Social Life Cycle Assessment of Green and Burnt Manual Sugarcane Harvesting in the Northeastern Thailand

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ARTICLE INFO

Received: 29 Sep 2021
Received in revised: 11 Jan 2022
Accepted: 18 Jan 2022
Published online: 11 Feb 2022
DOI: 10.32526/ennrj/20/202100190

Keywords:
Social life cycle assessment/ S-LCA/ Social performance/ Sugarcane/ Green and burnt sugarcane

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ABSTRACT

Despite green sugarcane harvesting being promoted in Thailand, with some limitations on the use of harvesting machines, green sugarcane harvesting is practiced manually in many sugarcane fields. Although the environmental benefit seems clear, this harvesting practice's social implications are yet unknown. This study assessed social performances of green and burnt manual sugarcane harvesting in North-Eastern Thailand, the region hosting the largest sugarcane plantation area, using the Social Life Cycle Assessment technique. Data collection was undertaken by surveys. The performance reference points method was applied to assess the different stakeholder's social performances. Key stakeholder groups examined were workers, local community, and farm owners. The main social issues included in this study are fair wages, working conditions, health and safety, local employment, economic development, social responsibility, and satisfaction of occupation. The results showed that the social performances of green and burnt sugarcane harvesting were generally similar except for the local community group. This is mainly due to the health impact of sugarcane burning on the local community. Different issues cause the farmers to harvest the burnt sugarcane; for example, labor shortage in the harvesting season and the difficult working conditions for green harvesting, causing the farm owners to bear higher costs. For these reasons, mechanized harvesting is suggested to help promote green harvesting to reduce local air pollution. However, technology development is in urgent need to make the harvesting machines more affordable and applicable to all geographical conditions.

1. INTRODUCTION

Sugarcane plays a vital role in the Thai economy; the country is the world's third-largest sugar exporter (Workman, 2020). Sugarcane is not only a feedstock for food; it is also a source of bio-energy such as bagasse-based electricity and molasses-based ethanol (Gheewala et al., 2019). Every year, Thailand produces a large amount of sugarcane to serve the sugar industry. In 2021, the nation grew more than 66 million tonnes of sugarcane (OCSB, 2021).

Despite its economic importance, the sugar industry has come under scrutiny for its impact on air quality, caused by burning sugarcane tops and leaves before harvesting-so-called "burnt harvesting". For this reason, via the office of the cane and sugar board, the Thai government has promoted "green harvesting", which requires no sugarcane burning before harvesting by means of mechanized sugarcane harvesting (Thansettakij Multimedia, 2019). However, to date, there are still some issues associated with using harvesting machines for the Thai sugarcane farmers, including the high cost of machines and the required conditions of sugarcane fields to use the harvesting machines (Chaya et al., 2019). Therefore,

Citation: Thuayjan T, Prasara-A J, Boonkum P, Gheewala SH. Social life cycle assessment of green and burnt manual sugarcane harvesting in the Northeastern Thailand. Environ. Nat. Resour. J. 2022;20(3):246-256. (https://doi.org/10.32526/ennrj/20/202100190)

in many sugarcane plantations in Thailand, green sugarcane harvesting still depends on manual labor.

Sustainable agriculture is one of the main goals emphasized in Thailand's sustainable development goals (Department of International Organizations, 2021). Life cycle thinking considers every stage of a product/service, from acquiring raw materials, transportation and distribution of product, use, reuse/processing, and waste management after use. This concept helps prevent shifting problems from one stage to another. Life cycle thinking is a useful concept for considering the environmental, economic, and social dimensions along the life cycle of a product or service, leading to sustainable development (Valdivia et al., 2013). The life cycle approach can thus support the transition to sustainable agriculture. Moreover, human well-being is identified as the main scope of sustainable development. Therefore, social consideration in the life cycle of the product is promoted to enhance sustainability (Rezaei Kalvani et al., 2021).

