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# Investment feasibility analysis of sugarcane harvesters: a case study of farmers in Udon Thani, Nakhon Ratchasima, and Khon Kaen, Thailand

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**Abstract**

Despite the continued growth of Thailand's sugarcane harvester service business, not all investments in sugarcane harvesters have been successful. This study aimed to analyze the investment feasibility of sugarcane harvesters for farmers in Northeast Thailand. Data were collected in the production year 2019/20 by interviewing 30 farmers with sugarcane harvesters in Udon Thani, Nakhon Ratchasima, and Khon Kaen. The study was based on financial feasibility, which was determined by calculating a proforma financial statement for a period of 12 years with a discount rate of 6.11%. The results found that a new small-scale sugarcane harvester presented the most worthwhile investment, with a net present value (NPV) of united states dollar (USD) 196,304, an internal rate of return (IRR) of 11.15%, and a payback period of 9.71 years. These results were followed by a new large-scale harvester, a used small-scale harvester, and a used large-scale harvester with NPVs of USD 152,630, USD 79,476, and USD 70,201, respectively. The IRRs were 9.25%, 9.56%, and 8.66%, respectively; and the respective discounted payback period was 10.75, 10.56, and 11.12 years. The results indicated that an investment in a new or smaller sugarcane harvester was more worthwhile than a used or larger sugarcane harvester under the same conditions. The investment of a new large-scale or small-scale harvester was better suited for an annual harvest of over 16,000 and 13,000 tons, respectively; whereas a used large-scale harvester or a used small-scale harvester would be appropriate for a minimum annual harvest of 11,000 and 10,000 tons, respectively.

**Keywords:** Investment feasibility, Financial feasibility, Sugarcane harvester, Green sugarcane harvesting

## 1. Introduction

Sugarcane is an important economic crop in Thailand that generates income for farmers, comprising up to 427,395 households and approximately 927,447 people [1]. There has been a growth in sugarcane cultivation areas across the country, due to the relatively high price of sugarcane and the expansion of sugar mills and related businesses [2]. During the production years of 2015/16 to 2019/20, sugarcane cultivation areas increased from 1.76 million hectares to 1.91 million hectares, accounting for an average growth of 2% per year. Thailand's northeastern region has the largest sugarcane cultivation area, followed by the central, northern, and eastern regions [3]. In the production year 2019/20, the northeastern region encompassed a total sugarcane planting area of 0.84 million ha, totaling 38.83 million tons of sugarcane production. Northeast Thailand's top five provinces with the largest sugarcane planting areas are Udon Thani, Nakhon Ratchasima, Khon Kaen, Chaiyaphum, and Kalasin.

Despite increases in sugarcane production within the aforementioned production years, sugarcane prices tended to decline concomitantly with world sugar prices, while sugarcane production, particularly harvesting costs, tended to increase. Previous studies on sugarcane production in northeastern Thailand demonstrated that the cost of harvesting was the highest proportion of total production costs at the farm-gate level. In the

Chaiyaphum province, harvesting costs accounted for 47.14% of total costs [4], and in the Udon Thani province, harvesting costs accounted for 38.19% of total costs [5]. In Thailand's central region, harvesting costs represented the largest proportion at 22.17%, followed by transportation costs of 11.67% [6]. Similarly, in Brazil, harvesting costs accounted for the largest proportion of total sugarcane production costs, ranging from 34.67% to 46.76%. The next highest proportion was transportation, which accounted for 11.95% to 16.83% of the total sugarcane production costs. These proportions varied greatly depending on the harvesting method used [7]. However, sugarcane harvesting in Thailand is primarily done through manual labor, which has become increasingly challenging, due to the country's aging society and shortage of labor in the agricultural sector, leading to a lack of available local labor, as well as higher wages [8]. According to a study by the Kasetsart University and Office of Agricultural Economics Foresight Center (KOFC); alien workers ranked second in sugarcane production in all agricultural production [9]. The burning of sugarcane leaves before manual harvesting has become widespread in all regions of Thailand; as it is faster, more convenient, and less expensive than cutting green sugarcane. However, this practice has resulted in severe environmental problems, such as greenhouse gas emissions and PM 2.5 dust [2,10].

Sugarcane harvesters have been recently employed to replace manual labor, addressing the high cost of harvesting, as well as the issue of burning sugarcane leaves post-harvest. Sommut's 2016 study on the cost of green sugarcane harvesting in central Thailand [11] reinforced that harvesting sugarcane through manual labor was more expensive than harvesting with a machine. The cost per ton for harvesting and transportation was united states dollar (USD) 9.81 for manual harvesting, USD 9.36 for employing a factory's combine harvester, and USD 8.56 using one's own combine harvester. Similarly, a study in 2020 found that the cost per ton of green cane harvesting and transportation using machinery was cheaper than through manual labor. The cost of sugarcane combine harvesting was USD 6.13 per ton and the cost of transportation was USD 4.30 per ton, totaling USD 10.43 per ton. The cost of sugarcane manual harvesting was USD 6.85 per ton and the cost of transportation was USD 4.12 per ton, resulting in a total cost of USD 10.97 per ton [12]. In 2020, the number of sugarcane combine harvesters in Thailand was between 2,000 and 2,500 units. The Thai government, in cooperation with the Office of the Cane and Sugar Board and the Bank for Agriculture and Agricultural Cooperatives, encouraged the use of sugarcane combine harvesters by offering low-interest rate loans to farmers, making it more financially attractive for farmers to invest in these machines [14]. Their goal was to increase the number of combine harvesters in Thailand to 3,400 to 4,500 units to be sufficient for the green sugarcane harvesting areas [13]. Although the sugarcane harvester service business has grown, not all investments in sugarcane harvesters have been successful, due to several problems; such as unsuitable farming conditions for machine usage, lack of knowledge in maintenance and repairing harvesters, high operating and maintenance costs, low liquidity of working capital, and underutilization of the harvesters. Sommut [11] found that farmers with an average harvest of 10,872 tons of sugarcane investing in a 300-horsepower sugarcane harvester would not find the investment worthwhile. A successful investment in a sugarcane harvester would require efficient operation and proper management, as well as the suitable preparation of sugarcane plots required for sugarcane harvester usage.

