

Technical, Economic and Environmental Evaluation on Mechanical Rice Straw Gathering Method

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Abstract: Rice straw is a rice by-product, which is currently mostly wasted in Vietnam, in particular in the Mekong delta. At present, the cost of straw gathering is increasing because of the increased use of combine harvesters. High labor cost and lack of labor makes manual collection unfeasible. Farmers therefore often just burn it, which causes pollution, increased greenhouse gas emissions and loss of opportunities to value add. An economic and environmental evaluation and technical field testing of a straw baler with 4 ha/day capacity was therefore conducted in Long An province. During the field testing data on the gathering capacity, fuel consumption, labor requirement and other cost items were collected. The test results showed that the baling cost is US\$19.0 per ton of rice straw, the pay-back period of 2.1 years and the internal rate of return of 38%. In addition to the baling cost, the transportation cost varies from US\$24 for a distance of 100 km to US\$32 for 150 km. The benefits of the machine are not only economical but also include the reduction of field burning.

Key words: Rice straw gathering, technical and economic evaluation, environmental benefits.

1. Introduction

Vietnam is one of the major rice producers with around 44.1 million tons of paddy harvested annually [1]. With the rate of straw per paddy yield of 0.9-1.1, a big amount of straw has been left in the field after harvesting [2, 3]. Combine harvester has been rapidly developed from 2007 in Mekong Delta and Vietnam. With the use of combine harvester, rice straw is spread throughout the field. Thus, collecting of straw has become more difficult and costly. In addition, shortage of labor during harvesting season usually causes higher gathering cost.

At present, rice straw is mainly burnt in open field in Mekong Delta, except in some provinces (such as Long An, Ben Tre, An Giang, etc.) where rice straw is collected to be used as animal feed, soil cover in dragon fruit cultivation, mushroom production, biogas production, etc.. When amount of rice straw from one hectare is burnt, about five tons of carbon dioxide is

emitted into the environment. It is estimated that burning rice straw in Vietnam emits about 23 Mt of CO₂, 24 Mt of CH₄, 68 Mt of CO annually if 50% of rice straw is burnt in the field [4].

With the need for reducing labor cost and increasing capacity in straw collection, market on rice straw baler has been developed in Vietnam since 2009 with both locally made and imported machines [5]. Local straw baler manufacturers include Z755 company, Phan Tan agricultural machinery company with self-propelled type, other institutions with their own research and design.

Based on initial testing and observation, each type of baler has their own advantages together with disadvantages.

Thus, a research on technical, economic, and environmental evaluation on mechanical straw gathering method is necessary. It is a basis to determine the feasibility and benefits of using straw baler.

This study was conducted with these objectives:

(1) Evaluate feasibility of straw baler application in Vietnam;

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- (2) Analyse economics of using baler;
- (3) Evaluate the impacts of baler application on environment and society.

2. Materials and Methods

The study was conducted with data gathering from secondary data sources and field tests for locally made and imported rice straw balers.

Survey on status on rice straw gathering: manual and mechanical, labor cost, straw price, use of rice straw, type of using straw baler and local demand on straw use.

Field tests were conducted in Can Tho province at (1) Vinh Thanh district and Long An province with two sites, (2) Tan An city in 2014 and (3) Vinh Hung district, Long An province in 2015.

2.1 Straw Balers Used

Kinds of straw balers used during the test include a baler made by Z755 company—a Hi-Star baler made in China with Japanese technology (Fig. 1) and a Hi-Star baler made in Japan. Specification of these machines was shown in Table 1. However, in this study, it was not a purpose to compare the three balers.

Depending on actual condition at each site, testing area is from 0.5 ha to 1 ha. One test was conducted with 1 ha size field in Vinh Hung district, Long An province and other two with 0.5 ha size field in Tan An city, Long An and Vinh Thanh district, Can Tho city.

Parameters monitored during the test were gathering capacity, specific fuel consumption, cutting height, straw yield and moisture content of straw.

- Actual working capacity of a baler was determined based on measured actual field area per

working time. In addition, speed of the machine working on the field was also determined. It is also basis for comparison of actual working and computed working capacity in the field.

- Fuel consumption was determined by measuring the level of fuel in a tank before and after operating.
- Cutting height of stubble after harvesting was randomly measured at different 15 points throughout the field.
- Straw yield was determined based on number of straw bale and weight of each bale. Straw yield corresponding to the different cutting heights was determined in one field with same variety, same paddy yield and same harvesting time.

2.2 Instruments Used

To gather data, instruments used during the tests include:

- Oven (Fig. 2) used for drying straw and paddy samples;
- Digital scale (Fig. 3) with accuracy of 0.01 g used for scaling sample of straw and paddy before and after drying;
- Common scale with accuracy of 0.2 kg used for scaling straw bale and fuel;
- Rulers used for measuring cutting height of stubble and field test area.



Fig. 1 Rice straw baler.

Table 1 Specifications of some straw balers used in this study.