Some previous studies compared the life cycle environmental impacts of green and burnt sugarcane harvesting practices. They showed that green harvesting could help reduce the environmental impacts (de Oliveira Bordonal et al., 2013; Pongpat et al., 2017). Some studies assessed the health impacts of burnt sugarcane harvesting on workers and locals living near the sugarcane fields (Barbosa et al., 2012; Matsuda et al., 2020). Although there have been some studies on the environmental and health aspects of green and burnt sugarcane harvesting, research on the social issues of these harvesting approaches on a variety of stakeholder groups is still limited.

Social Life Cycle Assessment (S-LCA) is a technique used to assess socio-economic and social effects (both positive and negative) that may occur throughout the product's life cycle, involving different stakeholders (UNEP, 2020). This method could help identify the social effects of green and burnt manual sugarcane harvesting on different stakeholders involved. A few previous S-LCA studies on sugarcane reported some social issues in sugarcane cultivation such as low wages, health and safety for workers, and air pollution for the local community (Prasara-A and Gheewala, 2018; Sawaengsak et al., 2019). However, the social effects of stakeholders involved in specific sugarcane harvesting practices, i.e., green and burnt harvesting, are yet unknown. This study compares the socio-economic and social performances of green and burnt manual sugarcane harvesting approaches using the S-LCA technique. The results of this study can help identify the social hotspots where improvement is needed, to help endorse green harvesting in order to reduce air pollution from cane trash burning. Moreover, it can be used to make recommendations to improve the social conditions of the stakeholders involved. In addition, the methodology used in this study could be applied to other agricultural products.

2. METHODOLOGY

The methods used for this study are detailed in the following sub-sections.

2.1 Context of the site studied

The selected study area was in Udon Thani Province, as this province has the largest sugarcane plantation area in the nation (OCSB, 2021). The location map of the study site is presented in Figure 1. This study site is located at the top of the North-Eastern Region of Thailand, near the Laos border. This implies that the problem of cane trash burning from this site would not only affect the local area, but it could also affect the neighboring country. Therefore, there is an urgent need to address the air emission problem of this study site. Most of the sugarcane farms in this area are small-scale farms. Both green and burnt sugarcane harvesting are prevalent in the area. Although the government is promoting harvesting machines, there are issues of them not being able to enter the fields due to the size of farms and the landscape not being suitable for their use. Therefore, human labor was primarily used to harvest green and burnt sugarcane.

2.2 Goal and scope

The goal of this study was to compare the socio-economic and social performances of green and burnt sugarcane harvesting using the Social Life Cycle Assessment (S-LCA) technique. The S-LCA study was conducted following the guidelines of UNEP (2020). There were three main groups of stakeholders included in this study, viz., workers, local community, and farm owners. The three key stakeholder groups were selected based on their relation to sugarcane cultivation and their relationships with each other. Based on the previous study on the S-LCA of sugarcane by Prasara-A and Gheewala (2018), these groups are most affected by sugarcane cultivation. Hence, they were selected to examine. In the site studied, the farm owners worked on their own farms and hired local workers. Most workers also owned sugarcane farms themselves.

Figure 1. Location map of the study site [Source: WordPress (2021)]

The system boundary of this study is shown in Figure 2. The reference unit is one rai of sugarcane plantation. Rai is an area unit used in Thailand; it equals 0.16 hectares. The system boundary of this study is cradle-to-gate, including land preparation, planting, fertilization, weed and pest management, harvesting, and transportation stages. These stages were included in the system boundary due to their significant contribution to the social effects of the sugarcane industry (Prasara-A and Gheewala, 2018).