Despite the northeastern region having the highest sugarcane planting area in Thailand, half of the total sugarcane output resulted in burnt sugarcane [3]. Green sugarcane harvesting in this region relies mainly on human labor, as the geographical conditions were not suitable for the use of harvesting machines, and most sugarcane farmers were small-scale producers who could not afford a harvesting machine [15]. The government's recent green sugarcane harvesting campaign and the low-interest-rate loan scheme for purchasing sugarcane harvesters resulted in the investment of sugarcane harvesters by large and medium-scale farmers. The Udon Thani, Nakhon Ratchasima, and Khon Kaen provinces were known for having the highest sugarcane production in Thailand's northeastern region [3]. To efficiently harvest their crops, the widespread use of sugarcane harvesters was implemented. In 2020, there were 342 sugarcane combine harvester units in use within these provinces, with 85 units owned by sugar mills and 257 units owned by individual farmers [12]. However, investing in a sugarcane harvester is a high-value venture that faces many risk factors. For example, in the production year 2019/20, sugarcane planting areas in these three provinces dramatically decreased due to severe drought, in which a significant amount of sugarcane was damaged, and alternative crops were planted [3]. These production risks affected the profitability and investment worthiness of obtaining a sugarcane harvester. Our research, therefore, aimed to analyze the investment feasibility of sugarcane combine harvesters in the northeast by size and condition as a guideline for decision-making business planning.

## 2. Materials and methods

### *2.1 Data collection*

This research was conducted using primary data through in-depth interviews with 257 farmers who owned a sugarcane combine harvester in the Udon Thani, Nakhon Ratchasima, and Khon Kaen provinces in the production year 2019/20 [12]. Our sample group consisted of 30 farmers or 11.67% of the population, which aligned with the

rule of thumb for the smallest numbers required for statistical analysis (30 respondents) [16,17], and 25-30 respondents for a sample size for in-depth interview [18,19]. Thirty sugarcane farmers were selected via a purposive sampling method based on their experience in operating a sugarcane combine harvester for more than one year. The survey was conducted from May to July 2020 through face-to-face interviews via a structured questionnaire.

*2.2 Data analysis*

The analysis of the annual costs and revenues of the sugarcane harvester business was calculated in USD per ton. Total costs consisted of fixed costs (e.g., depreciation of machinery and vehicles, taxes, insurances, etc.) and variable costs (e.g., labor cost, fuel cost, maintenance cost, etc.). Revenue was calculated from sugarcane cutting and transportation [20-22].

The investment feasibility of a sugarcane combine harvester was evaluated using the discounted cash flow technique, which calculated the present value of investment costs, operating costs, and revenue over the project life [23-26]. Sugarcane harvester investment as a private and commercial project was evaluated in terms of financial feasibility by applying four indicators: net present value (NPV); benefit-cost ratio (BCR); internal rate of return (IRR); and discounted payback period (DPP) [23-29]. Additionally, the switching value test (SVT) was commonly employed to perform sensitivity analysis, which reflected the risk level of the project with five key indicators [26], expressed as follows:

(1) NPV is the difference between the present value of the total benefits of the project and the present value of the project's total costs over a given period (Equation 1). A NPV > 0 indicates investment worthiness.

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} \quad (1)$$

where,
$B_t$ = project's benefits in year t
$C_t$ = project's costs in year t
$r$ = discount rate
$t$ = project period (1, 2, …, n)
$n$ = investment project period

The discount rate is commonly represented by the weighted average cost of capital (WACC). The WACC anticipates the long-term cost of capital, calculated by combining the cost of each capital component and weighing it according to its proportion in the firm's capital structure [29], as described in Equation 2.

$$WACC = W_e r_e + W_d r_d (1 - T) \quad (2)$$

where,
$W_e$ = proportion of firm's equity in capital structure
$W_d$ = proportion of long-term debt in capital structure
$r_e$ = cost of equity
$r_d$ = cost of debt
$T$ = corporate tax rate

Our research determined that the majority of farmers financed their investments in sugarcane harvesters through long-term debt, with an average debt-to-equity ratio of 80:20. Farmer equity relied on their own personal savings. The cost of equity, therefore, would be equal to the risk-free rate of return. Generally, a longer-term government bond yield was often used as a proxy for the risk-free rate [29]. The interest rate of the longer-term government bond of Thailand in 2019 was 3.05% [30]. The nominal interest rate for farmers' debt in 2019 was 6.875%, which was the minimum retail rate (MRR) charged by the Bank for Agriculture and Agricultural Cooperatives for high-class retail customers [31]. In Thailand, these farmers do not pay taxes on their income. When substituting the values of variables into Equation 2, the weighted average cost of capital (WACC) was 6.11%. This value was used as the discount rate in this study.

(2) BCR represents the ratio between the present value of the total benefits and costs throughout the investment project (Equation 3). A BCR > 1 indicates that the project has a positive NPV and is worthy of investment.

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}} \quad (3)$$

where,
$B_t$ = project's benefits in year t
$C_t$ = project's costs in year t
$r$ = discount rate
$t$ = project period (1, 2, …, n)
$n$ = investment project period

(3) IRR is the discount rate (r) that makes the NPV of the project equal to zero, as shown in Equation 4. A project is deemed worthy of investment when the IRR is greater than the discount rate or the opportunity cost of the capital.

$$IRR \text{ is } r \text{ that makes } NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t} = 0 \quad (4)$$

where,
$B_t$ = project's benefits in year t
$C_t$ = project's costs in year t
$r$ = discount rate
$t$ = project period (1, 2, …, $n$)
$n$ = investment project period

(4) DPP is the amount of time required to recover the initial cash investment of the project [27,29], obtained through Equation 5.

$$DPP = \frac{C_0}{(NPV + C_0) \div n} + 1 \quad (5)$$

where,
$C_0$ = initial investment
$NPV$ = net present value
$n$ = investment project period

(5) SVT signifies the percentage change of factors affecting the investment feasibility which makes the NPV equal to zero. The SVT indicates the project investment risk level, which reflects the sensitivity analysis [26]. There are two main factors of risks, including an increase in costs and a decrease in benefits, respectively. The measurements of the switching value test for costs and revenues are as follows:

(5.1) Switching value test of costs ($SVT_C$) is the percentage of the project cost increase that makes the net present value (NPV) equal to zero (Equation 6)

$$SVT_C = \frac{NPV}{PVC} \times 100 \quad (6)$$

where,
$NPV$ = net present value
$PVC$ = present value of costs

(5.2) Switching value test of benefits ($SVT_B$) is the percentage of the project benefit decrease that make the NPV equal to zero, as expressed in Equation 7.

$$SVT_B = \frac{NPV}{PVB} \times 100 \quad (7)$$

where,
$NPV$ = net present value
$PVB$ = present value of the benefits

Three further assumptions were made for our investment feasibility analysis:

1) The project operating life was based on the economic life of the major investment; the sugarcane combine harvester. A general guideline was to use an economic life of 10-12 years for most farm machinery, and a 15-year life for tractors [21]. The Valuers Association of Thailand stated that the lifespan of a sugarcane harvester was 12 years [32], and a study on the feasibility of investing in sugarcane combine harvesters in Kanchanaburi, Thailand also determined a project life of 12 years [11], which we used as the project life for the investment herein.

