Alternative solutions of rice straw open burning in An Giang province

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Abstract

An Giang has a rice output of over 4 million tons/year, ranking first in the country, thus generating a very large amount of straw. However, people still have the habit of burning straw after harvest, causing environmental pollution. Currently, a number of straw reuse models have been applied to replace open burning to improve economic efficiency and reduce environmental pollution. The current paper describes the results of pilot studies of 07 mushroom cultivation, 15 treatment of straw with urea for fodder production, and 14 composting farms. The main research methods applied include experimental implementation on a household scale, straw collected from fields, chemicals (i.e. lime, formaldehyde, urea etc.) and microbial products (Trichoderma) is purchased on the market; economic efficiency assessment is based on statistical analysis of actual measurement data; assessement of the greenhouse gas emissions based on the Decision 2626/QD-BTNMT. The study results shown that all models had a return on investment value close to or less than 1 year and the benefit-cost-ratio as low as 38%. This is very important for the farmers as they do not have much capital to invest.

Keywords: *Open burning, mushroom cultivation, fodder production, composting.*

JEL Classification: *F64, O13, Q53.*

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1. INTRODUCTION

An Giang Province is located in the Mekong River Delta. The province has abundant freshwater resources, which favours the development of agriculture. Crop fields occupy some 250 thousand hectares, which is 70% of the total area of the province. Over 4 million tons of rice are produced in An Giang every year, which is more than in any other provinces of Vietnam. Rice straw is the by-product of rice cultivation. Producing 1 ton of rice usually results in producing 1-1.5 tons of straw. So the total amount of straw produced in An Giang every year could be up to 6 million tons. Presently most of the rice straw is burned in the fields, which creates pollution problems, decreases soil fertility. Farmers burn the straw because for them it saves labour in preparing the fields for the next season and this way they burn some pests.

In 2023, the price for a roll of straw was 37,000 VND/roll. At times the price may reach 50,000 VND/roll including the transport fee. The main problem for the straw collection is the cost of the straw rolling machine, which is about 350 million VND. But it is still about 20% cheaper to rent such machines than hire labour going to do it manually. Farmers usually rent the straw collection machines for 6,000-8,000 VND per roll (or 0.9 to 1.2 million VND per ha) if there is local demand for the straw. If there is no demand, the farmers burn the straw in the field. Therefore, as long as there is enough demand in the market for the straw the farmers would rather sell it than burn it.

In recent times, there have been many research projects related to alternatives to open burning: mushroom cultivation, treatment of straw with urea for fodder production, and - composting [01-03]. However, there is a lack of research evaluating the economic efficiency and greenhouse gas emission reduction effectiveness of these models. Therefore, this research is necessary.

2. METHODOLOGY

2.1. Mushroom growing

Straw preparation for mushroom planting

Clean straw that does not have any mould must be washed with plenty of water and left for 5-7 days. The properly prepared straw should not have any sour smell and must have a dark yellow colour and moisture level of 70-75%. Otherwise, the edible mushrooms will not grow.

The prepared straw is mixed with cotton fibre. The added amount of cotton fibre is about 10% of the weight of the straw. The cotton fibre is prepared by dipping in lime water with pH=12. As it was found in prior research the addition of the cotton fibre increases the speed of the mushroom growth and the duration of production [01]. On a substrate with cotton fibre mushrooms could be harvested in 9 days, while without cotton fibre the mushrooms are harvested in 13 days. The duration of the harvest season increases from 15 days to 24 days.

The building for mushroom growing

In order for the building to grow mushrooms to keep moisture, it is necessary to insulate its inner walls and roof with foam panels and blue plastic. The room should be dark and have a concrete floor. The prior research indicated that increased moisture may double the mushroom yield.

For the purposes of ventilation, there should be a gap of 5-10 cm between the roof and the walls. Additional ventilation holes or windows could be made. Without proper ventilation, the lack of oxygen could ruin 40-100% of the mushroom harvest.