Specifications	Z755 (made in Vietnam)	Hi-Star (type No.1)	Hi-Star (type No.2)
Designed capacity (ha/hr.)	0.5	0.5	0.5
Power of tractor (HP)	40	40	40
Dimension of straw baler (mm) (Dia. × Length)	450 × 700	500 × 700	500 × 700
Twine threading system	Mechanical	Mechanical	Electro-mechanical



Fig. 2 Drying oven.



Fig. 3 Digital scale.

3. Results and Discussion

The study showed both survey result on manual gathering and field test result of straw balers which is popularly used in Vietnam. Based on these results, this study profiled benefits of application of mechanization on straw collection.

3.1 Straw Yield

The straw yield depends on variety of paddy, paddy yield and cutting height of stubble. In this study, straw yield and paddy yield was presented as ratio. With the cutting height of combine harvester of 30.5 cm, rice straw yield is 2.8 ton/ha. Compared to rice yield of 5.4 ton/ha, the ratio between rice straw collected and rice yield is 0.52. Meanwhile, the straw yield is 4.5 ton/ha with the cutting height of 14.5 cm, corresponding to ratio between straw and rice yield of 0.84. Although the straw yield is higher, the cost of harvesting also increased. Comparison of straw yield and fuel cost between two cutting heights at one field with same variety, same paddy yield was shown in Table 2.

Table 2 Comparison of straw yield and costs with different cutting height.

Parameter	30.5 cm cutting height (farmers' practice)	14.5 cm cutting height (for testing)
Paddy yield (ton/ha)	5.4	5.4
Straw yield (ton/ha)	2.8	4.5
Straw yield ratio	0.52	0.84
Fuel cost (US\$/ha)	10.0	16.7

3.2 Manual Straw Gathering

Before combine harvesting was used, farmers had collected all straw and paddy and piled at the middle of the field. After threshing, straw was piled. It makes easier to collect and handle straw. This study focused on economic analysis of straw gathering manually.

The result of analysis showed that the cost of manual straw gathering is US\$50/ton. It includes costs of manually gathering and transportation using tractor couple with a trailer. Capacity of straw manually gathering is 4-man-days/ha to transport straw from the field to the point at 1 km away [6]. The cost of labor is increasing because of lack of labor during harvesting time. It varies from US\$80 to US\$120 per working day, depending on cropping season.

3.3 Straw Mechanical Gathering

With application of mechanization, stages of straw collection were presented.

3.3.1 Harvesting

With a rapid increase in number of combine harvester in recent years (estimated 11,000 units, 2014), percentage of rice field harvested using combine harvester is about 80% in Mekong delta. Especially, this ratio is up to 90%-95% in some provinces such as An Giang, Kien Giang, Can Tho, etc.. The cutting height of combine harvester is common at 30 cm. When farmers need to gather straw, they request to harvest with lower cutting height of 20-25 cm. At some districts in Long An province with the need of using straw, farmers usually request to harvest with the cutting height as low as possible (20 cm). Based on survey data, the common cost of

harvesting is now from US\$60/ha to US\$70/ha in Mekong delta.

However, in some other provinces in the northern and central Vietnam, manually harvesting is still remained because straw is consumed on place. For example, to have straw for their cows, farmers in Quang Ngai province with small field harvest their rice manually with very low cutting height. It is similar to status of harvesting in Ben Tre province where farmers' rice field size is small, less than 0.5 ha. It needs about 10-12 man days for manual harvesting of 1 ha, corresponding to the cost of US\$90-US\$130/ha.

3.3.2 Field Sun Drying

Rice after harvesting, straw is fresh with moisture content from 50% to 60%. Thus, when rice straw is stored and used as animal feed, it must be dried before baling. Straw is usually sun dried about two days in open field after harvesting. Dried straw with moisture content from 11% to 12% is suitable for baling. In addition, drying straw before baling also facilitates for some kind of balers to work well in the field.

3.3.3 Baling

A baler was tested at the field to determine working capacity, specific fuel consumption, etc. (Fig. 4). Popular straw balers used in Vietnam have a capacity of 4 ha/day, corresponding to 0.5 ha/hr.. Time for baling is from 55 seconds to 60 seconds, including gathering time and twine threading time. The balers are mounted with a 40 HP tractor. Fuel consumption for straw baling is 5.8 liter/ha. With the cost of fuel and straw yield, the fuel cost for straw collection is US\$1.7/ton.

Thus, the cost of baling is US\$19/ton, including fuel cost, labor (tractor driver) cost, jute twine cost, etc.. Two types of jute twine used for baler are from locally made or imported mostly from Bangladesh. The cost of jute twine for baling is about US\$3.2/ton.

In case, farmer would like to collect straw from their own field, they can also request for a service with baler. The cost of baling service is US\$0.3/bale,



Fig. 4 Testing of baler in the field.



Fig. 5 Straw bale handling.

corresponding to US\$25.6 per ton of straw (in Long An province, updated in 2015).

3.3.4 Handling

Straw bales are usually handled to a trailer which is mounted with a tractor and gather at the point near the field. Required labour is from 3 to 4 people to handle all straw bales from a baler. It means the manually handling capacity of 3-4 persons is the same as capacity of the baler of 4 ha/day. Cost of handling straw bale on and off the trail is US\$12.8/ton. A common used trailer with dimension of 4-meter length, 2.2-meter width, and 3-meter height can carry 200 bales (Fig. 5).