2) The revenues from sugarcane harvesting were determined by sugarcane cultivation area and output. Within the past 12-year's data, it was found that the sugarcane cultivation area in 2008/09 was 443,829 hectares and

increased to 836,705 hectares in 2019/20, while the sugarcane outputs in 2008/09 were 27,666,155 tons and increased to 38,830,631 tons in 2019/20 [3]. Through the use of an exponential function to extrapolate the respective sugarcane cultivation areas and outputs in northeastern Thailand, the average growth rate was estimated at roughly 5% per year, and the variable costs of the sugarcane harvesting were based on the quantity of sugarcane being harvested. We, therefore, adopted the revenue and variable cost increases of 5% per year.

3) The exchange rate for USD: Thai Baht (THB) in the year 2020 was 1 USD:31.30 THB [33].

## 3. Results and discussion

The results of the investment feasibility analysis of sugarcane harvesters for sugarcane farmers in northeast Thailand were categorized into three topics: 1) general information of the respondents; 2) costs and revenues; and 3) the investment feasibility analysis of sugarcane harvester investments; detailed as follows:

### *3.1 General information of the respondents*

The study of the basic characteristics of 30 respondents in each of the three study provinces found that sugarcane farmers were mostly male, with a primary-level education. The age range was between 32-71 years, with an average of 53.8 years. Experience in sugarcane combine harvesting services varied from 1-21 years with an average of 5.7 years. Several past studies had also determined that most (sugarcane) farmers had low education and less experience with sugarcane harvesting services. This led to issues, such as poor proficiency in operating the harvesters, and inadequate knowledge of machine maintenance and repair [34].

Four categories of sugarcane combine harvesters were considered herein: (1) new large-scale sugarcane harvesters (301-350 horsepower); (2) new small-scale sugarcane harvesters (200-300 horsepower); (3) used large-scale sugarcane harvesters (301-350 horsepower); and used small-scale sugarcane harvesters (200-300 horsepower). The number of total sugarcane harvesters of all respondents was 34 harvesters, which consisted of fifteen new large-scale sugarcane harvesters, eight new small-scale sugarcane harvesters, eight used large-scale sugarcane harvesters, and three used small-scale sugarcane harvesters. Each of the thirty farmers owned either one or two harvesters (Table 1). Most farmers provided full services, including harvesting and transporting sugarcane, as they each had their own adequate machines and trucks. Farmers with a limited investment budget had set up a truck network by inviting sugarcane farmers with trucks to work together as a farmer group or business network. The standard rate for transportation services was set by the sugar mills and varied based on distance, ranging from USD 3.19 to USD 6.39 per ton. This network could be employed as a pilot model for small and medium sugarcane farmers in which to efficiently share benefits and machinery utilization.

**Table 1** Total number of respondents and sugarcane harvesters classified by province and type.

| Province | Number of respondents | Number of sugarcane harvesters classified by type | | | | Total number of harvesters |
|---|---|---|---|---|---|---|
| | | New sugarcane harvesters | | Used sugarcane harvesters | | |
| | | Large-scale | Small-scale | Large-scale | Small-scale | |
| Udon Thani | 10 | 1 | 3 | 6 | 3 | 13 |
| Nakhon Ratchasima | 10 | 6 | 3 | 2 | 0 | 11 |
| Khon Kaen | 10 | 8 | 2 | 0 | 0 | 10 |
| Total | 30 | 15 | 8 | 8 | 3 | 34 |

Source: Survey data, 2020.

All 30 farmers, having invested in a sugarcane harvester, provided their farm and services to other nearby sugarcane farmers through two service channels: providing services to farmers directly; and through the sugar factory. Direct harvesting services to farmers were primarily found in Udon Thani and Nakhon Ratchasima. Upon being contracted by a farmer, the sugarcane harvester owner would survey the sugarcane plot, determine the harvesting queue, harvest and transport the sugarcane to the sugar factory, and collect the service charge in cash from the farmers. Providing services through the sugar factory was predominant in Khon Kaen, where the sugarcane harvester owner would be contracted by the sugar factory according to a cut-to-order queue. The factory would survey the sugarcane plot of the farmer and issue a cutting order. After cutting and transporting the sugarcane to the factory, the harvesting and transporting service charges would be paid in the form of credits by the factory with the average payment period of 18.5 days. The service expenses would be deducted from the farmer's revenue of sugarcane sold to the factory.

In the production year 2018/19, the farmers had an average sugarcane cutting area of 239.93 hectares per person, with an average harvested sugarcane quantity of 17,279.61 tons per person. The average sugarcane cutting area in the production year 2019/20 decreased to 219.58 hectares per person, and the average harvested sugarcane quantity plummeted to 10,494.14 tons per person, accounting for a decreased rate of 8.48% and 39.27%,

respectively. The dramatic decreases of the harvested sugarcane areas and quantities were suffered from drought over the northeastern region, which resulted in the cane ratoon being damaged, leading some farmers to grow other alternative crops, like cassava and maize. Considering the harvested sugarcane quantity in the production year 2019/20 classified by the type of sugarcane harvester, we found that the new large-scale sugarcane harvester cut 12,294.29 tons per year, including sugarcane harvested from the owner's area and service area at 5,121.43 and 7,172.86 tons, respectively. The new small-scale sugarcane harvester cut 10,221.88 tons per year, including sugarcane harvested from the owner's area and service area at 4,793.75 and 5,428.13 tons, respectively. The used large-scale sugarcane harvester cut 8,326.43 tons per year including sugarcane harvested from the owner's area and service area at 5,699.29 and 2,627.14 tons, respectively. And the used small-scale sugarcane harvester cut 8,000.00 tons per year including sugarcane harvested from the owner area and service area with 3,000.00 and 5,000.00 tons, respectively (Table 2). The results indicated that the used large-scale sugarcane harvesters were aimed at use in the owner's area, whereas other types of sugarcane harvesters were more likely used in service areas.

