity, terrestrial acidification, freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, agricultural land occupation, water depletion, fossil fuel depletion, employment generation, worker income, wages and working conditions. The results reveal that the sugarcane cultivation causes highest impacts on freshwater ecotoxicity, freshwater eutrophication and marine ecotoxicity. Yields, cultivation practices and distance to the sugar mill are the key factors influencing the environmental and socio-economic impacts. Moreover, it is suggested that optimal quantities of fertilizers and pesticides consumed may help to increase yields. This will consequently lower the environmental impacts and reduce production cost. The distance from farm to sugar mill could also influence production cost and the environmental impacts. Mechanized harvesting is found to be a way to reduce production cost. However, it is associated with an increase in environmental impacts as well as reduction in employment. Wages and working conditions of jobs in sugarcane farming are found to be poorer compared to rice farming. Sugarcane farming may experience a lack of laborers in the future which may lead to more mechanization. Recommendations proposed to improve sustainability of the sugarcane cultivation include increasing yields, managing fertilizer and agro-chemical applications, and zoning agricultural crops.

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1. Introduction

Sugarcane is one of the crops having a high impact on the Thai economy. In 2012, Thailand was the world's second largest sugarcane exporter after Brazil (Illovo Sugar, 2012). It is a feedstock for both food and energy production. In Thailand, it is currently used to produce food (sugar) and bio-fuel (ethanol). Moreover, other products such as heat, electricity, cellulosic ethanol, pulp, bio-fertilizer and biogas production can also be produced from its by-products (Biofuels Digest, 2008; Gheewala et al., 2011; Kiatkittipong et al., 2009; Nguyen and Gheewala, 2008b; Nguyen et al., 2010; Pereira and Ortega, 2010; Ramjeawon, 2008; Renouf et al., 2013).

Thailand's Office of Agricultural Economics reported that over a hundred million tonnes of sugarcane was produced in 2014 (Office of Agricultural Economics, 2014a). Sugarcane is grown in central, northern and north-eastern Thailand. The north-eastern region has the largest growing area and production (Office of Agricultural Economics, 2014a). In 2014, the north-eastern region produced 41.5 million tonnes of the total of 103 million tonnes of sugarcane in the country, the north and central regions generating 29.6 and 31.8 million tonnes respectively. This indicates the significance of the north-eastern region for Thai sugarcane production.

The World Commission on Environment and Development defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987). The triple bottom line is a well-known concept aiming to help organizations to achieve

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sustainability considering environmental, economic and social aspects (Elkington, 2002).

Sustainability assessment of Thai sugarcane cultivation is essential as sugarcane is a source for several important products such as sugar, heat, electricity, ethanol, pulp, bio-fertilizer and biogas, etc. To promote the sustainable development of sugarcane cultivation, environmental, economic and social issues have to be addressed. There have been some studies in the past assessing environmental sustainability of Thailand's sugarcane cultivation (Kongboon and Sampattagul, 2012; Nguyen and Gheewala, 2008a; Yuttitham et al., 2012), as well as some assessing economic and social sustainability of sugarcane cultivation (Nguyen and Gheewala, 2008b; Silalertruksa and Gheewala, 2011). However, these previous studies assessed sustainability of the sugarcane cultivation at a larger scale. This paper aims to assess environmental, economic and social performances of the sugarcane cultivation at a more detailed level looking at sustainability performances in different stages of sugarcane cultivation. It will also consider sustainability characteristics of different sugarcane cultivation practices. Recommendations to improve sustainability of sugarcane cultivation in the areas studied will then be provided.

2. Material and methods

2.1. Site selection

The sites selected for this work are in the north-eastern region of Thailand which is the largest growing area and sugarcane producer in the nation (Office of Agricultural Economics, 2014a). This implies a high impact of data from this region. The Nakhon Ratchasima province was selected as it has the largest growing area and produces the largest amount of sugarcane in the region (Office of Agricultural Economics, 2014a). Data from two other provinces in the same region, Khon Kaen and Mahasarakham, were also collected to compare with data from Nakhon Ratchasima. However, site selection was on a voluntary basis. For Nakhon Ratchasima, data were collected from Phothong sub-district, Khong district. For Khon Kaen, data were collected from Subdeang sub-district, Khokphochai district. For Mahasarakham, data were collected from Phongern sub-district, Nachueak district.

