Toward Zero Agro-Waste: A Business Model for Sugarcane Leaves Management in Thailand

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Abstract. Sugarcane is one of the oldest crops ever cultivated by humans and has a long history. Currently, the prevalent practice of burning sugarcane fields increases environmental concerns because many farmers frequently use this method to facilitate the harvest process and prepare the area for the next planting crop. Thus, the effective use of sugarcane leaves with proper management can overcome this problem. This paper represents sugarcane leaf management by developing a business model focused on collection, densification, and transportation, explicitly targeting the conversion of waste sugarcane leaves into fuel for a biomass power plant. The business model is categorized into two primary groups: the farmer group and the middleman group. Both groups are incentivized to invest in tools and equipment for collecting and densifying biomass, thereby facilitating the effective performance of the model. Furthermore, an economic analysis has been conducted encompassing an investment cost evaluation and the estimation of the payback period for this business model. The results indicate that the farmer group demonstrates a payback period of 1.72 years, while the middleman group reveals a longer payback period of 2.06 years. This strategic approach not only enhances the value of biomass waste but also significantly reduces the unwanted burn on farming fields, effectively mitigating air pollution.

Keywords: Biomass, Sugarcane, Zero-waste, Management, Business model

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1 Introduction

Thailand is acknowledged as an agricultural-focused nation with a robust industry dedicated to converting agricultural resources. This industry encompasses processing agricultural commodities into food products, raw materials, and various items and tools. Currently, Thai farmers primarily concentrate on cultivating sugarcane [1]. While agriculture has long existed in Thailand, many farmers still lack the knowledge to effectively handle the agricultural waste left behind after harvesting, which leads to the improper disposal of these remnants. During the harvest season, there is a prevalent practice of incinerating these residuals, which gives rise to environmental problems that directly affect the daily lives of the population [2]. Despite the ongoing government efforts to regulate sugarcane harvests by burning methods for sale in factories [3], the issue is only partially resolved. Several factors continue to contribute to the burning of sugarcane plantations in Thailand. These factors include a labor shortage for harvesting, a lack of knowledge about biomass management from sugarcane leaves, and farmers who fail to recognize the value of utilizing sugarcane leaf residuals to create products. It is important that farmers have the appropriate knowledge and skills to handle challenging post-harvest biomass. These leftover residuals can be utilized to sustainably increase the value of biomass waste.

In accordance with the Alternative Energy Development Plan 2018–2037 (AEDP2018), the Thai government has instituted a policy aimed at promoting the utilization of renewable energy sources for electricity generation, with a specific focus on the use of biomass fuels [4]. Saleem [5] highlighted that agricultural waste presented a viable and sustainable fuel source for energy generation, with the energy content varying depending on the specific agricultural residuals. This biomass comprised agricultural waste left after harvest, such as white straw, rice husks, tea leaf remnants, and sugarcane leaves discarded post-harvest. Initial investigations revealed that sugarcane leaves exhibited a heat value of up to 17.41 MJ/kg. Meanwhile, water hyacinth, rice straw, rice husk, and tea leaf residuals possessed calorific values of 14.81 MJ/kg, 15.09 MJ/kg, 16.47 MJ/kg, and 17.10 MJ/kg, respectively [6]. Thailand, being the second-largest sugar exporter globally after Brazil [7], experiences a significant surplus of sugarcane leaves post-harvest. As reported by Dangprok et al. [8], the annual average quantity of sugarcane leaves remaining after harvesting in Thailand was approximately 17,016 ktons. Regrettably, this considerable volume of agricultural waste currently goes unused.

Numerous studies have demonstrated the utility of sugarcane leaves in various applications. Firstly, sugarcane leaves were extensively employed for biofuel production. For instance, Go et al. [9] conducted a study on the utilization of sugarcane leaves (SCL) as a biofuel, encompassing bioethanol and biomethane production in the Philippines. The findings indicated that the use of SCL could potentially have reduced coal consumption in electricity generation by up to 75% for the Visayas region. The study also highlighted that the potential of SCL was substantial enough to meet the demand for fuel ethanol and biomethane. Martins et al. [10] researched the natural senescence process of sugarcane leaves, which included the remobilization of nutrients and the effect on cell walls of producing second-generation bioethanol (2G-bioethanol) from sugarcane leaves. Sugarcane leaves were also employed for electricity generation. Silalertruksa et al. [11] introduced the bio-circular-green economy (BCG) for sugarcane to maximize waste usage after harvest. The study assessed the environmental sustainability of five models: sugarcane leaves for electricity generation, biochar, and soil conditioner, and vinasse for bio-fertilizer and electricity generation, with sugarcane leaves used for electricity generation exhibiting the least environmental impact. Fioranelli et al. [12] also looked into and used biomass integrated gasifier-gas turbine combined cycle (BIGCC) technology in Brazil's sugarcane industry. This