**Table 2** Number of tons of harvested sugarcane in the production year 2019/20, asset value, and the use of labor in sugarcane business management.

| Description | New sugarcane harvesters | | Used sugarcane harvesters | |
|---|---|---|---|---|
| | Large-scale (n=15) | Small-scale (n=8) | Large-scale (n=8) | Small-scale (n=3) |
| 1. Sugarcane harvested areas (hectares/harvester) | 281.60 | 219.30 | 140.90 | 120.00 |
| Farmer's own plots (hectares /harvester) | 97.03 | 106.10 | 88.79 | 44.80 |
| Harvesting service plots (hectares/harvester) | 184.57 | 113.20 | 52.11 | 75.20 |
| 2. Number of harvested sugarcane (tons/harvester) | 12,294.29 | 10,221.88 | 8,326.43 | 8,000.00 |
| Farmer's own plots (tons/harvester) | 5,121.43 (41.66%) | 4,793.75 (46.90%) | 5,699.29 (68.45%) | 3,000.00 (37.50%) |
| Harvesting service plots (tons/harvester) | 7,172.86 (58.34%) | 5,428.13 (53.10%) | 2,627.14 (31.55%) | 5,000.00 (62.50%) |
| 3. Yield per hectare (ton/hectare) | 43.66 | 46.61 | 59.09 | 66.67 |
| Farmer's own plots (ton/hectare) | 52.78 | 45.18 | 64.19 | 66.96 |
| Harvesting service plots (ton/hectare) | 38.86 | 47.95 | 50.42 | 66.49 |
| 4. Investment in assets for a set of combine harvester business | 661,825.62 | 519,487.99 | 377,464.04 | 311,822.78 |
| Land (USD) | 13,777.96 | 8,186.90 | 18,827.02 | 15,974.44 |
| Storage housing (USD) | 5,819.26 | 4,992.01 | 12,551.35 | 7,987.22 |
| Sugarcane harvester (USD) | 387,907.46 | 254,961.66 | 187,154.27 | 119,424.92 |
| Truck (USD) | 226,358.07 | 226,358.07 | 137,685.40 | 137,685.40 |
| Pick-up truck (USD) | 14,043.17 | 15,799.48 | 18,005.48 | 29,952.08 |
| Other machinery and agricultural equipment (USD) | 13,919.71 | 9,189.87 | 3,240.53 | 798.72 |
| 5. Labor for machinery driving and maintenance | | | | |
| 5.1 Family labor | | | | |
| Number of labor (person) | 2 | 2 | 3 | 1 |
| Number of man-day (day) | 74 | 73 | 80 | 97 |
| Wage rate (USD/ton) | 0.29 | 0.27 | 0.47 | 0.23 |
| 5.2 Hired labor | | | | |
| Number of labor (person) | 6 | 6 | 6 | 4 |
| Number of man-day (day) | 84 | 87 | 92 | 97 |
| Wage rate for the sugarcane harvester driver (USD/ton) | 0.29 | 0.36 | 0.33 | 0.38 |
| Wage rate for the truck driver (USD/ton) | 0.45 | 0.55 | 0.51 | 0.45 |
| Wage rate for other works (USD/ton) | 0.11 | 0.11 | 0.17 | - |

Source: author's calculation.

Asset investments in agricultural machinery and equipment necessary for sugarcane cutting and transportation services included buying land, storage housing cost, and investing in various agricultural machinery, varied by the type and size of the sugarcane harvester (Table 2). The total value of all assets in the investment of a new large-scale sugarcane harvester was USD 661,825.62, and USD 519,487.99 in the investment of a new small-scale sugarcane harvester. In the investment of used sugarcane harvesters, the total value of all assets in large harvesters was USD 377,464.04, whereas the total assets involved in small harvesters was USD 311,822.78. The

highest value within the total investment was the cost of the sugarcane harvester. The average price of a new large-scale sugarcane harvester was USD 387,907.46, accounting for 58.61% of the total value of all assets. The average price of a new small-scale sugarcane harvester was USD 254,961.66, which was 49.08% of the value of all assets. For used sugarcane harvesters, large-scale harvesters had an average value of USD 187,154.27, which was 49.58% of the value of all assets; whereas the small-scale sugarcane harvester averaged USD 119,424.92 or 38.30% of the value of all assets. The next highest asset value was that of the truck(s). From the survey, large-scale sugarcane combine harvesters required six trucks (three trailers) as the minimum for transportation circulation, while a requirement of four trucks (two trailers) was adequate for a small sugarcane combine harvester. The average truck price was USD 24,506.36, as most were used trucks, while the average price of the trailer was USD 88,672.65.

Manual labor in sugarcane harvesting services consisted of family labor (1-3 individuals) and hired labor (4-6 individuals), which varied by the type and size of the farm's sugarcane harvester. Family labor included such responsibilities as management, accounting, and machinery and vehicle maintenance, as well as operating the harvester(s) and truck(s). The responsibilities of the hired labor force consisted of driving the harvesters and trucks, repairing machinery and vehicles, collecting dropped sugarcane, and transporting fuel and spare parts for maintenance. The number of man-days for the hired workers was dependent on the factory's sugarcane crushing period, where 84-97 man-days were accounted for in the production year 2019/20.

*3.2 Costs and revenues of the sugarcane harvester business*

The analysis of the costs and revenues of sugarcane cutting and transporting services in the production year 2019/20, which was the base year of the study, were classified by the type of sugarcane harvesters; new and used harvesters, consisting of both large and small-scale harvesters (Table 3).