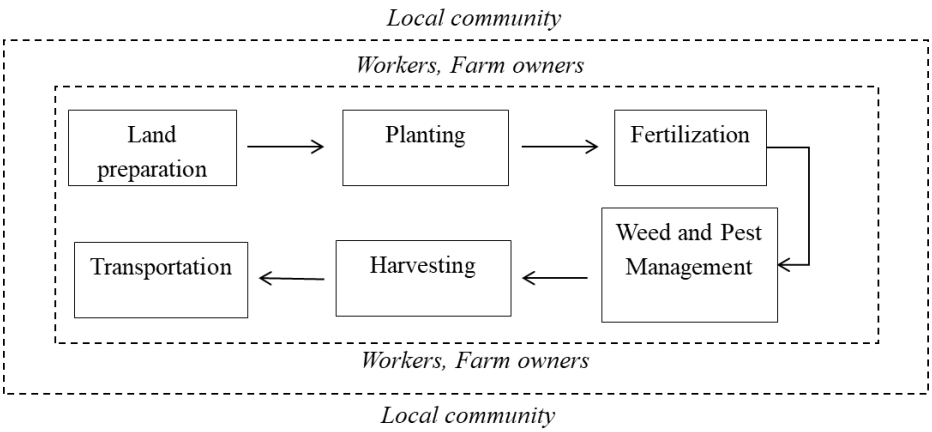

Figure 2. System boundary

2.3 Inventory analysis

A list of social issues and indicators examined are presented in Table 1. These key social issues were selected from the relevant guidelines and standards such as S-LCA guidelines of UNEP (2013), Sustainability Assessment of Food and Agriculture Systems Indicators (SAFA) (FAO, 2013), and Bonsucro standards (Bonsucro, 2014). The authors developed the social indicators (questions to ask interviewees) using definitions of social issues from the aforementioned guidelines and standards, together with discussion with experts and representatives of stakeholders involved. The Item Objective Congruence (IOC) was used to test the validity of indicators used; the indicators with IOC of 0.5 to 1.0 were acceptable. The IOC was obtained by asking three experts to provide validity scores ranging from -1 to 1. The IOC for each social indicator was calculated by dividing the sum of scores from all experts for each indicator with number of experts. The IOC calculated for each indicator used in this study are presented in Table 1.

Table 1. Social inventory analysis

Stakeholder group	Social issue	Social indicator/question	IOC[b]	Unit of indicator	Best performance
Workers	Fair wage	Do you receive a minimum wage (9 USD[a] per day)?	1.0	Yes or No	100 percent of workers answering “yes”
	Working conditions	Have you ever been forced to work at risk of danger?	1.0	Yes or No	100 percent of workers answering “no”
		Do workers of different genders working on the same kind of work receive the same wage?	1.0	Yes or No	100 percent of workers answering “yes”
	Health and Safety	Do all workers present on the field have access to first aid?	1.0	Yes or No	100 percent of workers answering “yes”
		Is there protective equipment in the workplace?	1.0	Yes or No	100 percent of workers answering “yes”
Community	Economic development	Does sugar cultivation contribute to local employment?	1.0	Yes or No	100 percent of people answering “yes”
		Does sugar cultivation help to reduce migration for other jobs outside the community?	0.6	Yes or No	100 percent of people answering “yes”
	Health and Safety	Are you exposed to pollution from sugarcane cultivation?	1.0	Yes or No	100 percent of people answering “no”
Farm owners	Social responsibility	Do you participate in a group of organic agriculture farmers or other groups that save the environment?	0.6	Yes or No	100 percent of farmers answering “yes”
		Do you cultivate organic sugarcane in your farm?	0.6	Yes or No	100 percent of farmers answering “yes”
		Are hazardous chemicals such as Furadan used in the sugarcane farms?	1.0	Yes or No	100 percent of farmers answering “no”
	Health and Safety	Do you prepare first aid equipment for employees?	1.0	Yes or No	100 percent of farmers answering “yes”
	Satisfaction of occupation	Are you satisfied with being a sugarcane farmer as a career?	1.0	Yes or No	100 percent of farmers answering “yes”

[a]as of October 2021
[b]IOC is Item Objective Congruence

Data collection was done using face-to-face surveys with stakeholders in 2018. Data were collected from farm owners, workers, and locals living in the community nearby. The number of samples for each stakeholder group was fixed to at least 30 persons. According to the study of Manik et al. (2013), the suggested minimum sample size for statistical significance is 30. The sample sizes for the different stakeholder groups are shown in Table 2. The farm owners included in this study were small-scale farmers as they are the majority of sugarcane farmers in the site studied. All stakeholders surveyed were asked questions about both green and burnt sugarcane harvesting because they were affected by both harvesting practices.