The ideal temperature for growing mushrooms is 35-39^{0}C according to Nguyen Lan Dung (2010) [01]. When the mushrooms are about to sprout, it is necessary to ventilate the room 3-4 times a day for 10-30 minutes.

The columns of mushroom straw substrate are installed on the concrete floor in a square formation about 1.2m apart from one another. The columns are installed on foundations made from PVC pipes and zinc poles. PVC pipes are placed 10cm deep into the concrete floor, leaving 5cm above the floor. Then the 1.5m long 21mm in diameter zinc poles are installed. The detachable zinc poles can hold the weight of the 50kg mushroom column and can be easily removed when it is necessary to replace the straw substrate. The zinc poles are usually dried in the sun to kill any unwanted bacteria before placing the straw substrate.

After each mushroom harvesting season, it is necessary to disinfect the building to ensure that no diseases are passed to the next season. The building is washed with water and soap (0.1kg/m^2), then the cement floor is treated with oil paste (0.7kg/m^2), then the room is sprayed with formaldehyde solution (1L of formaldehyde per 30L of water) and sealed for 12 hours. This procedure reduces the risk of diseases by 80%.

Economic efficiency assessment is based on statistical analysis of the actual measurement data presented in tables 1 and 2. Assessement of greenhouse gas emissions is based on the Decision 2626/QD-BTNMT [04].

2.2. Treat straw with urea for animal feed

The straw normally has a lower nutritional value than grass. The treatment of the straw with urea increases the protein content and makes it better for the digestion of cows.

Urea, also called carbamide (because it is a diamide of carbonic acid), is an organic compound with the chemical formula $CO(NH_2)_2$. Urea serves an important role in the metabolism of nitrogen-containing compounds by animals and is used as a component of animal feed, providing a relatively cheap source of nitrogen to promote growth.

The animal feed preparation in the study was based on Nguyen Van Bac's research (National Agricultural Promotion Centre) [02] in which 100kg of dry straw was mixed with 4kg of urea and 80-100L of fresh water. If the straw is fresh, then only 60-70L of water is added. This mix is kept in a plastic bag for 7-10 days but could stay in the plastic bag ready to use for up to 6 months.

After 7-10 days, the mixed straw can be fed to the cows. At first about 1-2 kg are given to each cow in mix with other foods, in order to get the cows used to this new type of feed. Then the amount of straw is increased every day by up to 7-10kg.

Economic efficiency assessment is based on statistical analysis of actual measurement data presented in table 3. Assessement of the greenhouse gas emissions is based on the Decision 2626/QD-BTNMT [04].

2.3. Composting straw to produce organic fertiliser

The straw, including the spent straw from mushroom growing, can be composted and turned into organic fertiliser. The fungi used in this study is the commercial version of the Trichoderma genus, which has over 90 species and is found in most types of soil. The fungi grow at optimal temperatures of 25^{o}C to 30^{o}C, which is suitable for An Giang climate. Trichoderma is a good option for the composting process it has the capacity to degrade cellulose and suppress other fungi that infect plants and cause diseases.

An equivalent of 20 rolls of straw, about 500kg of spent straw from growing mushrooms are mixed with 100kg of manure and 100kg of rice husk ash or coconut fibre. The 3kg of Trichoderma is added to the mixture. The proportions were determined and based on prior research.

It is important to mix the compost pile every 15 days. The spent straw from mushroom growing could be ready as fertiliser in 30 days.

Economic efficiency assessment is based on on statistical analysis of actual measurement data presented in table 4. Assessement of the greenhouse gas emissions is based on the Decision 2626/QD-BTNMT [04].

3. RESULTS AND DISCUSSION

3.1. Mushroom growing

Seven households that grow mushrooms in Chau Thanh District, An Giang Province under the project research team's supervision were observed. One household grew mushrooms the traditional way (Control), and the other six used the indoor mushroom column method developed by the research team. Five of them were started and funded by the study in March 2023. The other one was a previously established bigger operation with 8 mushroom growing locations sites 30 m^2 each. The details of each case study are summarised in Table 1.