work used bagasse and sugarcane leaves to make electricity; the technology was successfully integrated into sugarcane industrial processes with a small power capacity of 15 MW.

In the context of previous research on biomass waste management, utilizing sugarcane leaves for electricity generation has become a compelling topic in Thailand, primarily due to the substantial annual quantity of sugarcane leaves left after harvesting. The utilization of sugarcane leaves for electricity generation signifies a proactive measure to diminish dependence on finite fossil fuels. However, in underdeveloped regions, the limited access to technology, machinery, and tools poses significant obstacles in the collection and transportation processes, hindering the effective use of agricultural waste as a bio-energy source. For Thai farmers, there is a lack of knowledge concerning managing waste sugarcane leaves, including collection, densification, and transportation to fuel biomass power plants. Consequently, a significant portion of these agricultural residues are left abandoned and subjected to burning in open fields, leading to environmental concerns, particularly during harvesting seasons.

This study introduces a method for managing agricultural waste through collecting and densifying processes (referred to as processing) and transportation processes. These procedures are demonstrated within a sample group, aligning with the zero-biomass waste management model. The primary goal of this model is to foster knowledge development among Thai farmers, empowering them with the skills to manage sugarcane leaves left over from harvesting effectively. The model also seeks to promote the utilization of existing technology, encouraging farmers to leverage agricultural waste for sustainable practices. The contributions of this study can be summarized as follows:

- **Business Model:** This paper presents the business model for the utilization of benefits from sugarcane leaves to facilitate access to tools and equipment for the processing of biomass. This approach helps address the issue of agricultural waste incineration after harvest and provides income-generating opportunities for farmers.
- **Economic Analysis:** To demonstrate the best management solution, the study conducts a comprehensive analysis of the economics, expenses, and average returns for two selected sample groups: the farmer and middleman groups. This analysis enables a comparison of costs and profits, guiding sellers toward the most favorable model for achieving economic sustainability.

2 Methodology

The fundamental principle of the zero-biomass waste management model is to empower farmers to appropriately dispose of biomass after harvesting and ensure the availability of biomass for electricity generation in biomass power plants. This paper establishes guidelines for the effective management of biomass waste, with a specific focus on the residues derived from sugarcane leaves after harvesting. The zero-biomass waste management model comprises both sellers and buyers. The sellers are persons who own or process the biomass, which are considered into 2 groups: a farmer who owns the biomass designated hereafter as A, and a middleman who buys the biomass from the farmer and processes it for sale hereafter called B. On the other side, buyers of biomass who have biomass demand for use as fuel include biomass power plants in sugar factories.

2.1 Business model for utilization of sugarcane leaves

The business model for the utilization of sugarcane leaves is strategically designed to capitalize on knowledge regarding biomass management techniques and technology, fostering effective learning among farmer groups. To implement and assess the model, two specific sample groups are chosen, A and B, as mentioned above. The A-group comprises

sugarcane farmers, collectively cultivating an area of 197.63 acres (referred to as farmers). Concurrently, the B-group is called middlemen, who acquire biomass from farmers, overseeing the same area of 197.63 acres.

To facilitate the implementation of the model, both groups are provided with the essential tools and equipment for biomass collection and densification. This work aims to establish a framework for efficient biomass utilization including collecting, densifying, and transportation. Fig. **1** visually represents the zero-biomass waste management model, outlining the interconnected processes inherent in the model. In addition to enhancing the value of agricultural waste, the model takes a proactive approach to address the urgent issue of incineration.