Data collection approach for this study has been granted ethics approval by the Mahasarakham University Ethics Committee for Research Involving Human Subjects (approval number: 118/2018), with exemption review method. To protect the interviewees’ identity, verbal consents were granted

before starting the surveys. Hence, paper-based consent forms were not used in this study.

2.4 Impact assessment

This study applied the performance reference points method because it is suggested for use when undertaking an S-LCA study at a site-specific level as the results are more accurate (Chhipi-Shrestha et al., 2015). The performance reference point method assesses social performances by comparing a product's current social performance with the performance reference points based on internationally accepted minimum performance levels, relevant guidelines, and standards (Russo Garrido et al., 2018). The characterization, weighting, and interpretation of results are described in the following sub-sections.

Table 2. Number of samples of different stakeholder groups

Stakeholder group	Description	No. of samples	
		Green harvesting	Burnt harvesting
Workers	Employees working in sugarcane fields	41	41
Community	People who live in the nearby area	30	30
Farm owners	Farmers who own sugarcane plantations	34	34

2.4.1 Characterization

The inventory data for each indicator were characterized into the percentage of respondents answering yes or no following social criteria (see details in Table 1). This was adapted from the characterization method used in Aparcana and Salhofer (2013) and Manik et al. (2013). The characterized score for each indicator was in the range of 0-100. In addition, the statistical analysis technique, "Cochran's Q test" was used to assess whether the proportion of respondents answering yes and no for the green and burnt sugarcane harvesting options were significantly different. The analysis was undertaken for each social indicator at a confidence level of 0.50. Cochran's Q test was used because it is possible for use when response is two possible outcomes (in this case, yes or no).

2.4.2 Weighting

The weighting step was undertaken to aggregate the social performance values of different social indicators belonging to the same social issue into a single value. The same principle also applies to the values for different social issues belonging to the same stakeholder group. Weighting was done at the levels of social indicators and social issues. The weighting factors were based on stakeholders' perceptions and were obtained using surveys. Stakeholders were asked to rate the importance of social indicators/issues using a score of 1-100. Zero refers to least important, while 100 refers to most important. The weighting factors were calculated using the following Equations 1 and 2.

$$\text{Weighting factor}_i = \text{AI}_i / \Sigma \text{I}_i \quad (1)$$

Where; Weighting factor$_i$ is weighting factor for each social indicator; AI$_i$ is average of importance scores from all stakeholders for that particular social indicator; ΣIi is sum of the average of importance scores of all social indicators within the same social issue.

$$\text{Weighting factor} = \text{AI}/\Sigma\text{I} \quad (2)$$

Where; Weighting factor is weighting factor for each social issue; AI is average of importance scores from all stakeholders for that particular social issue; ΣI is sum of average of importance scores of all social indicators within the same stakeholder group.

After getting the weighting factors for social indicators and social issues, the weighted social performances of social indicators and social issues were calculated using the following Equations 3 and 4.

$$\text{WIN} = \text{AIN}_i \times \text{Weighting factor}_i \quad (3)$$

Where; WIN is weighted social performance of social indicator; AIN$_i$ is average of indicator results; Weighting factor$_i$ is weighting factor for that particular indicator.

$$\text{WIS} = \Sigma\text{WIN} \times \text{Weighting factor} \quad (4)$$

Where; WIS is weighted social performance of social issue; ΣWIN is Sum of weighted social performances of social indicators within the same social issue; Weighting factor is weighting factor for that social issue.

