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Energy efficiency, greenhouse gas emissions, and cost of rice straw collection in the mekong river delta of vietnam

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ABSTRACT

Collection is still a major challenge in the supply chain of rice straw to prepare feedstock for further use. Straw needs to be gathered from the field and compressed into bales to make it compact and easy to transport. With the introduction of combine harvesters, the collection of rice straw has become harder and more costly. This created negative impacts on other businesses that use rice straw. Mechanization of rice straw collection was introduced in Vietnam in 2013 and it has rapidly developed since. Most of the rice straw produced in the dry season in the Mekong River Delta (MD) of Vietnam is collected for mushroom and for livestock fodder production or for use as mulching materials. In order to quantify the performance of the mechanical operation of rice straw collection, this study conducted an analysis of energy efficiency, greenhouse gas emission (GHGE), and cost of rice straw collection in the MD for five collection machines that operated on the same field, the same rice variety, and the same harvest time under a demonstration in the MD. With rice straw yield of 4.72 t per ha, the collection machines operated at a capacity of 0.87–2.47 t per hour. This mechanized operation can reduce labor requirement by 90%. Specific weight of baled straw was from 73 to 104 kg per cubic meter, which is heavier by 50–100% than that of loose-form straw, at a moisture content of 12.4 (±1.21)% in wet basis. Total energy consumption, ranging from 351 to 588 MJ per ton of straw collected, accounted for 10–17% of the total energy input using this collected straw for biogas production. Energy consumption from fossil fuels results in GHGE of 60–165 kg CO_2 equivalent per ton of collected straw. The cost of straw collection, which ranged from US$12 to US$18 per ton of straw in the MD, accounted for 10–20% of the total investment cost of biogas or mushroom production. This study illustrated the feasibility of the mechanization of rice straw collection for further processing. Despite the GHGE of this may cause through the consumption of fossil fuels, mechanized rice straw collection creates more benefits such as avoiding in-field burning, producing feedstock for further sustainable processing, and adding value to rice production.

1. Introduction

Rice straw is a by-product of harvesting paddy. After traditional manual harvesting, rice straw is carried out from the field and saved for other uses. However, with farmers' wide adoption and use of combine harvesters that leave the rice straw spread out in the field, gathering them has become a more difficult and tedious task. This has resulted in the increase in the cost of gathering straw which, together with the heavy labor requirement during harvesting season, make manual collection of rice straw unfeasible.

In Vietnam, the total area planted to rice is about 7.5 million ha, with a total yield of 40 million tons (Mt). About 55% of the country's rice production occurs in the Mekong River Delta (MD) (Tran and Dinh, 2014). Correspondingly, about 13 million tons of rice straw from 60% of the rice straw produced in the MD are surplus. They are left to be burned in the field or considered as waste material while most of the remaining 40% is collected for mushroom production, livestock fodder production, or for use as mulching material. In the MD, about 90% of the paddy is harvested by combine harvesters (Nguyen et al., 2013) and the rice straw left spread out in the wet field becomes a main constraint in the their efficient collection.

Because of this, farmers are left with no option but to burn the straw in the field. A case study conducted in 2004 in the cities of Can Tho and Tien Giang (two intensive rice production areas in MD)

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Nomenclature and Units

EE	Energy efficiency
EC	Energy consumption
GHGE	Greenhouse gas emission
MD	Mekong river delta of vietnam
CO_2-eq	Carbon dioxide equivalent
h	Hour
ha	Hectare
kg	Kilogram
L	Liter
m	Meter
% MC	Moisture content in wet basis
t	Ton
VND	Vietnamese dong

showed that 87% of the total rice straw was burned and the remaining had limited uses (Ngo, 2005). Open field burning of rice straw has become the key factor hampering sustainable management in intensive rice systems in Southeast Asia. Aside from causing pollution and reducing the opportunities for value adding, burning brings losses in nutrients such as 80% of nitrogen, 25% of phosphorus, 21% of potassium, and soil organic matter. This also kills beneficial soil insects and microorganisms (Mandal et al., 2004). In addition, rice straw burned in the field increases the emission of greenhouse gases (GHGs), such as methane (CH_4), at a rate of 1.2–2.2 g per kg dry straw (Kadam et al., 2000; Yevich and Logan, 2003). Other researches, on the other hand, showed that partial removal of rice straw from the field does not significantly affect grain yield (Buresh et al., 2008; Bijay-Singh et al., 2008; Thuy et al., 2008). Off-field rice straw could be used for non-energy purposes such as biochar, fertilizer, mushroom production, animal bedding, fodder, and the conversion of energy into fuel, heat, or electricity.