The summary statistics of the survey results are provided in Table 2. All farms that used the project model clearly required much less straw than the traditional model (90% less) and used less space (80-90% less). The amounts of capital investments are similar, but better disease control allows having more harvests each year.

The profit per harvest is similar for control and the new method farms. But since the new method allows having more harvests each year at a lower cost it brings much more money and pays off faster. The Return on Investment (ROI) and the Benefit-

Table 1: Revenue and cost of the control and the 6 case-studies

Items	Unit	Control	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
Site area	m^2	300	60	60	40	30x8	26	35x2
Amount of straw used for each harvest	Rolls/kg	500/ 10,000	40/ 800	50/ 1,000	50/ 1,000	40x8/ 6,400	30/ 600	30x2/ 1,200
Capital investment of 1st year	million VND	30	12	50	N/A	232	15	35
Number of harvests per each year	-	2	3	2	5	5	6	5
Cost per harvest per year	million VND	15/30	4/12	9 /18	6.2/31	2.6x8/ 13x8	2.5/15	7.7/38.5
Profit for each harvest per year	million VND	6 /12	7/21	12/24	6/30	3.6x8 /18x8	3/18	9.6/48

Note:
Control: Vinh Hoa B Hamlet, Can Dang Commune
Farm 1: Farm 6: Vinh Quoi Hamlet, Vinh An Commune
Farm 2: Phuoc Thanh Village, Vinh Binh Town
Farm 3: Tan Thanh Hamlet, Vinh Thanh Commune
Farm 4: Thanh Hung Hamlet, Binh Thanh Commune
Farm 5: Vinh Phuc Hamlet, Vinh Hanh Commune

Table 2: Revenues and costs of the control and the 6 farms

No	Item	Unit	Control	Average (Range)
1	Site area	m^2	300	47.7 ± 18.1 (26 to 70)
2	Amount of straw used for each harvest	Rolls/kg	500/ 10,000	45.0 ± 10.5 (30 to 60) 900±210 (600 to 1,200)
3	Initial investment	million VND	30	28.2 ± 15.5 (12 to 50)
4	Number of harvests per year	Batches	2	3.3 ± 1.5 (2 to 6)
5	Cost per harvest	million VND	15	5.3 ± 2.7 (2.5 to 9)
6	Profit per harvest	million VND	6	6.9 ± 3.5 (3 to 12)
7	Profit per year	million VND	12	26.5 ± 11.4 (18 to 48)
8	Annual Return on Investment (ROI)	%	40	108 ± 53 (48 to 175)
9	Return on investment	Years	2.5	1.2 ± 0.7 (0.6 to 2.1)
10	Benefit-Cost Ratio (BCR)	%	40	131 ± 26 (97 to 175)

Cost Ratio (BCR) are much higher for the new method farms. The higher BCR gives the growers room to better manage the fluctuations in the process for straw and mushrooms. The farmers will still make money in cases if the prices for mushrooms drop and/or the prices for straw increase.

The analysis of the costs and benefits of the studied model of mushroom growing is complicated because of big individual differences between farmers and their households. That depends on the initiative and attitude of the farmers and their families. It is also hard to assess the exact labour costs because it is difficult to quantify the inputs of senior people and children. Still, the study results showed significant financial advantages of the studied mushroom growing model, which should provide an incentive for the farmers in An Giang Province to adopt it.

The project conducted a survey participated by 30 local farmers in 4 communes (An Hoa, Hoa Binh Thanh, Vinh Binh, and Can Dang). According to the survey, 16 out of 30 farmers expressed interest in trying the proposed mushroom-growing model (53%). Ten farmers requested technical support and inquired about possible financial support for the initial investment (33%).

3.2. Straw treatment with urea

The 14 farmers who participated in the study indicated that the main benefit of feeding the straw treated to urea to cows is that it saves time and labour required to find and deliver fresh grass. The straw treated with urea is cheaper than the grass and has a higher nutritional value. It is accepted that the nutrition value of 1 kg of treated straw is equivalent to 2.0 kg of fresh glass [03].