After getting the weighted social performance of all social issues, given that all stakeholder groups

are equally important, the social performance of each stakeholder group was calculated by simply summing up weighted social performances of all the social issues for each stakeholder group as shown in Equation 5.

$$SPS = \Sigma WIS \quad (5)$$

Where; SPS is social performance of stakeholder group; ΣWIS is sum of weighted social performances of social issues within the same stakeholder group.

2.4.3 Interpretation of results

To ease the interpretation of results, the classification system shown in Figure 3 was used in this study. This classification system was adapted from Sawaengsak et al. (2019). The social performances calculated from the previous section were classified into five groups, with the scores in each group ranging between 0-100.

Poor	Fair	Medium	Good	Very good
0-20	21-40	41-60	61-80	81-100

Figure 3. Classification of results

3. RESULTS AND DISCUSSION

The social indicator results, weighting factors, and the weighted social performances of social indicators, for the green and burnt sugarcane harvesting, are shown in Table 3. In addition, Table 3 also indicates whether there was a difference in proportion (between the green and burnt harvesting groups) of stakeholders answering yes or no for each social indicator, using Cochran's Q test, measured at 95 percent confidence.

Table 3. Social indicator results, weighted performance of social indicators, and weighting factors

Stakeholder groups	Social issues	Social indicators	The average of indicator results		Weighting factor	Weighted performance of social indicator for green harvesting	Weighted performance of social indicator for burnt harvesting
			Green harvesting	Burnt harvesting			
Workers	Fair wage	• Minimum wage (9 USD/day)	59[b]	76[b]	1.00	59	76
			Social performance of fair salary			59	76
	Working conditions	• Absence of forced labor to work at risk of danger	100[a]	100[a]	0.50	50	50
		• Workers of all genders working on the same kind of work receive the same remuneration	100[a]	100[a]	0.50	50	50
			Social performance of working conditions			100	100
	Health and Safety	• All workers present on the field have access to first aid	49[b]	44[b]	0.49	24	22
		• There is protective equipment in the workplace	54[b]	46[b]	0.51	27	24
			Social performance of health and safety			51	45
Community	Economic development	• Local employment	75[a]	75[a]	0.68	51	51
		• No migration for other occupations outside the community	81[a]	81[a]	0.32	26	26
			Social performance of economic development			77	77
	Health and Safety	• None of the exposure of pollution from sugarcane farming	100[b]			38[b]	0.86
			Social performance of health and safety			86	32

[a]Analysis of Cochran's Q test to find the proportion of each group of stakeholders answering yes/no at $p<0.05$, indicating that there was no significant difference at 95% confidence.

[b]Analysis of Cochran's Q test to find the proportion of each stakeholder group answering yes/no at $p>0.05$, indicating a significant difference at 95% confidence.

Table 3. Social indicator results, weighted performance of social indicators, and weighting factors (cont.)

Stakeholder groups	Social issues	Social indicators	The average of indicator results		Weighting factor	Weighted performance of social indicator for green harvesting	Weighted performance of social indicator for burnt harvesting
			Green harvesting	Burnt harvesting			
Farm owners	Social responsibility	• Participation in a group of organic agriculture members or other groups that save the environment	100[a]	100[a]	0.24	24	24
		• Organic sugarcane is cultivated	16[a]	16[a]	0.38	6	6
		• Avoid the use of hazardous chemicals prohibited for use in sugarcane farms such as Furadan	100[a]	100[a]	0.38	38	38
			Social performance of social responsibility			68	68
	Health and Safety	• The first aid equipment is prepared for employees	39[a]	39[a]	1.00	39	39
			Social performance of health and safety			39	39
	Satisfaction of occupation	• Satisfaction in sugarcane planting career	82[a]	82[a]	1.00	82	82
			Social performance of satisfaction of occupation			82	82

[a]Analysis of Cochran's Q test to find the proportion of each group of stakeholders answering yes/no at $p<0.05$, indicating that there was no significant difference at 95% confidence.
[b]Analysis of Cochran's Q test to find the proportion of each stakeholder group answering yes/no at $p>0.05$, indicating a significant difference at 95% confidence.

