Sustainability Assessment of Natural Rubber Primary Processing: A Review

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Abstract. Natural Rubber is an important commodity for the world due to its valuable properties such as good elasticity and renewable. Natural rubber is used to produce various important products such as tire, sport equipment, and medical devices. With increasing demand for these products, the demand of natural rubber is projected to jump in the future. To fulfil this demand, the increasing of natural rubber production is unavoidable. However, to use natural rubber in producing those final products, it needs to flow through primary processing such as crumb rubber manufacturing process, crepe rubber processing and latex centrifuge processing. These processes become source of income for countries such as Indonesia, Malaysia and Thailand as well as citizen of those countries. Despite of these positive impacts, the environmental impacts of natural rubber primary processing such as greenhouse gas emission, waste, high water and energy consumption are identified. Thus, to maintain sustainability, monitoring of sustainability impacts from natural rubber primary processing is necessary. Sustainability assessment is a procedure to evaluate sustainability impacts of products, process and policies. This paper aims to review sustainability assessment process applied in Natural Rubber Primary Processing.

1. Introduction

Natural rubber is used to make various important products such as tire, engine components, sport equipment, medical and laboratory devices. An increasing demand of these products force the natural rubber industry to escalate their production. Natural rubber industry consists of various organizations with different activities that configure natural rubber industry supply network. This network consists of several stages including rubber plantation stage, primary natural rubber processing, secondary natural rubber processing stage, customer stage and recycle or disposal stage [1].

Natural rubber primary processing are implemented to change latex from rubber plantations into several work in process products such as crumb rubber, crepe rubber, high concentrated latex and rubber smoke sheet. Different processes are required to make these work in process products. For example, [2] explained the process to make crepe rubber. It started from transforming low concentrated latex from plantation into cubical shape using coagulation process. Then this cubical is rolled and dried to reduce the water contents. At this stage, the cubical form are transformed into blanket form. This is followed by cutting these blanket into standard size required by the suppliers. Figure 1 displays the natural rubber primary processing.
In general, rubber plantations and primary natural rubber processing are located in developing countries such as Indonesia, Thailand Sri Lanka and Malaysia while secondary processing are found in developed countries such as European Union, United States, Japan, South Korean and China. Natural rubber plantations and primary processing have been source of income for citizen in those developing countries. However, each country may have different combination of natural rubber primary processing. For example, Indonesia is dominated by crumb rubber manufacturing and rubber smoke sheet processors [1] while Sri Lanka is dominated by crepe manufacturing and rubber sheet processors [2]. This situation is influenced by the mastership of technology for processing latex by rubber plantations and the structure of industry that absorb the products from natural rubber primary processing. In Indonesia, majority rubber plantations apply coagulation process for their latex to form coagulated latex while in other countries such as Sri Lanka and Malaysia, latex is sold in form of low concentrated latex (fluid) and is not coagulated (see figure 1).

Despite the positive impacts of natural rubber primary processing, these processes have been responsible for some environmental impacts such as air and water pollution as well as high water consumption. With increasing concern for environmental and social impacts in natural rubber industry, stakeholders in this industry formulated sustainability standard. Sustainable Natural Rubber Initiative (SNR-i) is one standard formulated by International Rubber Study Group. One requirement in this standard is to push the primary processors to monitor the use of water, the wastewater and the emission resulting from the processes. Sustainability assessment is a process to evaluate integrated nature-society system in short or long term perspective in order to define which activities should or should not be taken to make society to be more sustainable [3,4]. This process can be used to evaluate sustainability impacts of products, processes and policies. This paper aims to review sustainability assessment processes that focused for assessing natural rubber primary processing.

2. Research Methods

This research has objectives to review and to analyze sustainable assessment research in natural rubber primary processing and to highlight potential gaps in literature that require further
investigation. To achieve these objectives, a review of literature is used as research method. Papers with focus on sustainability assessment in natural rubber primary processing from different Journals and Sources were reviewed.

2.1. Research Process

The research process consists of two main steps. First step is focused on searching and selecting journal papers. The keywords used for searching and selecting the papers were sustainability assessment and natural rubber industry. The searching was implemented on Scopus database. Further restriction related to publish year of paper between 2009 to 2019 was applied in the searching process.

