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Reprint of Alternative cropping systems for greenhouse gases mitigation in rice field: a case study in Phichit province of Thailand

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ABSTRACT

Seeking new practical approaches as alternative ways for greenhouse gas (GHG) mitigation to incentivize farmers' behaviors regarding farming is a challenging point. Thus, five alternative crop rotations (rice, corn, mung bean, soybean and watermelon) under ten alternative cropping systems were investigated. Data were collected using field surveys and structured questionnaires at the same 144 farms (in irrigated and rainfed areas of 72 farms equally) covering two crop years. GHG emissions were evaluated based on the concept of the life cycle assessment of the greenhouse gas emissions (LCA-GHG) of products. Economic analyses of each cropping system were preformed: cost-benefit analysis, net profit and marginal abatement cost (MAC). Results revealed that rice cultivation was the major source of GHG emissions, particularly due to the planting and burning of rice residue stages, while GHG emissions of crop rotation systems were generated mainly from the land preparation stage. On a per area basis, large farms show significantly higher GHG emissions than small and medium farms. Conversely, for per kg of crops produced, small farms generated the highest GHG emissions, compared to the other sizes of farms. This study strongly supports the implementation of a triple cropping system in irrigated areas, which suggests that crop rotations after the first and second rice harvesting with mung bean gained the highest B/C ratio at 1.48; the negative abatement potential was −5.47 ton CO_2eq ha^{-1}, the negative abatement cost was −2378.31 Baht ha^{-1} and the negative MAC was −434.86 Baht ton^{-1} CO_2eq. For rainfed areas, the double cropping system with selecting mung bean is recommended because it is the most profitable as the B/C ratio is 1.52, the negative abatement potential is −7.34 ton CO_2eq ha^{-1}, the negative abatement cost is −2161.11 Baht ha^{-1} and the negative MAC is −294.48 Baht ton^{-1} CO_2eq. Alternative cropping systems with selecting crop rotation not only reduce GHG emissions in the rice field but also increase the benefits to farmers.

1. Introduction

Thailand is an agricultural country. Of the total land area in Thailand, 21.28 million ha or 41% is engaged in the agricultural sector. In this regard, 10.88 million ha or 21% is accounted for by rice fields, and 10.4 million ha or 20% is accounted for by other croplands (maize, sugarcane, cassava, mung bean and soybean) (Singhapreecha, 2014; OAE, 2014). However, rice cultivation is an important emitter of greenhouse gases (GHG) into the atmosphere, especially methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) (Zheng et al., 2000; Xu et al., 2002; Ghosh et al., 2003; IPCC, 2001, 2007). All have the potential to contribute to global warming since their atmospheric concentrations have been increasing. Rice fields are a possible area for reducing emissions through changes in cultivation practices (Cai et al., 2003; Scheehle and Kruger, 2006; Connor and Comas, 2008).

Alternative approaches to crop rotation can greatly increase yield and soil health and sustain efficient farming (Doran et al., 1998; Collins et al., 2000) by decreasing nitrogen fertilizer use, substantially lowering related N_2O emissions (Mosier et al., 1998; Zou and Huang, 2007; Maelinda and Noorlidah, 2008) and allowing the fields to dry out occasionally, which can decrease CH_4 emissions (Smith and Almaraz, 2004; Pattey et al., 2008).

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Meanwhile, today, the climate change situation can severely affect farmers. A shorter period of rainfall means a long period of drought, causing water scarcity. Phichit is one of the provinces where water distribution for farming has been stopped by Thailand's government almost every year because the water level in major dams and reservoirs remains critically low and poses an immediate risk of water shortages. Farmers should refrain from planting a second rice crop. This is a major cause of crop failure, income volatility, liability increase and poverty for farmers. Alternatively, giving farmers the incentive to plant crops that consume less water can be an effective way to solve these problems. However, there is no information available, and there is a lack of research to convince farmers of the economic benefits of introducing a multiple cropping system into rice fields or to convince government agencies of the practical guidelines for GHG mitigation in rice fields. These issues raise the question of which cropping systems are beneficial and efficient for farmers, the environment and society as a whole and which are appropriate under different cropping systems and with limitations in different areas, in particular, for irrigation systems.