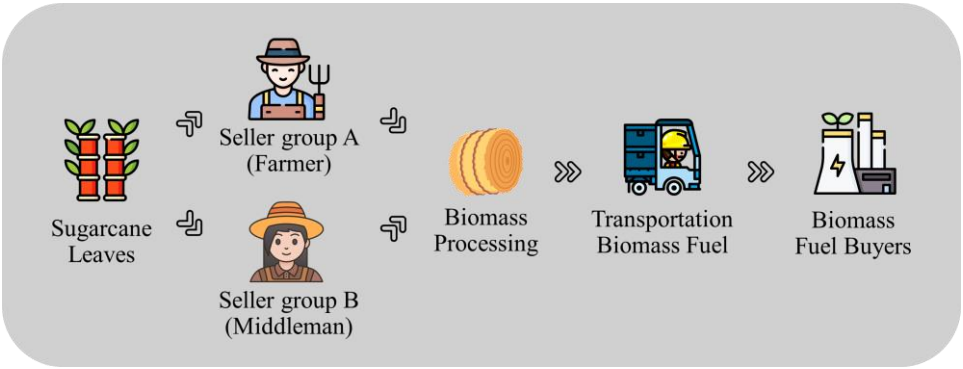

Fig. 1. Zero-biomass waste management model

Sugarcane, recognized as one of the most economically significant crops in the world, holds value across diverse applications, serving as a primary source of sustenance for both humans and animals. Beyond sugar production, various components of sugarcane, including its leaves, present valuable by-products. Northeastern Thailand is notable for extensive sugarcane cultivation across numerous areas, with Udon Thani Province, Khon Kaen Province, Nakhon Ratchasima Province, Chaiyaphum Province, and Kalasin Province ranking highest in sugarcane cultivation within this region [13]. While the widespread cultivation of sugarcane contributes to increased agricultural production, it also gives rise to the challenge of sugarcane field burning, particularly during the annual harvest. The practice of burning sugarcane is primarily attributed to the scarcity of labor for harvesting fresh sugarcane, a task complicated by the sharp and thorny nature of sugarcane leaves, thus extending the harvesting process. Moreover, post-harvest, the residual sugarcane leaves are burned to prevent fires that could impact the germination of the next generation of sugarcane plants [3]. In light of these challenges, this paper proposes the utilization of prototype areas in Udon Thani and Kalasin provinces, as depicted in Fig. 2, to serve as a model for the study of zero-waste biomass management.

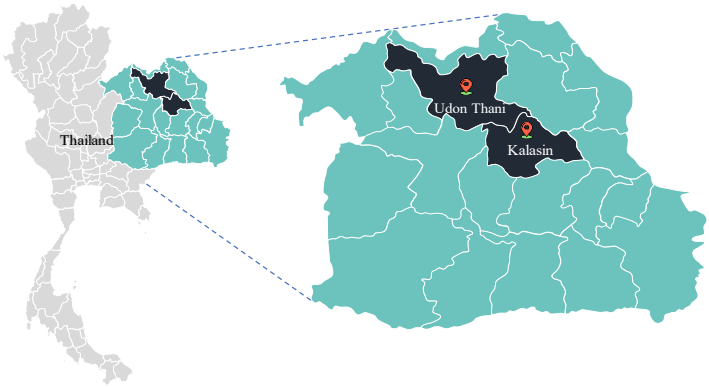

Fig. 2. Location of the selected groups

2.2 Economic computations of typical returns and expenses

The payback period is a commonly employed metric for evaluating economic cost-effectiveness, providing insights into the duration required for the net operating benefits or net profit (after deducting various expenses) to offset the initial investment cost. Denoted as the payback period ($Y_{Payback}$), this metric serves as a crucial indicator in financial assessments. It can be calculated by dividing the initial investment (*Initial investment*), representing costs like the purchase of agricultural equipment, by the annual net return (*Annual net profit*), as demonstrated in Equations (1) and (2). A shorter payback period suggests that the investment is financially advantageous, as it signifies a quicker recovery of the initial investment through the generated returns. Understanding and optimizing the payback period is integral to making informed financial decisions and assessing the viability of investments.

$$Y_{Payback} = \frac{\text{Initial investment}}{Annual\ net\ profile} \tag{1}$$

$$Annual\ net\ profile = W_{Leaves,year} \times P_{net} \tag{2}$$

where $W_{Leaves,year}$ is sugarcane leaves weight (tons/year), and P_{net} is net profit ($/ton).