This is followed by analysing those papers using thematic analysis. Four themes were applied including: objects of assessment, tools for assessment, indicators used in the assessment and presentation of assessment results. Object of assessment is first theme that used to present natural rubber primary processes that have been assessed in the literature. Tools for assessment are the second theme that used to map methods, models or tools used in assessment process. Third theme is indicators for assessment, which refers to criteria used in assessment process. Fourth theme is presentation of assessment result, which refers to how the assessment results are presented and which decisions are supported by the results. Figure 2 presents the research process.

3. Result and Discussion

3.1. Statistic of Reviewed Papers

The process of searching and paper selection resulted 11 related papers from various journals including Journal of Cleaner Production, Resources, Conservation and Recycling, Procedia Social and Behavioural Sciences, Kasetsart Journal of Social Sciences, Atmospheric Pollution Research and Environmental Development. From the reviewed papers, it has not been found the paper that focused to review sustainability in natural rubber primary processing, particularly paper with a focus to review sustainability assessment process. This paper fills this gap by reviewing the sustainability assessment process applied in natural rubber primary processing. Figure 1 displays distribution of reviewed papers based on journals.

![Figure 2. Research Process](image)

![Figure 3. Distribution of Reviewed Papers Based on Journals](image)
3.2. Objects of Sustainability Assessment

The main issue in the reviewed papers is to investigate environmental impacts from natural rubber primary processing. [5] investigated the environmental impacts from crepe manufacturing in Sri Lanka. They found that this process consumed high fresh water and released wastewater and greenhouse gas emission to environment. For more detail, water is highly consumed within wet processing including coagulation, maceration, and rolling. The similar result was found by [6] when investigated the environmental impacts of ribbed smoke sheet production in Indonesia. They found that coagulation and milling were the processes consumed the highest water. Furthermore, [7] found the burning (smoke) and milling station were sourced for greenhouse gas emission.

[8] investigated environmental impacts of centrifuge latex process. They found that this process uses chemicals, consumes energy, uses combustion and produces wastewater. These can cause environmental impacts such as global warming, acidification, eutrophication, human toxicity and photochemical oxidation. Furthermore, [9] and [10] compared greenhouse gas emission between centrifuge processor, crumb rubber processor and ribbed smoke processor in Thailand. They found that crumb rubber processor produced highest greenhouse gas emission compared to other processor. This was mainly sourced from the use of electricity and diesel within the process. [11] evaluated eco efficiency in crumb rubber manufacturing in Indonesia. They found that environmental impacts were sourced from the use of acid during coagulation process and the use of plastic on packaging process.

| Table 1. Classification of Papers Based on the Object of Sustainability Assessment |
|---------------------------------|---------------------------------|-----------------|
| **Object of Sustainability Assessment** | **Reviewed Papers** |
| Crepe Rubber Processing | [2] [5] [12] |
| Crumb Rubber Processing | [11] [9] [10] [13] [12] |
| Rubber Smoke Sheet Processing | [6] [7] [9] [10] [12] |
| Centrifuge Processing | [14] [9] [10] [12] |

3.3. Tools and Indicators for Sustainability Assessment

Since the focus of reviewed paper is the environmental impacts, material flow analysis and life cycle assessment are the sustainability assessment tools used by the most reviewed papers. Material flow analysis is good to identify the flow of materials from first process until the final process. This tool can be used to identify the consumption of latex, water, chemicals and the production of emission from each process. [5,6] used material flow analysis to investigate environmental impacts of crepe manufacturing and ribbed smoke sheet. Life cycle analysis was used by [8] to evaluate centrifuge latex process, by [11] to assess crumb rubber processing and by [7] to evaluate ribbed smoke sheet processing. Other approaches were demonstrated by [10] that used ecological footprint, by [12] that used mathematical models to predict greenhouse gas emission from activities in natural rubber primary processing and by [5] that used material flow cost analysis to evaluate the flow of cost within crepe rubber processing.

In term of indicators, majority of reviewed papers used environmental indicators including water consumption, energy consumption, chemicals use, total wastewater, greenhouse gas emission. Only one reviewed paper [5] was found to use economic indicators including cost of energy and materials. There is no social indicator has been used in assessment process in reviewed papers.