**Table 3** Average costs and revenues of sugarcane harvester services in the production year 2019/20 (base year).

| Description | New sugarcane harvesters | | Used sugarcane harvesters | |
|---|---|---|---|---|
| | Large-scale | Small-scale | Large-scale | Small-scale |
| 1. Harvesting costs (USD/ton) | 5.01 | 4.57 | 5.34 | 4.56 |
| 1.1 Fixed costs | 1.95 | 1.60 | 1.71 | 1.18 |
| Depreciation | 1.85 | 1.52 | 1.60 | 1.17 |
| Insurance | 0.10 | 0.08 | 0.11 | 0.01 |
| 1.2 Variable costs | 3.06 | 2.97 | 3.63 | 3.38 |
| Labor | 0.40 | 0.46 | 0.50 | 0.38 |
| Fuel | 1.68 | 1.83 | 2.00 | 2.16 |
| Maintenance | 0.94 | 0.63 | 1.09 | 0.80 |
| Others | 0.04 | 0.05 | 0.04 | 0.04 |
| 2. Transportation costs (USD/ton) | 2.63 | 3.57 | 2.95 | 3.01 |
| 2.1 Fixed costs | 1.03 | 1.24 | 1.00 | 1.04 |
| Depreciation | 0.84 | 1.01 | 0.80 | 0.83 |
| Insurance | 0.19 | 0.23 | 0.20 | 0.21 |
| 2.2 Variable costs | 1.60 | 2.33 | 1.95 | 1.97 |
| Labor | 0.45 | 0.55 | 0.51 | 0.45 |
| Fuel | 0.92 | 1.50 | 1.20 | 1.27 |
| Maintenance | 0.23 | 0.28 | 0.24 | 0.25 |
| 3. Management costs (USD/ton) | 0.29 | 0.27 | 0.47 | 0.23 |
| 4. Total costs (USD/ton) | 7.93 | 8.41 | 8.76 | 7.80 |
| 5. Total revenues (USD/ton) | 10.34 | 11.40 | 10.49 | 9.58 |
| 5.1 Revenue from harvesting | 6.24 | 6.39 | 6.20 | 5.75 |
| 5.2 Revenue from transportation | 4.10 | 5.01 | 4.29 | 3.83 |
| 6. Profit (USD/ton) | 2.41 | 2.99 | 1.73 | 1.78 |
| 7. Annual harvesting quantity (tons) | 12,294.29 | 10,221.88 | 8,326.43 | 8,000.00 |

Source: author's calculation.

The new large-scale sugarcane harvester provided average sugarcane cutting and transporting services of 12,294.29 tons/year. The total costs were USD 7.93/ton; consisting of the cost of cutting the sugarcane (USD 5.01/ton), sugarcane transportation (USD 2.63/ton), and the cost of management (USD 0.29/ton). Farmers subsequently earned an average of USD 6.24/ton from cutting sugarcane and USD 4.10/ton from transportation, totaling USD 10.34/ton. Their net income, after expenses, was approximately USD 2.41/ton. New small-scale sugarcane harvesters provided average cutting and transporting services of 10,221.88 tons/year. The total costs were USD 8.41/ton, consisting of USD 4.57/ton for sugarcane cutting, USD 3.57/ton for transportation, and USD

0.27/ton for managerial expenses. The farmers earned an average income from sugarcane-cutting services of USD 6.39/ton and transportation services of USD 5.01/ton, resulting in a total income of USD 11.40/ton. The farmers, therefore, earned a total net profit of USD 2.99/ton.

The used large-scale sugarcane harvesters provided 8,326.43 tons/year for both cutting and transporting services. Total costs were USD 8.76/ton, consisting of USD 5.34/ton for cutting, USD 2.95/ton for transportation, and USD 0.47/ton for managerial expenses. The average income earned was USD 6.20/ton for cutting and USD 4.29/ton for transportation, totaling USD 10.49/ton. The farmers earned a total net profit of USD 1.73/ton. Notably, the used small-scale sugarcane harvesters cut just less than that of the large-scale harvesters at 8,000.00 tons/year. The total cost was USD 7.80/ton, consisting of USD 4.56/ton for sugarcane cutting, USD 3.01/ton for transportation, and USD 0.23/ton for managerial expenses. The farmers earned an average income from sugarcane cutting services of USD 5.75/ton and transportation services of USD 3.83/ton, totaling USD 9.58/ton, resulting in an average total net profit of USD 1.78/ton.

The proportion of the cost structures for sugarcane cutting and transporting varied according to the type of sugarcane combine harvester. For example, new sugarcane combine harvesters had a relatively high cost for depreciation, whereas used sugarcane harvesters had a relatively high cost for fuel and maintenance. In the same condition of usage, the total harvesting cost of small-scale a sugarcane combine harvester was less expensive than a large-scale sugarcane combine harvester. This proved consistent with previous studies on the costs of commercial sugarcane combine harvesters [11,34,35]. The calculated costs of sugarcane transportation depended on the distance from the sugarcane plot to the sugar factory, varying between USD 2.63-3.57/ton, which was in the range of acceptable transportation costs from the previous related study accounting for USD 1.37-4.15/ton [34].

As fuel and maintenance costs are the predominant variable costs within the sugarcane harvester business, sugarcane farmers interested in investing in a sugarcane harvester must focus on controlling or reducing these costs by purchasing a sugarcane harvester, which is suitable for their geographical conditions and planting pattern of the farm's sugarcane plots. The small-scale sugarcane harvester, for example, is more conducive to smaller plots, with short groove lengths, and shorter distances between cane rows. This information should be added as a recommendation that a small sugarcane harvester is appropriate for a sugarcane plot with a row spacing of 1.31-1.50 m, whereas a large sugarcane harvester is suitable for a sugarcane plot with a row spacing of 1.51-1.90 m [14].

According to a study of manual sugarcane harvesting costs in northeastern Thailand during the 2019/20 production year, the cost per ton for cutting green sugarcane via manual labor was USD 6.85, and the cost for cutting burnt sugarcane was USD 5.98 [12]. This study pointed out that the use of a sugarcane harvester for all types of sugarcane was more cost-effective than manual harvesting, with costs ranging from USD 4.56-5.34 per ton. Therefore, large-scale farmers may be better served with a harvester, rather than the use of manual labor. Additionally, the rate for hiring a sugarcane harvester was relatively low, ranging from USD 5.75-6.39 per ton, compared to manual harvesting. This makes the harvester a cost-effective option for moderate or small-scale farmers looking to cut green cane. The findings were consistent with a study conducted in Brazil, where the cost of sugarcane harvesting using machinery was found to be lower than that of manual harvesting. The cost of sugarcane harvesting by machinery ranged from USD 9.68-10.56 per ton, while the cost of green cane harvesting through manual labor ranged from USD 14.39-15.05 per ton [7]. Large-scale manual harvesting is both labor-intensive and time-consuming, and often involves burning the sugarcane before harvesting, which results in high $CO_2$ and PM 2.5 emissions. Many previous studies indicated that mechanical harvesting significantly reduces costs and time for large-scale sugarcane farms, as well as provides several environmental benefits [7,14,36]. In Thailand, green cane harvesting via a combine harvester can generate a faster queue of delivery to mills and an increase of cane price by USD 1 per ton. Medium-scale farms have the option to either purchase a sugarcane harvester for use on their own farms and provide services to other farmers, or to hire a sugarcane harvester in their local area. Small-scale farms, on the other hand, may consider hiring service providers in their local area as a suitable alternative for green cane harvesting, due to the lack of capital and the limited size of their farms. Mechanization in agriculture is often viewed as harming employment opportunities for countries with high population densities and a surplus of labor. However, the mechanization of power-intensive operations, such as sugarcane harvesting, is less likely to have minimal effects on labor displacement [36]. While sugarcane harvesting mechanization in Brazil created less jobs, it also led to better working conditions and higher income for workers [7]. The study found that mechanization of sugarcane harvesting in the study area helped to reduce the shortage of agricultural labor during the harvesting season, lower costs, save time, and allowed farmers to quickly prepare for the next crop cultivation.