It was calculated that it costs 2.13 million VND to produce 800kg of treated straw. The cost per kg is 2,663 VND. The cost of fresh grass (based on labour cost of 200,000 VND per day and harvest of roughly 30-70kg a day depending on the season) is 2,857-6,667 VND/kg. Figure 1 shows the comparison of the costs of urea-treated straw versus fresh glass.

The straw treatment pilot study was initially conducted in 10 farms in Vinh Loi Hamlet (Vinh Nhuan Commune), Hoa Loi 2, Hoa Loi 4 Hamlets (Vinh Loi Commune), Hoa Phu 2 Hamlet (An Chau Town), Binh

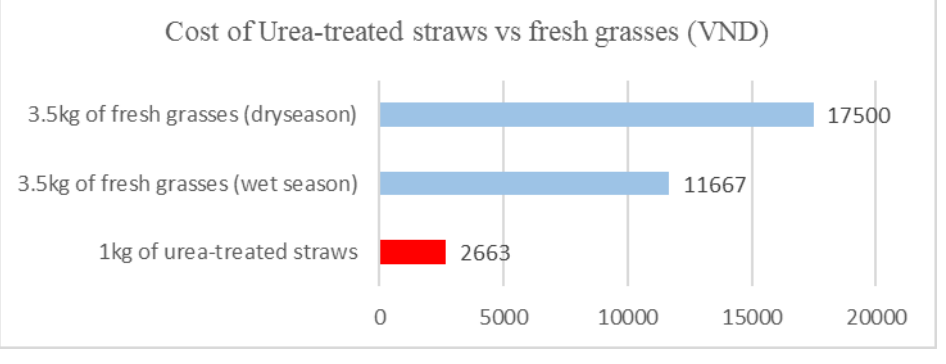
Table 3. Summary statistics of the straw treatment with urea for fodder preparation in 14 pilot farms

No	Item	Unit	Average (Range)
1	Site area	m^2	15.5 ± 3.8 (10 to 24)
2	Amount of straw used for each batch	Rolls/kg	18.1 ± 14.5 (8 to 60) 362±290 (160 to 1,200)
3	Initial investment	millions VND	9.6 ± 5.8 (3 to 20)
4	Number of batches per year	Batches	8.4 ± 5.6 (3 to 20)
5	Cost per each batch	millions VND	1.4 ± 0.4 (0.5 to 2.0)
6	Profit per each batch (estimated saved labour time)	millions VND	4.7
7	Profit per year (estimated)	millions VND	39.7
8	Annual Return of Investment (ROI) (estimated)	%	365
9	Return of investment (estimated)	Year	0.3
10	Benefit-cost ratio (BCR) (estimated)	%	338

An 1 Hamlet (An Hoa Commune), An Phu Hamlet (An Hoa Commune), and Vinh Phu Hamlet (Vinh An Commune). Four more farms were included in the study since March 2023. Table 3 shows the summary statistics of the collected data.

The calculations of profits, ROI and BCR in this study are based on the estimate of saved labour, which otherwise would have been spent on cutting and delivering grass.

The research team has surveyed 30 local farmers in 4 communes (An Hoa, Hoa Binh Thanh, Vinh



▲ *Figure 1: Cost of urea-treated straw versus fresh glasses*

Binh, Can Dang). Nine out of 30 (equivalent to 30% of them) expressed interest in the straw treatment model and 5 of them asked to consider them for providing technical support and some financial support.

3.3. Composting straw to produce organic fertiliser

The conducted study indicated that composting straw may increase farmer's income and could be done during between crop cycles.