The mechanization of rice straw collection was introduced in Vietnam in 2013 and has rapidly developed since then. Now, farmers are using rice straw more productively. However, there is limited information on the techno-economic aspect of rice straw collection machines. This study conducted an analysis of energy consumption (EC), greenhouse gas emissions (GHGE), and cost of rice straw collection in the MD of Vietnam. It resulted in profiles of the researched factors (EC, GHGE, and cost) of this practice in the context of using off-field straw for further processing, such as biogas and mushroom production, considered within the research.

2. Materials and methods

2.1. Scope and function unit

The study was done with its in-situ measurements conducted during a demonstration of rice straw collection machines at the Cuu Long Rice Research Institute, Can Tho City, Vietnam in the dry season of 2016. Profiles of EC, GHGE, and cost of straw collection were identified in the context of using off-field straw for further processing. Fig. 1 shows the system boundary of this research. Rice straw is collected and transported to the side of the field by the collection machines. EC and cost accounted for (a) direct energy, which includes the fuel consumption of the collection and handling machines and the manpower for driving and handling; and (b) indirect energy obtained from the production and maintenance of the machines. GHGE was calculated indirectly based on EC.

The collection machines used in the research included: (1) a roller baler pulled by a tractor, which gathers the straw in a bale

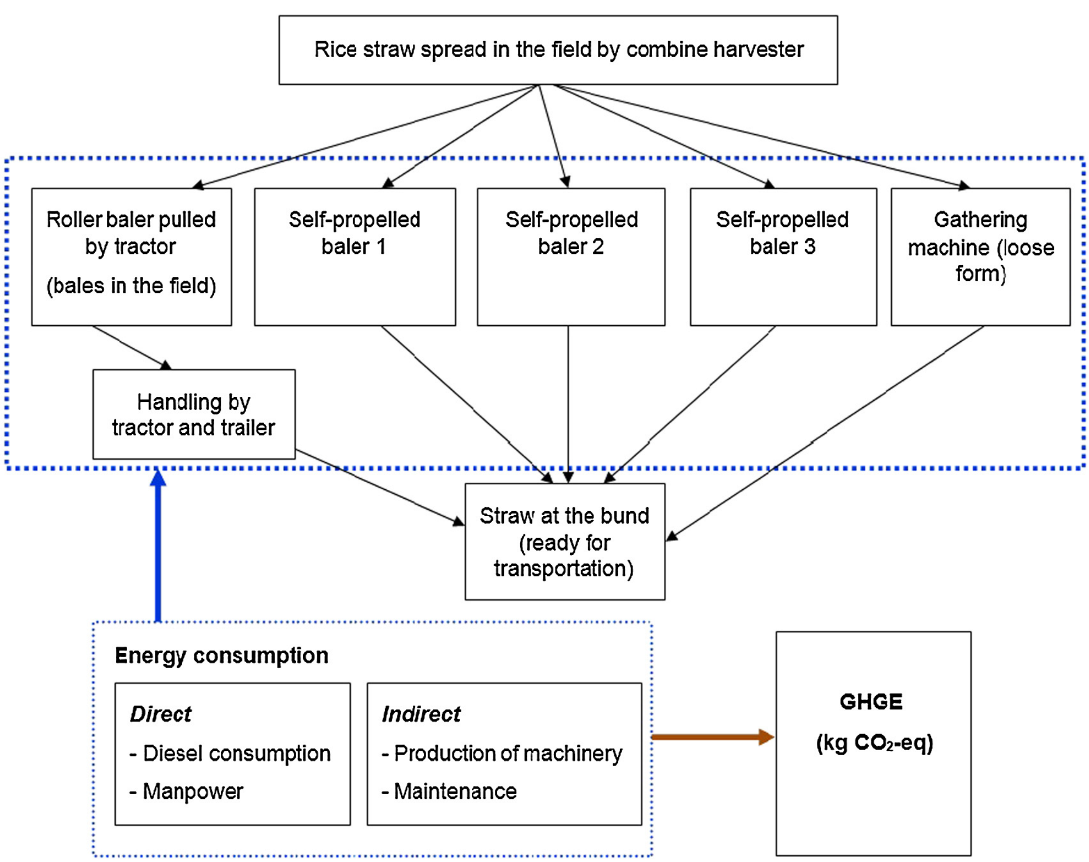

Fig. 1. System boundary of the research.