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Research article

Life cycle GHG evaluation of organic rice production in northern Thailand

Sanwasan Yodkhum [a], Shabbir H. Gheewala [c, d], Sate Sampattagul [a, b, *]

[a] Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand
[b] Center of Excellent on Energy, Economic and Ecological Management, Science and Technology Research Institute, Chiang Mai University, Thailand
[c] The Joint Graduate School of Energy and Environment (JGSEE), King Mongkut's University of Technology Thonburi, Bangkok, Thailand
[d] Center of Excellence on Energy Technology and Environment, PERDO, Bangkok, Thailand

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ABSTRACT

Greenhouse gas (GHG) emission is one of the serious international environmental issues that can lead to severe damages such as climate change, sea level rise, emerging disease and many other impacts. Rice cultivation is associated with emissions of potent GHGs such as methane and nitrous oxide. Thai rice has been massively exported worldwide however the markets are becoming more competitive than ever since the green market has been hugely promoted. In order to maintain the same level or enhance of competitiveness, Thai rice needs to be considered for environmentally conscious products to meet the international environmental standards. Therefore, it is necessary to evaluate the greenhouse gas emissions throughout the life cycle of rice production in order to identify the major emission sources and possible reduction strategies.

In this research, the rice variety considered is Khao Dawk Mali 105 (KDML 105) cultivated by organic practices. The data sources were Don-Chiang Organic Agricultural Cooperative (DCOAC), Mae-teang district, Chiang Mai province, Thailand and the Office of Agricultural Economics (OAE) of Thailand with onsite records and interviews of farmers in 2013. The GHG emissions were calculated from cradle-to-farm by using the Life Cycle Assessment (LCA) approach and the 2006 IPCC Guideline for National Greenhouse Gas Inventories. The functional unit is defined as 1 kg of paddy rice at farm gate. Results showed that the total GHG emissions of organic rice production were 0.58 kg CO_2-eq per kg of paddy rice. The major source of GHG emission was from the field emissions accounting for 0.48 kg CO_2-eq per kg of paddy rice, about 83% of total, followed by land preparation, harvesting and other stages (planting, cultivation and transport of raw materials) were 9, 5 and 3% of total, respectively. The comparative results clearly showed that the GHG emissions of organic paddy rice were considerably lower than conventional rice production due to the advantages of using organic fertilisers.

1. Introduction

Rice is an important staple food crop in many parts of the world. It is vital for the nourishment of the population in Asia, as well as in Latin America and Africa (Alikhani et al., 2013). In Thailand, rice is one the most planted crops (11.59 Mha) for domestic consumption as well as worldwide export and is thus of high economic importance for the country (OAE, 2014). In 2014, the total paddy rice product of Thailand was 36.8 Mt. Also Thailand was the world's 6th largest rice producer and the largest exporter in the world with an export of 10.3 Mt, accounting approximately a quarter of the total rice export in world market (BOT, 2014). About 22% of the rice paddy is grown in northern Thailand due to the region's appropriate climate and geography (RD, 2014). The rice variety chiefly planted in the northern region during the wet season is Kao Dok Mali 105 (KDML 105), commonly referred to as fragrant jasmine rice. It is very popular the world over due to its high quality and high aroma level. Its price in the rice world market is almost double that of other cultivars of rice (Kong-ngern et al., 2011).

Although rice production generates wealth and jobs, it also creates environmental impacts, especially greenhouse gas (GHG) emissions from cultivation which is one of the important

* Corresponding author. Faculty of Engineering, Chiang Mai University, Chiang Mai, Thailand.
E-mail address: sate@eng.cmu.ac.th (S. Sampattagul).

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contributors to global warming. Field emissions of rice cultivation are caused by the practice of flooding the field during cultivation leading to anaerobic conditions which favour methane formation and release (Thanawong et al., 2014). That is the largest contributor to life cycle GHG emissions of rice production comprising approximately 70% of the overall life cycle GHG emissions (Hokazono and Hayashi, 2012). Field emissions of rice cultivation include CH_4 which may react with hydroxyl radicals in the troposphere (Bayer et al., 2015) and N_2O which, in addition to being a potent GHG, can also contribute to the destruction of stratospheric ozone (Akiyama and Yagi, 2005).

Thailand's agriculture sector has been considered as one of the biggest contributors to the national GHG emissions comprising about a quarter of the total; and rice cultivation contributes approximately 60% of the GHG emissions from the agriculture sector (ONEP, 2011). It has received significant attention in global climate change discussions due to its uniqueness among cultivated crops for emitting both methane (CH_4) and nitrous oxide (N_2O), two GHGs that are more potent than carbon dioxide (CO_2) in driving climate change (Brodt et al., 2014). To address this issue, Thailand has set up an ambitious alternative rice cultivation plan towards environmental protection, especially climate change mitigation in rice cultivation which is concerned with GHG emissions reduction. Moreover at present, Thailand is promoting alternative rice cultivation, especially organic rice for sustainable agricultural development and to increase the value of agricultural products. The aim of this study is to evaluate the GHG emissions of organic KDML 105 rice cultivation in northern Thailand by life cycle assessment (LCA) to confirm that organic rice cultivation can reduce GHG emissions when compared with conventional rice cultivation it should also be an alternative rice cultivation practice friendly to the environment.