The study was conducted in 15 farms in Vinh Hoa A, B Hamlets (Can Dang Commune), Hoa Phu 2, Hoa Long 3 Hamlets (An Chau Commune), An Phu Hamlet (An Hoa Commune), Vinh Phuc

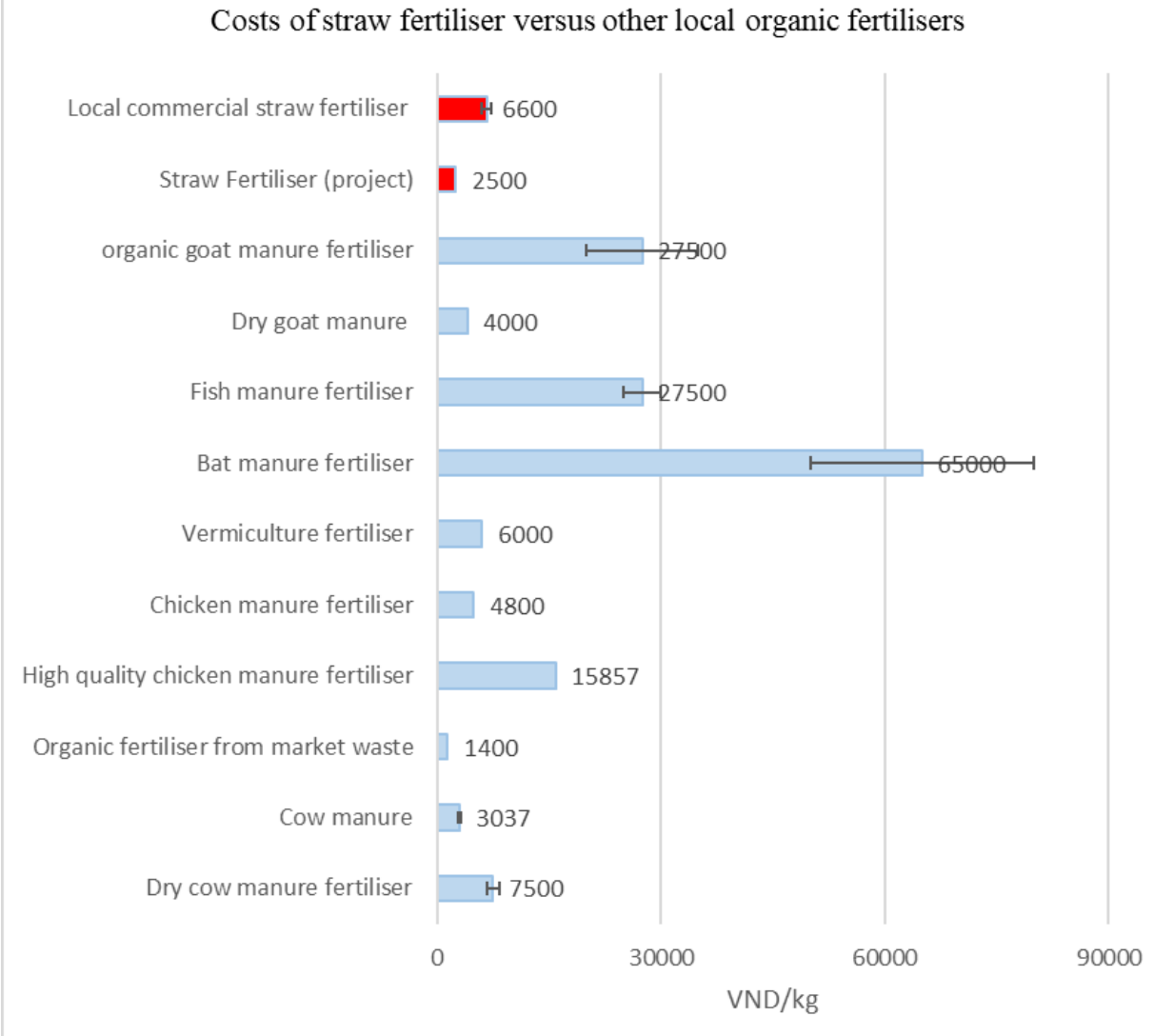
Note:

(*) One farm used 600kg of loose straw, and another used 200 rolls of spent straw from mushroom growing.

(**) Four farms didn't sell the compost but used it for their gardens.