3.1 Workers

The wages for all stages of sugarcane cultivation were not different between the green and the burnt harvesting except for harvesting. In sugarcane harvesting, the workers are paid wages based on the amount of sugarcane they can cut. Fifty-nine percent of workers in the green sugarcane harvesting reported that they were paid at least the minimum daily wages (Minimum wage is 9 USD/day, based on local general wage). Seventy-six percent of workers in the burnt sugarcane harvesting reported that they received at least the minimum wage.

Green sugarcane harvesting requires expertise and strength. The green sugarcane farms have dense sugarcane leaves and grass. Workers have to peel off the sugarcane leaves before cutting, resulting in longer working hours. In addition, in Thailand, the hot weather can slow down the work. Sawaengsak et al. (2021) reported that workers who are more skilled and healthy could cut sugarcane in large quantities, resulting in wages greater than or equal to the minimum wage. In the study area, the workers reported that the maximum amount of green sugarcane that a worker could cut was about 100 bales a day (the wage equals 9 USD/day). This means that some of them earned less than the minimum wage. While for burnt sugarcane, a worker could cut at least 150 bales (the wage equals 9 USD/day). This implies that every worker could secure the minimum wage by cutting the burnt sugarcane. This information corresponds to reports about the sugarcane harvesting in the Eastern Region of Thailand, where the workers could cut about 100 bales green sugarcane a day but about 300 bales of burnt sugarcane (Kijjakosol, 2019).

There was no difference between the result indicators of the green and burnt sugarcane harvesting for working conditions. There was no report on forced labor to work at risk of danger and wage discrimination among different genders of workers. Therefore, the social performance score for this social issue is 100 for both harvesting approaches. A similar study by Prasara-A and Gheewala (2018) in a different province in the North-Eastern Region of Thailand also reported that there was no wage discrimination among different genders in sugarcane cultivation.

The social performance for the health and safety issue for green and burnt harvesting is at a "Medium" level. Compared to other social aspects, this issue did

not perform very well. A study by Du et al. (2019) also identified health and safety as one of the impact categories with the highest risks for sugarcane production in Brazil. In the green sugarcane fields, forty-nine percent of workers reported access to first aid equipment, and fifty-four percent of workers said there was some equipment in the farms. Some added that they often prepared the first aid and the protective equipment themselves. For workers in the burnt sugarcane fields, forty-four percent reported that they had access to first aid supplies and forty-six percent said there was protection equipment in the farm. These results show that more first aid kits and protective gear were provided in the green sugarcane harvesting farms. This is because the working conditions in the green sugarcane farms are more complex. However, the calculated social performances of this social issue are at the same level (medium) for both green and burnt harvesting.

3.2 Community

Social indicator results for local employment and migration for other occupations outside the community issues are the same for both green and burnt sugarcane harvesting. Seventy-five percent of the locals surveyed reported that the sugarcane farm owners hire local workers. In comparison, twenty-five percent of locals said that workers were from other regions (employed in the harvesting season only). Eighty-one percent of the locals responded that there was no migration of people for jobs outside the community. The performance for this social issue is at the "Good" level. This result is supported by a study in Brazil where a positive relationship was found between sugarcane and economic development (Tomei et al., 2020). For health and safety issues, all of the locals surveyed responded that they were not affected by the green sugarcane harvesting. Sixty-two percent of locals reported being affected by sugarcane burning, as the dust and smoke from burning sugarcane blew into their houses. Thirty-eight percent of the locals said they were not affected because their houses were quite far from the sugarcane fields.

3.3 Farm owners

Regarding the social responsibility issues, the results for both green and burnt sugarcane harvesting are the same as their cultivation practices were similar. Even though all of the farm owners surveyed claimed that they had participated in a group of organic agriculture farmers or other groups that save the environment, only sixteen percent of them grew organic sugarcane. Some of the farm owners interviewed commented that the reason for not opting to grow organic sugarcane is that the organic sugarcane has lower yields than conventional sugarcane. However, a study by Coulis (2021) revealed that organic sugarcane farming has a beneficial effect on soil biological processes even after a short period of conversion from conventional farming. However, all farm owners surveyed claimed that they did not use any prohibited chemicals in their sugarcane farms.