*3.3 Investment feasibility analysis*

The cash flows of costs and revenues of sugarcane combine harvester services were estimated over 12 years, with the assumption that variable costs and revenues increased by 5% per year. The present value of costs and revenues were adjusted by the discount rate of 6.11% to analyze the feasibility of sugarcane harvester investments. We found that investments for all types of sugarcane combine harvesters in the study areas were acceptable. A new large-scale sugarcane harvester had a discounted payback period of 10.75 years, a net present value of USD 152,630, a benefit-cost ratio of 1.11, and an internal rate of return on investment of 9.25% (Table 8). Additionally, the $SVT_C$ and $SVT_B$ determined that business costs can increase as high as 11.38%, and business revenues can reduce by up to 10.22%. The investment of a new small-scale harvester provided the best performance with a discounted payback period of 9.71 years, a net present value of USD 196,304, a benefit-cost ratio of 1.17, and an internal rate of return on investment of 11.15%. Business costs can increase by 16.99%, and the business revenues can reduce by up to 14.52%.

A used large-scale sugarcane harvester had a discounted payback period of 11.12 years, a net present value of USD 70,201, a benefit-cost ratio of 1.07, and an internal rate of return on the investment of 8.66%. The business cost can increase as much as 7.47%, and the business revenue can decrease up to 6.95%. The investment of a used small-scale sugarcane harvester had a discounted payback period of 10.56 years, a net present value of USD 79,476 USD, a benefit-cost ratio of 1.10, and an internal rate of return on investment of 9.56%. The business cost can increase as much as 9.87%, and the business revenue can decrease as much as 8.99%.

The results of the investment feasibilities of sugarcane harvester services were consistent with previous related studies. For example, an investment in a new sugarcane harvester was often considered more worthy than a used sugarcane harvester [34]. This finding was in line with a study conducted by Banchi *et al*., 2019; which revealed that newer sugarcane harvesters had lower costs and greater efficiency than older ones [37]. In the same condition of usage, a small-scale sugarcane harvester was more worthy of investment than a large-scale sugarcane harvester [8,34]. In some cases, large-scale sugarcane harvesters in Chaiyaphum and Kanchanaburi provinces produced a negative net present value and were rejected for investment [8,34]. A feasibility study in the sugar-energy sector in Brazil found that the investment in new large-scale sugarcane harvesters had negative internal rates of return (IRR). Outsourcing harvesters, therefore, was deemed economically superior to purchasing harvesters [28].

The amount of harvested sugarcane quantity per season was an important factor that affected the cost of sugarcane harvesting and the worthiness of sugarcane harvester investment. This is consistent with the findings of Banchi et al, 2019; which further demonstrated that higher cane yield resulted in lower operating costs for harvesting machines [37]. Therefore, sugarcane farmers must consider the potential harvested sugarcane area and quantity when choosing the appropriate type of combine harvester. This suggestion aligns with their findings that selecting the appropriate size of a sugarcane harvester is crucial. Farmers must avoid the oversizing of machines which will affect its fixed production costs [28]. The investment in new machinery, whether large-scale or small-scale, was considered appropriate for an annual harvest of more than 16,000 and 13,000 tons, respectively; whereas the investment in large-scale or small-scale used machinery was estimated to be appropriate for an annual harvest of more than 11,000 and 10,000 tons, respectively.

Further past studies conducted worldwide found that various factors affect the cost efficiency, feasibility, and break-even point of sugarcane harvester investments. In Brazil, the mechanized harvesting system using a two-row harvester was found to be more economically viable and provided greater cash flow, compared to the single-row harvester [27]. A study in Louisiana, USA, showed that transport operations between the farm and mill greatly impacted the efficiency of harvest operations. Every minute a truck waited at the mill increased total harvest fuel and labor costs by approximately USD 1.30 per acre. [22].

**Table 4** Cash flows and present values of costs and benefits for the investment in a new large-scale sugarcane harvester.

Unit: USD

| Description | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 | 2026/27 | 2027/28 | 2028/29 | 2029/30 | 2030/31 |
| 1. Cash Benefit: | | | | | | | | | | | | | |
| 1.1 Revenues from sugarcane harvesting and transporting services | 0 | 127,130 | 133,487 | 140,161 | 147,169 | 154,527 | 162,254 | 170,366 | 178,885 | 187,829 | 197,220 | 207,081 | 217,435 |
| 1.2 Revenues from selling land | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24,743 |
| 1.3 Revenues from selling other farm assets (Salvage value) | 0 | 0 | 0 | 0 | 0 | 0 | 301 | 0 | 0 | 0 | 0 | 0 | 252,334 |
| 1.4 Total Benefits | 0 | 127,130 | 133,487 | 140,161 | 147,169 | 154,527 | 162,555 | 170,366 | 178,885 | 187,829 | 197,220 | 207,081 | 494,512 |
| 2. Cash Costs: | | | | | | | | | | | | | |
| 2.1 Purchasing farm assets | 661,826 | 0 | 0 | 0 | 0 | 0 | 0 | 1,505 | 0 | 0 | 0 | 0 | 0 |
| 2.2 Operating costs (Labor, fuel, maintenance, and others) | 0 | 60,772 | 63,810 | 67,001 | 70,351 | 73,868 | 77,562 | 81,440 | 85,512 | 89,787 | 94,277 | 98,991 | 103,940 |
| 2.3 Insurance costs | 0 | 3,540 | 3,540 | 3,540 | 3,540 | 3,540 | 3,540 | 3,540 | 3,540 | 3,540 | 3,540 | 3,540 | 3,540 |
| 2.4 Total Costs | 661,826 | 64,311 | 67,350 | 70,541 | 73,891 | 77,408 | 81,102 | 86,485 | 89,052 | 93,327 | 97,817 | 102,530 | 107,480 |
| 3. Net Benefits (3 = 1.4-2.4) | -661,826 | 62,819 | 66,136 | 69,620 | 73,278 | 77,119 | 81,453 | 83,881 | 89,833 | 94,502 | 99,404 | 104,551 | 387,032 |
| 4. Present Value of Total Benefits (PVB) | 0 | 119,810 | 118,556 | 117,316 | 116,089 | 114,875 | 113,884 | 112,484 | 111,307 | 110,143 | 108,991 | 107,850 | 242,718 |
| 5. Present Value of Total Costs (PVC) | 661,826 | 60,608 | 59,817 | 59,043 | 58,286 | 57,545 | 56,819 | 57,101 | 55,410 | 54,727 | 54,057 | 53,399 | 52,754 |
| 6. PVB-PVC (6 = 4-5) | -661,826 | 59,201 | 58,739 | 58,273 | 57,803 | 57,330 | 57,065 | 55,382 | 55,897 | 55,416 | 54,934 | 54,451 | 189,964 |
| 7. Sums of PVB | 1,494,022 | | | | | | | | | | | | |
| 8. Sums of PVC | 1,341,392 | | | | | | | | | | | | |
| 9. Net Present Value (9 = 7-8) | 152,630 | | | | | | | | | | | | |