The annual weight of sugarcane leaves ($W_{Leaves,year}$) can be determined using Equation (3). In this study, the total number of areas (A_{farm}) is assumed to be 197.63 acres per year. Net profit is calculated based on Equations (4) and (5). The total operating cost ($C_{Operation}$) includes various components such as fuel expenses for the sugarcane leaf sweeper truck ($C_{Fuel,sweep}$), fuel expenses for the sugarcane leaf roll truck ($C_{Fuel,roll}$), expenses of rope for rolling sugarcane leaves (C_{Rope}), labor expenses (C_{Labor}), expenses for procuring sugarcane leaves from farmers ($C_{Biomass,buy}$), transportation expenses ($C_{Transportation}$), and maintenance expenses ($C_{Maintenance}$). All costs are in $/ton. It is noted that the $C_{Biomass,buy}$ is only for the B group, which is an extra cost for the middleman model.

$$W_{Leaves,year} = A_{farm} \times W_{lumps} \times N_{lumps} \tag{3}$$

$$P_{net} = P_{sell} - C_{Operation} \tag{4}$$

$$C_{Operation} = C_{Fuel,sweep} + C_{Fuel,roll} + C_{Rope} + C_{Labor} + C_{Biomass,buy} + C_{Transportation} + C_{Maintenance} \tag{5}$$

where W_{lumps} is the Weight of sugarcane leaves lumps (tons/lump), N_{lumps} is the average number of sugarcane leaves lumps (lump/acre), and P_{sell} is biomass selling price ($/ton).

3 Results and Discussions

The business model for biomass processing (collecting and densifying as rolls) is divided into two distinct groups covering the selected area in Northeastern Thailand:

- Farmer Group (Group A):

Sub-Group A1: This sub-group operates on 197.63 acres in Udon Thani Province, designated as area A1, which is 30 kilometers from the biomass power plant.

Sub-Group A2: Another sub-group, also part of Group A, operates on an additional 197.63 acres in Udon Thani Province, designated as area A2, which is 50 kilometers from the biomass power plant.

- Middleman Group (Group B):

Sub-Group B1: This sub-group engages in the purchase of biomass from farmers for further processing. It operates within a 197.63 acres area in Kalasin Province, 30 kilometers from the biomass power plant.

The selected groups were well-appointed with information and guidance pertaining to the preparation of sugarcane leaves, their collection and storage, as well as machinery operation and maintenance. In order to facilitate the collection of the sugarcane leaves, a sugarcane leaf sweeper truck and a sugarcane leaf roll truck were provided to both Group A and Group B. Based on the results obtained from processing sugarcane leaves post-harvest, it was observed that Group A1 achieved an average yield of 20.59 lumps/acre from processing sugarcane leaves. The processing time averaged 120.17 minutes/acre, with the sugarcane leaf bales having an average weight of 0.168 tons/lump. Group A2, on the other hand, obtained an average yield of 19.08 lumps/acre from sugarcane leaf processing. The processing time averaged 120.68 minutes/acre, with sugarcane leaf lumps weighing an average of 0.170 tons/lump. Group B1, representing the middleman group, achieved an average yield of 19.35 lumps/acre from sugarcane leaf processing. The average processing time was 105.43 minutes/acre, and the sugarcane leaf bales had an average weight of 0.164 tons/lump. Fig. **3** illustrates the process of collection and densification. For these above, it was found that Group A did not have experience in the operation. Therefore, it was necessary to have a research team to assist and resolve on-site issues. On the other hand, the middleman group (Group B) has previous experience in sugarcane leaf rolling, enabling them to process faster. Detailed information is provided in Table 1.