2. Methodology

2.1. Site and rice cultivation

This study estimates GHG emissions from organic rice cultivation in Chiang Mai province, northern Thailand which is an essential production area for high quality rice for domestic consumption and worldwide export. The rice variety is Khao Dawk Mali 105 (KDML 105) which is the commonly grown rice variety in that region. Organic rice farming is performed using only organic fertilizers (no pesticides or chemical fertilizers). This rice variety is planted during the rainy season (July–November) over a period of approximately 120 days. The water regime of rice farming during the cultivation period is continuous flooding and for 180 days preseason before the cultivation period is non-flooding; only a single crop is planted each year.

Data sources of this study include primary data, onsite records and interviews with farmers in 2013, by using data information supplied by Don-Chiang Organic Agricultural Cooperative (DCOAC), Mae-teang district, Chiang Mai province, Thailand and the Office of Agricultural Economics (OAE) of Thailand and secondary data, specifically literature on Thailand by the Ministry of Agriculture and Cooperatives (MOAC).

2.2. System boundaries

The estimation of GHG emissions from rice cultivation follows LCA according to ISO 14040 (ISO, 2006a), ISO 14044 (ISO, 2006b) and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). The system boundaries are “cradle-to-farm gate” including land preparation, rice planting, cultivation and paddy harvesting. In this study, it is assumed that rice has been cultivated for more than 20 years which is commonly the case in the region; hence, GHG emissions from land use change (LUC) were not estimated (IPCC, 2006). GHG emissions from the manufacture of machinery used for rice cultivation have not been considered but those from fuel used during operation are included. The system boundary of the study is shown in Fig. 1.

2.3. Functional unit

The functional unit of this study was 1 kg paddy rice at farm gate. GHG emissions from rice cultivation under consideration are CO_2, CH_4 and N_2O. Each gas was converted into CO_2-eq, using global warming potential (GWP) equivalent factors (CO_2, CH_4 and N_2O have GWP of 1, 25 and 298, respectively) (IPCC, 2007). In addition, emission factors (EF) of GHG emissions were sourced from the Thailand Greenhouse Gas Management Organization (TGO) (TGO, 2014).

2.4. Estimation of GHG emissions from raw material inputs and transport

Rice cultivation uses raw materials such as organic fertilisers (green manure seed, farm yard manure, compost and biofermented juice: made from fermentation process of organism such the plant and animal scraps) as shown in Fig. 2. Fuels (diesel and gasoline) are used for farm machinery and transport of raw materials. GHG emissions from inputs for rice cultivation are calculated through equation (1).

$$GHG_R = A_i \times EFi \tag{1}$$

where GHG_R is amount of GHG emissions from the production of raw materials/other inputs (kg CO_2-eq), A_i is activity data in the unit of raw materials/other inputs used (such as kg, litre and kWh), EF_i is the GHG emission factor for the production of raw materials/other inputs (kg CO_2-eq/unit of input) and i is the type of raw materials/other inputs. The GHG emission factors of raw materials and other inputs relevant to this study are shown in Table 1.

In this study, GHG emission from green manure seed was not considered as it was regarded as offset CO_2 emissions as plants acquire CO_2 from the atmosphere through photosynthesis to produce oxygen and carbon is fixed into the trees accumulating biomass in the form of organic carbon (IISD, 2000). The density of diesel and gasoline were 850.4 and 739.0 kg/m^3 respectively (DEDE, 2004). Green manure (sunn hemp) was planted before land preparation to be incorporated when fully grown into the rice fields for improving soil nutrients. One kg of seeds yields about 450 kg of green manure at full maturity (LDD, 2006). In addition, raw material transportation from the retailer to the field site was included. However, transportation of raw materials from the manufacturer to retailer was not included in the estimation. From the data collection, it was found that 7-tonne trucks were used to transport raw materials. GHG emissions from transport of raw material for rice cultivation practice have been calculated through equation (2) (TGO, 2013).

$$GHG_T = \sum (W_i \cdot D_i \cdot EF_T) \tag{2}$$

where GHG_T is amount of GHG emissions from raw material transport (kg CO_2-eq), W_i is weight of raw material (tonne), D_i is transportation distance (km) and EF_T is emission factor of transportation by 7-tonne truck (0.1402 kg CO_2-eq/t-km).

2.5. Estimation of field emissions

GHG emissions from rice field include direct air emissions of