For health and safety issues, thirty-nine percent of the farm owners reported providing some first aid facilities to employees. They added that the employees were always careful in their work and often prepared the first aid equipment they needed. Regarding career satisfaction, eighty-two percent of both harvesting groups responded that they were satisfied with their career as sugarcane growers and will continue to grow in the future. They commented that the area was suitable for sugarcane cultivation, and they have expertise in sugarcane growing and that selling sugarcane could earn a living. However, several of the farm owners surveyed commented that if the price of sugarcane falls in the future, they might change to grow other crops instead.

From Table 3, when considering each social issue, both green and burnt harvesting have social performance scores at the same level, except for fair wages for workers and health and safety for the community. The green harvesting has lower social performance for fair salary (medium level) than that of the burnt harvesting (good level) because of the lower wages for workers. Lower wages in green harvesting were caused by challenging working conditions for green harvesting, making some of the workers unable to earn the minimum wage. The social performance of health and safety for the community for burnt harvesting (fair level) is lower than green harvesting (very good level). This resulted from the lower rate of locals affected by the pollution from sugarcane burning. The results shown in Table 3 suggest that the social issue that needs urgent attention is all stakeholder groups' health and safety. This includes the problems of sugarcane burning and first aid kits provided to the workers.

Table 4 shows weighted social performances of different social issues, weighting factors, and the social performances of different stakeholders for green and burnt sugarcane harvesting

Table 4. Weighted social performances of different social issues and social performances of stakeholders, and weighting factors

Stakeholder groups	Social issues	Weighting factor	Performance of social issues		Weighted performance of social issues	
			Green harvesting	Burnt harvesting	Green harvesting	Burnt harvesting
Workers	Fair wages	0.32	59	76	19	24
	Working conditions	0.33	100	100	33	33
	Health and safety	0.35	51	45	18	16
	Social performance of workers				70	73
Community	Economic development	0.49	77	77	38	38
	Health and safety	0.51	86	32	44	16
	Social performance of community				82	54
Farm owners	Social responsibility	0.22	68	68	15	15
	Satisfaction of occupation	0.39	39	39	15	15
	Health and safety	0.39	82	82	32	32
	Social performance of farm owners				62	62

From Table 4, when considering the overall social performances of different stakeholder groups for green and burnt harvesting, the social performances of workers and farm owners are at the same level (good) except for the community. For the community stakeholder group, the social performance of green harvesting is at the "very good" level, while the one for burnt harvesting is at the "medium" level. This is mainly due to the problem of sugarcane trash burning.

The root cause of this burnt sugarcane harvesting is related to manual harvesting. Burning sugarcane before cutting is practiced to ease the productivity of manual harvesting. Another issue in sugarcane cultivation is a shortage of labor for harvesting. The farmers have to get the harvested sugarcane to the sugar factories in time. Therefore, a large number of sugarcane cutters are needed at the same time. This results in a labor shortage in some areas (Thansettakij Multimedia, 2019). However, the problem of sugarcane burning has to be addressed urgently as it causes a negative health impact on locals and also other stakeholders who also live in the community in the long term.

To solve the problem of sugarcane burning, the government has started to educate the farmers about the health impact of particulate matter caused by sugarcane burning. They have also provided loans for farmers at a low-interest rate to buy sugarcane cutting machines (Khaosod, 2019). However, as mentioned earlier in the introduction section, there are still issues about using sugarcane harvesting machines, such as the high cost of machines and conditions of sugarcane fields for using harvesting machines, such as proper interval distance between sugarcane rows and size of sugarcane fields. For this reason, the majority of the Thai sugarcane farmers (mostly small-scale farmers) seem not yet ready to use the harvesting machines (Chaya et al., 2019).