Table 4. Summary statistics of the straw composting in 15 pilot farms

	Items	Unit	Average (Range)
1	Site area	m^2	11.4 ± 4.2 (7 to 20)
2	Amount of straw used for each batch	Rolls/kg	38.1 ± 14.9 (20 to 80) (*) 762 ± 298 (400 to 1,600) (*)
3	Initial investment	millions VND	4.6 ± 2.0 (2 to 10)
4	Number of batches each year	Batches	2.3 ± 1.0 (1 to 4)
5	Cost per batch	millions VND	3.3 ± 2.1 (1.5 to 10.0)
6	Profit per batch	millions VND	5.3 ± 3.1 (3.1 to 14.0) (**)
7	Profit per year	millions VND	8.7 ± 2.5 (5 to 14)
8	Annual Return of Investment (ROI)	%	219 ± 84 (140 to 320)



▲ *Figure 2: Cost of the straw fertiliser versus the prices for other commercial organic fertilisers*

Hamlet (Vinh Hanh Commune), Vinh Phu Hamlet (Vinh An Commune), Vinh Thuan, Vinh Loi, Vinh Hoa Hamlets (Vinh Nhuan District), Hoa Loi 2,3 Hamlets (Vinh Loi Commune).

The studied straw composting model showed high values of ROI and low initial investment costs. At the same time, the Benefit-Cost Ratio does not include the farmer's labour and the costs of the area used for composting. Often the composting process is set up right within farmers' residences. The compost product is not uniform in quality and not as easy to store as commercial fertiliser. It leads to the conclusion that overall, the process of straw composting provides additional income opportunities for farmers, but also has some issues that may prevent its wide adoption.

Figure 2 below shows the comparison between the costs of the produced composted straw fertiliser (2000-kg batch of straw) versus other local fertilisers. As Figure 2 shows the cost of making compost fertiliser from straw is much lower than all other available organic fertilisers.

The research team has surveyed 30 local farmers and 15 of them expressed interest in the straw composting model. Five farmers were asked to consider them for providing technical support and some financial support.

3.4. CO_2 emissions of each model versus open burning

Based on greenhouse gas emission factors [04], the CO_2 emissions included estimates of CO_2 generated from straw transportation for 10 km on average from the field are calculated. Table 5 below shows the CO_2 emissions from transportation.

Figure 3 below shows the estimates of $CO_{2\text{-eq}}$ generation from the three studied models, straw rolling transportation, and burning. The calculations were done using assessments from the literature [05]. The calculations show that in all studied models the CO_2 generation is much lower compared to open burning.

As can be seen in Figure 3 the amount of $CO_{2\text{-eq}}$ generated from treated straw is quite high. But considering that a similar amount of $CO_{2\text{-eq}}$ is released if cows are fed other food.