3.3.5 Transporting

Straw bale is usually transported from the point nearby field to the market of storage places with different distances. With a distance of 100 km from Vinh Hung district to Tan An city, straw bale is transported by a 10-ton truck which contain 400 bales. The cost is computed at US\$24.0/ton.

With longer distance, straw bale is usually transported from Long An province to Ben Tre province by boat with a traveling time about 2.5 days. A boat can carries from 900 bales to 1,100 bales with

a cost of US\$434 for transportation with a distance of 150 km. Thus, the cost of transporting for 150 km is US\$32.0/ton. In some other cases, straw is purchased as far as 100 km away and delivered within 50 km, the travel might take 14 hours. The cost of transportation of 20-ton straw by boat was US\$20/ton, which applies for a total transportation distance between 30 km and 100 km.

In short word, straw after baling is transported to the market by truck with the distance about 50 km, by boat with longer distance about 100 km or more. The average cost of straw bale transportation is US\$0.3/ton/km.

3.3.6 Marketing

Based on survey data, straw bale is usually used for soil cover of fruit crops (dragon fruit tree) in Long An province. Meanwhile, it is mainly used as animal feed in Ben Tre province where there is limited straw potential. Due to high cost of transportation, price of 1 bale is from US\$1.1 to US\$1.3, corresponding to US\$87.9/ton. Straw is usually stored for about 6 months for use during fallow and growing periods.

3.4 Economic Analysis

Economic benefits of investment in straw baler was analysed with the two parameters: pay-back period and internal rate of return. Basic data for computation these factors includes investment cost, operating cost, operating time per year, etc. (Fig. 6).

With the cost of Hi-star baler of US\$8,500, baling cost of US\$19.0/ton, assumed number of working day per year of 40 days (based on survey data), the pay-back period is 2.1 years and Internal Rate of Return (IRR) is 38%. Because the IRR is high, the investment on this machine is good and accepted by farmers.

For rice farmers, they could have additional income from sale of straw at the field. The price varies from US\$13/ha to US\$52.2/ha with different cropping seasons and places. For example, in Vinh Hung, Long

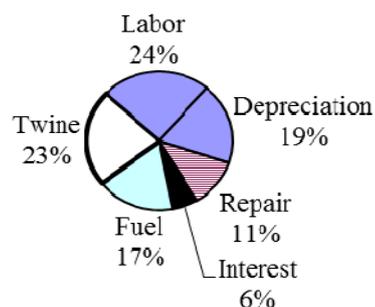


Fig. 6 Components of baling cost.

An, farmer sold the straw field with a low price of US\$13.0/ha in wet season. Meanwhile, it is much higher in dry season and in other provinces, such as Quang Ngai and Ben Tre where straw is used as animal feed.

3.5 Technical Feasibility Assessment

Locally made baler was designed and fabricated by Z755 company, which has lower price (US\$4,800) compared to others. However, it still has some problems during working at the field such as stuck with wet straw and twine broken. In addition, due to very complex operating principle of the baler, some parts of the machine have low level of durability. Meanwhile, time during harvesting season is short and valuable. In case in Mekong delta, the machine could work about 30 days/crop and from 2-3 crops per year depending on place to place.

The Hi-star baler made in China with Japanese technology with a little higher price of US\$5,900 could work well with both dried and wet straw in the field. Farmers have high appreciation on this type of machine because the acceptable cost and durability on working at the field.

The Hi-star made in Japan with an electromechanical twine threading system has a price of US\$8,500, which could work well with dried straw and easier in operation. With this function, the straw bale is threaded with twine and released at the outlet automatically. In addition, this machine could be matched with simple tractor because it has a separated hydraulic system.



Fig. 7 Burning of straw in the open field.

3.6 Environmental Impact

With percentage of C in straw of 41% [7], and based on combustion equation, burning 1 ton of straw will emit 1.2 tons of CO₂. With straw yield of 2.8 ton/ha, amount of CO₂ emission reduction is 3.4 ton/ha when straw is collected and used. When products from straw are replaced for fossil fuel in industry, 1 ton of straw will reduce 0.8 ton of CO₂ emission (Fig. 7).

With annual rice production of 44.1 million tons in Vietnam and assumption of cost for sale 1 ton CO₂ (CDM) of US\$7, it can be saved around US\$160 million/year [8].

4. Conclusions

For technical feasibility, each type of baler has its own advantages and disadvantages. The most commonly used balers are Hi-star which was made with Japanese technology. This type of baler with high durability could work well with both dried and wet straw for diversified purposes.

With the application of mechanical straw gathering method, collection cost is much reduced from US\$50/ton for manually collection and US\$19/ton for collection using the baler. With the right business models, farmers could have additional income from sale of straw from the field. Using balers, the dependence on labor force for straw collection during harvesting time is reduced.

Aside from economic benefit, application of mechanization in straw collection contributes to reduce GHG emission from reduce amount of rice

straw burnt in open field. When fossil fuel is replaced by products from straw in heating supply in industry, it could also contribute to reduce amount of CO₂ emission.

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