Source: author's calculation.

**Table 5** Cash flows and present values of costs and benefits for the investment in a new small-scale sugarcane harvester.

Unit: USD

| Description | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 | 2026/27 | 2027/28 | 2028/29 | 2029/30 | 2030/31 |
| 1. Cash Benefit: | | | | | | | | | | | | | |
| 1.1 Revenues from sugarcane harvesting and transporting services | 0 | 116,549 | 122,376 | 128,495 | 134,920 | 141,666 | 148,749 | 156,187 | 163,996 | 172,196 | 180,806 | 189,846 | 199,338 |
| 1.2 Revenues from selling land | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14,702 |
| 1.3 Revenues from selling other farm assets (Salvage value) | 0 | 0 | 0 | 0 | 0 | 0 | 399 | 0 | 0 | 0 | 0 | 0 | 202,463 |
| 1.4 Total Benefits | 0 | 116,549 | 122,376 | 128,495 | 134,920 | 141,666 | 149,149 | 156,187 | 163,996 | 172,196 | 180,806 | 189,846 | 416,504 |
| 2. Cash Costs: | | | | | | | | | | | | | |
| 2.1 Purchasing farm assets | 519,488 | 0 | 0 | 0 | 0 | 0 | 0 | 1,997 | 0 | 0 | 0 | 0 | 0 |
| 2.2 Operating costs (Labor, fuel, maintenance, and others) | 0 | 56,940 | 59,787 | 62,777 | 65,915 | 69,211 | 72,672 | 76,305 | 80,121 | 84,127 | 88,333 | 92,750 | 97,387 |
| 2.3 Insurance costs | 0 | 3,169 | 3,169 | 3,169 | 3,169 | 3,169 | 3,169 | 3,169 | 3,169 | 3,169 | 3,169 | 3,169 | 3,169 |

**Table 5** (Continued) Cash flows and present values of costs and benefits for the investment in a new small-scale sugarcane harvester.

Unit: USD

| Description | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 | 2026/27 | 2027/28 | 2028/29 | 2029/30 | 2030/31 |
| 2.4 Total Costs | 519,488 | 60,110 | 62,957 | 65,946 | 69,085 | 72,381 | 75,841 | 81,472 | 83,290 | 87,296 | 91,502 | 95,919 | 100,556 |
| 3. Net Benefits (3 = 1.4-2.4) | -519,488 | 56,439 | 59,420 | 62,549 | 65,835 | 69,285 | 73,308 | 74,715 | 80,706 | 84,900 | 89,303 | 93,927 | 315,947 |
| 4. Present Value of Total Benefits (PVB) | 0 | 109,838 | 108,689 | 107,552 | 106,427 | 105,314 | 104,492 | 103,122 | 102,043 | 100,976 | 99,919 | 98,874 | 204,429 |
| 5. Present Value of Total Costs (PVC) | 519,488 | 56,648 | 55,915 | 55,198 | 54,495 | 53,807 | 53,133 | 53,791 | 51,825 | 51,190 | 50,567 | 49,956 | 49,355 |
| 6. PVB-PVC (6 = 4-5) | -519,488 | 53,190 | 52,774 | 52,354 | 51,932 | 51,506 | 51,358 | 49,330 | 50,218 | 49,785 | 49,352 | 48,918 | 155,074 |
| 7. Sums of PVB | 1,351,674 | | | | | | | | | | | | |
| 8. Sums of PVC | 1,155,370 | | | | | | | | | | | | |
| 9. Net Present Value (9 = 7-8) | 196,304 | | | | | | | | | | | | |

Source: author's calculation.

**Table 6** Cash flows and present values of costs and benefits for the investment in a used large-scale sugarcane harvester.

Unit: USD

| Description | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 | 2026/27 | 2027/28 | 2028/29 | 2029/30 | 2030/31 |
| 1. Cash Benefit: | | | | | | | | | | | | | |
| 1.1 Revenues from sugarcane harvesting and transporting services | 0 | 87,377 | 91,746 | 96,333 | 101,150 | 106,207 | 111,518 | 117,093 | 122,948 | 129,096 | 135,550 | 142,328 | 149,444 |
| 1.2 Revenues from selling land | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33,811 |
| 1.3 Revenues from selling other farm assets (Salvage value) | 0 | 0 | 0 | 0 | 0 | 0 | 648 | 0 | 0 | 0 | 0 | 0 | 121,681 |
| 1.4 Total Benefits | 0 | 87,377 | 91,746 | 96,333 | 101,150 | 106,207 | 112,166 | 117,093 | 122,948 | 129,096 | 135,550 | 142,328 | 304,935 |
| 2. Cash Costs: | | | | | | | | | | | | | |
| 2.1 Purchasing farm assets | 377,464 | 0 | 0 | 0 | 0 | 0 | 0 | 3,241 | 0 | 0 | 0 | 0 | 0 |
| 2.2 Operating costs (Labor, fuel, maintenance, and others) | 0 | 50,441 | 52,963 | 55,611 | 58,392 | 61,311 | 64,377 | 67,596 | 70,976 | 74,524 | 78,251 | 82,163 | 86,271 |
| 2.3 Insurance costs | 0 | 2,575 | 2,575 | 2,575 | 2,575 | 2,575 | 2,575 | 2,575 | 2,575 | 2,575 | 2,575 | 2,575 | 2,575 |
| 2.4 Total Costs | 377,464 | 53,017 | 55,539 | 58,187 | 60,967 | 63,887 | 66,953 | 73,412 | 73,551 | 77,100 | 80,826 | 84,739 | 88,847 |
| 3. Net Benefits (3 = 1.4-2.4) | -377,464 | 34,360 | 36,207 | 38,146 | 40,182 | 42,320 | 45,213 | 43,682 | 49,397 | 51,996 | 54,724 | 57,589 | 216,089 |
| 4. Present Value of Total Benefits (PVB) | 0 | 82,346 | 81,484 | 80,632 | 79,788 | 78,954 | 78,582 | 77,311 | 76,502 | 75,702 | 74,910 | 74,126 | 149,669 |
| 5. Present Value of Total Costs (PVC) | 377,464 | 49,964 | 49,327 | 48,703 | 48,092 | 47,493 | 46,906 | 48,470 | 45,766 | 45,211 | 44,667 | 44,133 | 43,608 |
| 6. PVB-PVC (6 = 4-5) | -377,464 | 32,382 | 32,158 | 31,929 | 31,696 | 31,461 | 31,676 | 28,841 | 30,736 | 30,490 | 30,242 | 29,993 | 106,061 |
| 7. Sums of PVB | 1,010,004 | | | | | | | | | | | | |
| 8. Sums of PVC | 939,803 | | | | | | | | | | | | |
| 9. Net Present Value (9 = 7-8) | 70,201 | | | | | | | | | | | | |