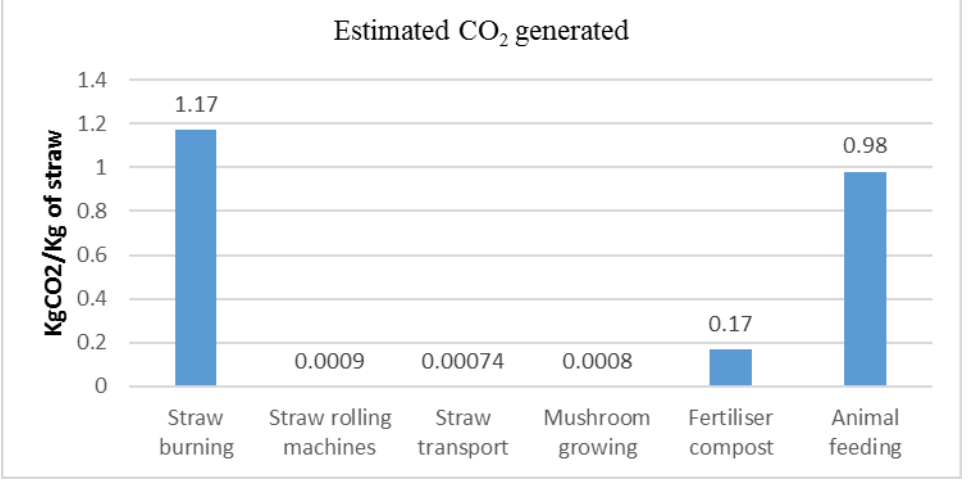
4. CONCLUSION

Each studied alternative to open burning in this study proved to be relatively easy to implement for the farmers in An Giang Province. It is anticipated that the farmers will continue these practices after the end of the project. The study results indicate that each alternative provides financial incentives for farmers. Each mushroom growing site provided income of 18-30 million VND per year and each composting operation provided 5-14 million VND per year. The calculated ROI and CBR values were high. The straw urea treatment model for fodder production did not bring income in the form of money, but it saved a lot of time and labour for farmers.

If such alternatives to open burning are replicated across An Giang Province it would increase the demand for straw and reduce the burning of straw in the fields.

Table 5: The amount of CO_2e generated from transporting straw in Chau Thanh and An Giang Province in 2022 [05]

Item	Number of trips		Amount of straw (tons)		CO_2e generated (tons)	
	Chau Thanh District	An Giang	Chau Thanh District	An Giang Province	Chau Thanh District	An Giang
By boats	2,075	8,720	51,883	217,993	26.2	109.9
By trucks	8,071	33,910	121,061	508,651	101.7	427.3
Total	10,146	42,630	172,944	726,644	127.9	537.2



▲ *Figure 3: Estimated CO_2-eq generated from different models of straw uses in An Giang province [05]*

As indicated by the farmers the biggest challenges to continuing and spreading these practices could be the changes in prices and quality of rice straw in the market throughout the year. Most farmers do not have warehouses for storing the straw and will have to depend on the supply of the straw from the unstable rice straw market. Another problem is the quality of the straw. It could be contaminated with pesticides, which will make it unsuitable for use to feed animals or grow mushrooms.

In the future, the research team plans to continue optimising the mushroom growing and straw composting methods. It is also important to assess the potential contamination of straw with pesticides and heavy metals.

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1. INTRODUCTION

Plastic is a lightweight, hygienic, and durable material that can be molded in a variety of ways and used in various applications. Most plastics are non-biodegradable, they only photodegrade into small pieces called microplastics. The plastic products mentioned in this study are plastics of fossil origin, not plastics of biological origin. Among single-use plastic products, plastic bags are the world's leading products in popularity among consumers and are considered a symbol of "disposable" culture.

In the effort to protect the earth from plastic waste, many countries in the world have been applying regulations to limit and eventually ban the use of single-use plastic products such as cups, plates, cutlery, spoons, etc., and replaced with environmentally friendly products. The ban on single-use plastics has been coming into force in many countries in the world today. Since 2020, 170 countries have committed to "significantly reducing" the use of plastic from now until 2030.

International experience gained includes both successes and failures in reducing and eliminating the use and discharge of nondegradable plastic bags and single-use plastic products in distribution systems, including countries that have succeeded in voluntarily agreeing to reduce nondegradable plastic bags and single-use plastic products such as Austria and South Korea; countries that have succeeded in taxing and collecting fees for using plastic bags such as Ireland and Japan; countries that have succeeded in implementing a ban on single-use plastic products and nondegradable plastic bags include Antigua and Barbuda, Australia, and the United States; countries failed to implement the ban on single-use plastic products and nondegradable plastic bags such as Rwanda, South Africa, Bangladesh and countries with similar characteristics to Vietnam such as China and Thailand.

Currently in the world as well as in Vietnam, the use of plastic bags and plastic products in business and consumption activities is quite popular because of the conveniences they bring. When released into the environment, a plastic bag can take up to 500 -1000 years to completely decompose. So to date, there are more than 9.1 billion tons of plastic waste accumulated on earth. The abuse of non-biodegradable plastic bags and single-use plastic products has left various negative consequences on human health, the environment and ecosystem, etc, hindering the sustainable development goal set by the international community and nations.

According to data from the Ministry of Natural Resources and Environment, the amount of plastic waste and plastic bags in Vietnam is currently quite high, accounting for about 8-12% of household solid