Another reason for burnt sugarcane harvesting is that it has more productivity. This issue also causes higher production costs for green sugarcane burning. Kijjakosol (2019) reported that the cost of harvesting 1 tonne of burnt sugarcane for manual harvesting was 2.1-2.4 USD lower than that of the green sugarcane. On the other hand, the selling price of green sugarcane per 1 tonne was 0.9 USD higher than burnt sugarcane (Mitr Phol Group, 2020). Obviously, the cost of manual harvesting of green sugarcane is more than that of burnt sugarcane. The farm owners are disadvantaged by using labor to cut the green sugarcane.

As discussed earlier, the issues that need urgent attention are the problem of sugarcane trash burning and the low rate of first aid kits provided to the workers. The first problem seems to bear enormous pressure on the sugarcane farm owners. Different factors are causing the sugarcane farmers to harvest the burnt sugarcane. These include the need to harvest sugarcane quickly to send to the sugar mills, lack of labor to harvest sugarcane, the workers prefer cutting burnt sugarcane, and harvesting burnt sugarcane having lower production cost for harvesting. With social pressure about the impacts of sugarcane trash burning on all stakeholders, mechanized green sugarcane harvesting seems appropriate. However, there is an urgent need for technology development for cheaper machines to make them more affordable for

sugarcane farmers. Moreover, the equipment needs to be developed for use in any geographical condition.

4. CONCLUSION

The social life cycle assessment results of green and burnt sugarcane harvesting using a case in Udon Thani Province in the North-Eastern Region of Thailand were presented. This study site was selected as it hosts the largest sugarcane plantation area in the country. In addition, it is near the border of a neighboring country, which means that the social and environmental impacts caused by sugarcane production from this area may affect the locality and another country. This study compares the social performances of the two different sugarcane harvesting practices used at the site study, i.e., green and burnt harvesting. Both approaches of sugarcane harvesting in this area still mainly rely on human labor as the geographical conditions are not suitable for the use of harvesting machines. The stakeholder groups included workers, the community, and farm owners. Moreover, it identifies hotspots needing improvement to help reduce environmental impact and improve the social conditions of stakeholders involved in sugarcane production.

The main findings reveal that the social performance scores for most of the social issues for green and burnt harvesting are at the same level, except fair wages for workers and health and safety for the community. For the fair wages aspect, green harvesting has “medium” social performance, while burnt harvesting has “good” social performance. The main issue lowering the social performance for green harvesting is the difficult working conditions for workers to make at least the minimum wage. This is because the sugarcane harvesting is paid per amount of the sugarcane they could cut.

For the health and safety of the community, burnt harvesting has lower social performance than green harvesting. This impact is caused by the cane trash burning before harvesting. Considering all the social issues examined, the problems that need urgent attention are the sugarcane trash burning and first aid kits provided to the workers. However, the overall social performances of workers and farm owners are at the same level (good level) except for the community. The social performance of green harvesting for the community group is in the “very good” level, while it is in the “medium” level for burnt harvesting.

In summary, burnt harvesting has lower social performance; the difference is mainly from the problem of sugarcane trash burning. To address this problem, factors making the farm owners choose burnt harvesting are needed to be understood and resolved. This includes the necessity to harvest sugarcane quickly to be delivered to sugar mills, a scarcity of labor to harvest sugarcane, employees preferring to cut burnt sugarcane, and cheaper cost for burnt harvesting. Moreover, the current issue of air pollution from cane trash burning, mechanized sugarcane harvesting appears to be the best option. However, technology development for less expensive machines is critical to make them accessible to all sugarcane producers. Furthermore, the equipment must be designed to work in any environment.

ACKNOWLEDGEMENTS

This work was supported by the Research Chair Grant of the National Science and Technology Development Agency, Ministry of Science and Technology, Thailand under grant number (P-16-51880); Thailand Research Fund and the Office of the Higher Education Commission (OHEC) under grant number (MRG6180276). All the anonymous stakeholders providing inputs for this research are gratefully acknowledged.

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