Source: author's calculation.

**Table 7** Cash flows and present values of costs and benefits for the investment in a used small-scale sugarcane harvester.

Unit: USD

| Description | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | Year 11 | Year 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 | 2026/27 | 2027/28 | 2028/29 | 2029/30 | 2030/31 |
| 1. Cash Benefit: | | | | | | | | | | | | | |
| 1.1 Revenues from sugarcane harvesting and transporting services | 0 | 76,677 | 80,511 | 84,537 | 88,764 | 93,202 | 97,862 | 102,755 | 107,893 | 113,287 | 118,952 | 124,899 | 131,144 |
| 1.2 Revenues from selling land | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28,688 |
| 1.3 Revenues from selling other farm assets (Salvage value) | 0 | 0 | 0 | 0 | 0 | 0 | 160 | 0 | 0 | 0 | 0 | 0 | 104,258 |
| 1.4 Total Benefits | 0 | 76,677 | 80,511 | 84,537 | 88,764 | 93,202 | 98,022 | 102,755 | 107,893 | 113,287 | 118,952 | 124,899 | 264,090 |
| 2. Cash Costs: | | | | | | | | | | | | | |
| 2.1 Purchasing farm assets | 311,823 | 0 | 0 | 0 | 0 | 0 | 0 | 799 | 0 | 0 | 0 | 0 | 0 |
| 2.2 Operating costs (Labor, fuel, maintenance, and others) | 0 | 44,763 | 47,001 | 49,351 | 51,818 | 54,409 | 57,130 | 59,986 | 62,986 | 66,135 | 69,442 | 72,914 | 76,559 |
| 2.3 Insurance costs | 0 | 1,728 | 1,728 | 1,728 | 1,728 | 1,728 | 1,728 | 1,728 | 1,728 | 1,728 | 1,728 | 1,728 | 1,728 |
| 2.4 Total Costs | 311,823 | 46,491 | 48,729 | 51,079 | 53,547 | 56,138 | 58,858 | 62,513 | 64,714 | 67,863 | 71,170 | 74,642 | 78,288 |
| 3. Net Benefits (3 = 1.4-2.4) | -311,823 | 30,186 | 31,782 | 33,457 | 35,217 | 37,064 | 39,163 | 40,242 | 43,179 | 45,424 | 47,782 | 50,257 | 185,803 |
| 4. Present Value of Total Benefits (PVB) | 0 | 72,262 | 71,506 | 70,758 | 70,018 | 69,286 | 68,673 | 67,844 | 67,134 | 66,432 | 65,737 | 65,049 | 129,621 |
| 5. Present Value of Total Costs (PVC) | 311,823 | 43,814 | 43,279 | 42,754 | 42,239 | 41,732 | 41,235 | 41,274 | 40,267 | 39,795 | 39,331 | 38,874 | 38,425 |
| 6. PVB-PVC (6 = 4-5) | -311,823 | 28,448 | 28,227 | 28,004 | 27,779 | 27,553 | 27,437 | 26,569 | 26,867 | 26,637 | 26,406 | 26,174 | 91,196 |
| 7. Sums of PVB | 884,319 | | | | | | | | | | | | 884,319 |
| 8. Sums of PVC | 804,843 | | | | | | | | | | | | 804,843 |
| 9. Net Present Value (9 = 7-8) | 79,476 | | | | | | | | | | | | 79,476 |

Source: author's calculation.

**Table 8** Financial feasibility index of the investment in various sugarcane harvesters.

| Description | New sugarcane harvester | | Used sugarcane harvester | |
|---|---|---|---|---|
| | Large-scale | Small-scale | Large-scale | Small-scale |
| Discounted Payback Period (DPP) | 10.75 | 9.71 | 11.12 | 10.56 |
| Net Present Value (NPV) | 152,630 | 196,304 | 70,201 | 79,476 |
| Benefit-Cost Ratio (BCR) | 1.11 | 1.17 | 1.07 | 1.10 |
| Rate of Return on Investment (IRR) | 9.25 | 11.15 | 8.66 | 9.56 |
| Switching Value Test of Costs ($SVT_C$) | 11.38 | 16.99 | 7.47 | 9.87 |
| Switching Value Test of Benefits ($SVT_B$) | 10.22 | 14.52 | 6.95 | 8.99 |

Source: author's calculation.

## 4. Conclusion

Our findings showed that a new small-scale sugarcane harvester provided the highest positive NPV of USD 196,304, indicating the worthiest investment; followed by a new large-scale sugarcane harvester, a used small-scale sugarcane harvester, and a used large-scale sugarcane harvester, with USD 152,630, USD 79,476, and USD 70,201, respectively. New harvesters were considered to be a more favorable investment than used sugarcane harvesters, just as small-scale sugarcane harvesters were judged to be more worthy of investment than large-scale sugarcane harvesters used under similar conditions. Ultimately, northeast Thailand's sugarcane farmers must essentially select a machine size suitable for their geographical conditions and planting patterns of their sugarcane plots.

## 5. Ethical approval

This study was conducted according to the standards and basis for approval by the Khon Kaen University Ethics Committee in Human Research (Reference number: HE633203, Date of approval: January 12, 2021).

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