(a) (b)

Fig. 3 (a) Sweeping process; (b) Densification process

Table 1. Details of sugarcane leaves densification process

Details	A		B	Unit
	A1	A2	B1	
Average number of sugarcane leaves lumps	20.59	19.08	19.35	lump/acre
Average working time	120.17	120.68	105.43	minutes/acre
Fuel consumption rate	5.19	5.06	4.86	liters/acre
Average time to sweep sugarcane leaves	27.63	27.83	19.28	minutes/acre
Average time to roll sugarcane leaves	5.80	6.31	4.44	minutes/lump
Average lump size	D120 x 120	D120 x 120	D120 x 120	centimeter
Weight of sugarcane leaves lumps	0.168	0.170	0.164	tons/lump
Average yield of sugarcane leaves	3.47	3.24	3.18	tons/acre
Annual yield of sugarcane leaves	685	640	628	tons/year

Table 2. Payback period of 2 proposed business sub-models

Details	A		B	Unit
	A1	A2	B1	
Machine cost				
Investment in agricultural machinery	17,202.53	17,202.53	17,202.53	$*
Operation costs				
Fuel costs for sugarcane leaves sweeper truck	0.25	0.26	0.20	$/ton
Fuel costs for sugarcane leaves roll truck	0.99	0.99	1.07	$/ton
Cost of rope for sugarcane leaves roll	2.55	2.53	2.62	$/ton
Labor cost	1.36	1.35	1.40	$/ton
Cost of buying sugarcane leaves from farmers	-	-	1.14	$/ton
Transportation cost	8.60	9.46	8.60	$/ton
Maintenance cost	0.31	0.34	0.34	$/ton
Total operation costs	14.07	14.93	15.38	$/ton
Biomass selling price	**28.67**	**28.67**	**28.67**	**$/ton**
Net profit	14.60	13.74	13.30	$/ton
Payback period	1.72	1.96	2.06	year

* Remark: $1 = 34.89 Baht

The economic evaluation of sugarcane leaf business models was carried out. The investment cost of all three models was equal since all the equipment required was the same. A purchase price for processed sugarcane leaves of 28.67 $/ton has been based on the rates set by the Office of the Cane and Sugar Board under the Ministry of Industry of Thailand [14], which will be used as fuel in biomass power plants. This pricing strategy aims to reduce the reliance on fossil fuels in electricity production and contribute to the establishment of national energy security. Based on the operational outcomes, it was noted that the farmer

Group A1 generated a net profit of 14.60 $/ton and could pay back their initial investment within an estimated time frame of 1.72 years. The sugarcane leaf processing revenue of Group A2 amounted to 13.74 $/ton, with an approximate payback period of 1.96 years. The payback period is expected to be faster if these two groups of farmers are able to expand their operations to encompass more than 197.63 acres, making more profit per year. For the middleman group (Group B1), there was an extra cost of sugarcane leaf bought from farmers for 1.14 $/ton. Therefore, this group yields less profit of 13.30 $/ton, resulting in a longer payback period of 2.05 years. The data indicates that farmer groups have a shorter payback period compared to the middleman group. This difference can be primarily attributed to the expenses associated with acquiring sugarcane leaves from farmers. Consequently, investing in farmer groups appears to be a more attractive option due to their comparatively quicker return on investment. Exhaustive details are available in Table 2.

4 Conclusion

The collection and densification of sugarcane leaves, which are established as business models, are proposed in two different concepts called the farmer and the middleman groups. The middleman group showed faster sweeping, collecting, and densifying of the sugarcane lump than the farmer groups due to its expertise and more experience. In both A and B groups, with the same targeted area of 197.63 acres, the yields of sugarcane leaves were approximately 628 to 685 tons/year. Consequently, the calculated payback period was to be within the range of 1.72 to 2.06 years. Thus, Group A1 exhibited a notably short payback period because there were no expenses related to purchasing sugarcane leaves, a cost incurred by the middleman group. Additionally, the shorter biomass transportation distance in Group A1 compared to Group A2 facilitated a quicker payback. In summation, the farmer model, where they owned sugarcane leaves, is recommended due to a potential shorter payback period. Moreover, if they gain more experience and expand to a larger area, the return on investment will be shorter.

Finally, the recommended course of action to further develop this work was to focus on creating a biomass trading platform with the aim of optimizing the efficiency of trading processes due to transportation costs being an important factor influencing the payback period. Presently, the trading options available to buyers and sellers are somewhat constrained, lacking considerations for transport distance, purchase price, biomass quantity, and biomass type. Considering the aforementioned elements in biomass trading, it laid the groundwork for a more efficient and effective biomass trading process.

The research team would like to thank the Center of Alternative Energy Research and Development, Khon Kaen University, for supporting our work.

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