2.2. Data collection

Data were collected using questionnaires and interviews with sugarcane farm owners and laborers working in the farms. Questionnaires used in this study can be found in the Supplementary material. Data used in this paper were collected for one cropping cycle, in February 2014. Data about cultivation practices, input–outputs used in sugarcane cultivation, employment generation in sugarcane farms, production and transportation costs of sugarcane, selling price of sugarcane, and wages paid to laborers working in the farms were collected from the farm owners. Data about wages received and working conditions were collected from laborers working in the farms. Working conditions were also evaluated from interviewing the farm owners in case they are self-employed. The number of people surveyed in this work are shown in Table 1.

Table 1
Numbers of surveys used in this work.

Provinces	Farm owners	Laborers working in farms
Nakhon Ratchasima	20	30
Khon Kaen	7	10
Mahasarakham	10	10

2.3. Cases studied

General sugarcane cultivation practice in the areas studied includes land preparation, planting, maintenance and harvesting stages. Land preparation is fully mechanized. Tillage is practiced 2–3 times before planting. Planting is mostly mechanized; however, in some areas it is still manual. In the planting stage, fertilizers are required. All farms use chemical fertilizers; some use both chemical and bio-fertilizers. Chemical fertilizer types used in sugarcane cultivation vary from site to site. Main chemical fertilizer types used in the areas studied are shown in Table 2. In some farms, filter cake from sugar factory is used as a soil conditioner before planting. Although, the sugarcane crop requires water, only some farms have irrigation. Most of the farms depend on rain as the sole water source in sugarcane cultivation. Only 30 percent of surveys from Nakhon Ratchasima reported that they sometimes have access to irrigation water. However, the quantity of water used is not recorded. On the other hand, all farms studied in Khon Kaen and Mahasarakham depend on rain as the only water source.

Crop maintenance practices are varied across the sites studied. The maintenance practice is thought to influence the crop yield and would consequently influence sustainability performance of the sugarcane cultivation (Gheewala et al., 2011). Weeding, pesticide and fertilizer applications are the general practices in crop maintenance. The frequency of weeding, fertilization and pesticide application differs from site to site, the numbers ranging from 1 to 4 times per year.

Sugarcane is harvested annually. In the areas studied, the crop is re-grown to produce 1–2 ratoon crops before new planting. Harvesting is mostly manual in all areas. However, mechanized harvesting was found in one large farm in Nakhon Ratchasima. In some sites, sugarcane leaves are burnt before harvesting, to ease manual harvesting. However, in some sites, sugarcane is manually harvested green. In all areas, cane residues (tops and leaves) in the fields are burnt after harvesting to quickly remove them from the fields.

After harvesting, in most farms tillage is re-done as land preparation for the next ratoon crop. Tillage is done about 2–3 times after harvesting. This is to get rid of weeds and the remaining cane trash in the field. In this stage, the tillage has to be done carefully to avoid damage to crops. The tractors used for tillage after harvesting are the smaller ones such as compact tractor and ploughing 2-wheel tractor.

Five cases of sugarcane cultivation practices were set for sustainability characteristics assessment (see Table 2). Based on the information available from this study, cultivation practices for Khon Kaen and Mahasarakham are quite consistent within the same sub-districts. Therefore, only one cultivation practice for each province was set as the case studied. However, cultivation practices in Nakhon Ratchasima differ within the same sub-district. Therefore, three different cases of cultivation practices were set to study for this province.

2.4. Assessment of environmental impacts

Environmental impacts were assessed using Life Cycle Assessment (LCA) as a tool. LCA is a tool used to assess the environmental impacts caused by a product/service through its life cycle stages. The LCA for this study was conducted following the ISO 14040 standard series (International Organization for Standardization, 2006a,b).

2.4.1. Goal and scope definition

The functional unit is 1000 tonne of sugarcane transported to sugar mill. LCA was used to assess the environmental impacts of

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