It is necessary to implement a joint concept of the life cycle assessment of the greenhouse gas emissions (LCA-GHG) of products whose results serve to pinpoint and improve the practices and conditions behind GHG emissions, along with a cost-benefit analysis to propose an economically worthwhile farm management method that produces a smaller amount of GHG. In Thailand, LCA-GHG has been assessed in various publications in recent years, e.g. for cassava (Nguyen et al., 2007; Moriizumi et al., 2012), palm oil (Silalertruksa et al., 2012; Saswattecha et al., 2015), sugarcane (Yuttitham et al., 2011) and rice (Kasmaprapruet et al., 2009). Unfortunately, no studies have investigated farmers' activities for the whole cropping calendar. No studies have evaluated GHG emissions and farmers' profit from rice production and crop rotation patterns after rice harvesting. Therefore, the aim of this study is to evaluate GHG emissions and farmers' profit from five alternative crop rotations (rice, corn, mung bean, soybean and watermelon) under ten alternative cropping systems.

2. Materials and methods

2.1. Site selection

Multi-stage sampling was employed for this study as follows. Firstly, at the provincial level, purposive sampling was used, focusing on farmers who have grown rice and had dominant types of crop rotation after harvesting rice each year. They voluntarily participated and provided their information and opinions. This method depends on the study's specific objective, what, exactly, needs to be investigated and finding people who can and are willing to provide information (Bernard, 2002). Therefore, Phichit province was chosen as a case study as the topography can be divided into irrigated and rainfed areas. This can reflect drought and flood events unequivocally. Frequently, the areas are far away from the Yom and Nan rivers, which have faced drought events and in which flood events have damaged the nearby areas. Secondly, at the district and sub-district levels, cluster sampling was used to determine two clusters: irrigated areas and rainfed areas, which may have different impacts on GHG emissions (Lee et al., 2015) and farmers' income and benefits (Mushtaq et al., 2015). Moreover, farmers' net household income (calculated by subtracting expenses from total revenue) of each district and sub-district were set as the criterion, based on the assumption that money is what people seek to improve their livelihood and in what convinces farmers to change their behavior. Four districts (Bang Mun Nak, Taphan Hin, Bueng Na Rang and Pho Prathap Chang districts) with the highest net incomes and four other districts (Sam Ngam, Wachira Barami, Wang Sai Phun and Thap Khlo districts) with the lowest net incomes in Phichit province were selected as samples (Fig. 1). Lastly, at the farm level, purposive sampling considering different farm

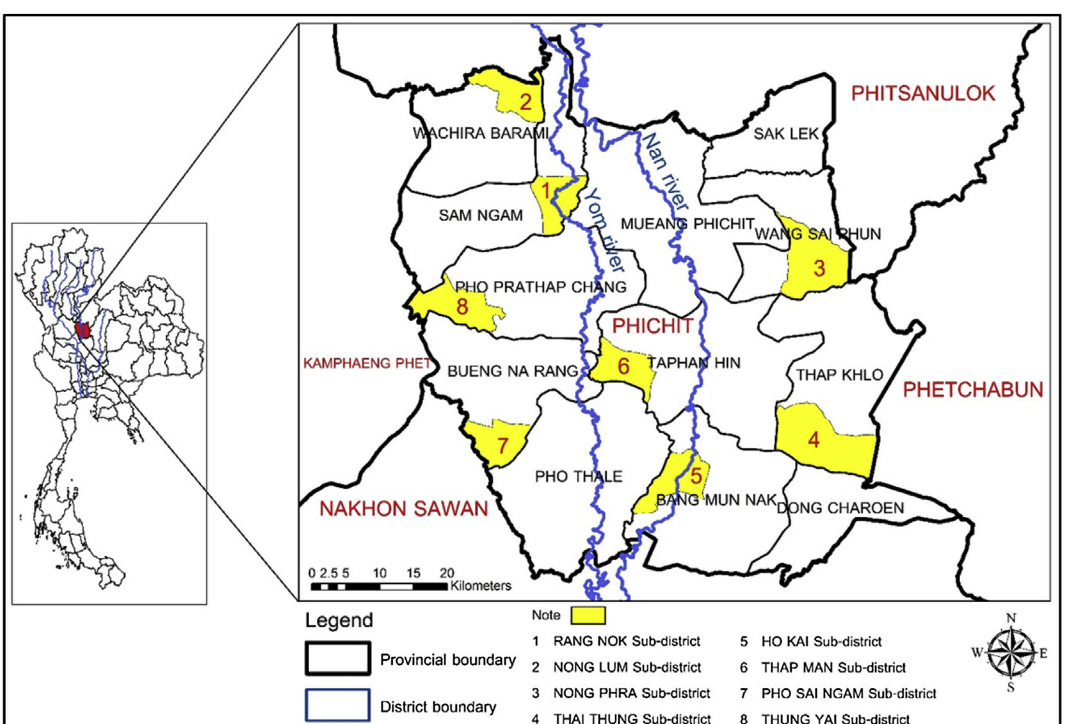

Fig. 1. Study area.