3.3.1. Presentation of Sustainability Assessment Result

Since majority of reviewed papers used material flow analysis and life cycle assessment to evaluate sustainability, the result of assessments were presented using measurement units. For example, [5] presented greenhouse gas emission using Kg e and wastewater using Metric Ton (MT). Furthermore, [10] displayed their result in form of index that is calculated using mathematical equation. For example, index for greenhouse gas emission was calculated by multiplying total greenhouse gas emission with area required to sequestering a ton CO₂ and equivalence factor of forest.
In term of supporting decisions, some reviewed papers demonstrated the use of assessment result to define the alternative for reducing the environmental impacts. For example, [5] used the assessment result to determine the options to reduce water, chemicals and energy consumption for crepe manufacturing. In similar way, [8] used the assessment result to determine the options for improvement in centrifuge latex processing. Furthermore, [6] demonstrated the use of assessment to define productivity improvement in ribbed smoke sheet processing.

4. Possibility for Future Research and Conclusion

4.1. Possibility for Future Research
Based on the analysis of reviewed papers several possibility for future research are identified:

- Due to limited research in reviewed papers that focused on social and economic impacts, further research are required to assess social and economic impacts from the natural rubber primary processing in developing countries.
- The opportunities is widely open to use different sustainability assessment tools such as multi criteria indicators, simulation and composite indicators.
- There is limited research to evaluate crumb rubber processing. Hence, further research is required to assess crumb rubber processing.
- The use of assessment result to support decisions making are limited, hence there are opportunities for demonstrating the development of policies based on the sustainability assessment result.

4.2. Conclusion
Based on the results, some conclusions are obtained as follows.

- The review indicates that the dominant environmental impacts from natural rubber primary processing are high water consumption, greenhouse gas emission and wastewater.
- The review indicates that majority of reviewed papers are focused to assess environmental impacts of natural rubber primary processing. The evaluation of social and economic impacts are rare in reviewed papers.
- The review indicates that material flow analysis and life cycle assessment are dominant tools used in review papers to assess sustainability.

References
[1] Sitepu M H, McKay A and Holt R J 2016 Towards a Framework for Sustainable Development Planning in the Indonesian Natural Rubber Industry Supply Network Procedia CIRP 48 164–9
[2] Dunuwila P, Rodrigo V H L and Goto N 2018 Sustainability of natural rubber processing can be improved: A case study with crepe rubber manufacturing in Sri Lanka Resour. Conserv. Recycl. 133 417–27
[3] Ness B, Urbel-Piirsalu E, Anderberg S and Olsson L 2006 Categorising tools for sustainability assessment
[4] Sala S, Ciuffo B and Nijkamp P 2015 A systemic framework for sustainability assessment Ecol. Econ. 119 314–25
[5] Dunuwila P, Rodrigo V H L and Goto N 2018 Financial and environmental sustainability in manufacturing of crepe rubber in terms of material flow analysis, material flow cost accounting and life cycle assessment J. Clean. Prod. 182 587–99
[6] Marimin, Darmawan M A, Machfud, Islam Fajar Putra M P and Wiguna B 2014 Value chain analysis for green productivity improvement in the natural rubber supply chain: a case study J. Clean. Prod. 85 201–11

[7] Phairuang W, Tekasakul P, Hata M, Tekasakul S, Chomanee J, Otani Y and Furuuchi M 2019 Estimation of air pollution from ribbed smoked sheet rubber in Thailand exports to Japan as a pre-product of tires Atmos. Pollut. Res. 10 642–50

[8] Jawjit W, Pavasant P and Kroeze C 2015 Evaluating environmental performance of concentrated latex production in Thailand J. Clean. Prod. 98 84–91

[9] Jawjit W, Kroeze C and Rattanapan S 2010 Greenhouse gas emissions from rubber industry in Thailand J. Clean. Prod. 18 403–11

[10] Musikavong C and Gheewala S H 2017 Ecological footprint assessment towards eco-efficient oil palm and rubber plantations in Thailand J. Clean. Prod. 140 581–9

[11] Maulina S, Sulaiman N M N and Mahmood N Z 2015 Enhancement of Eco-Efficiency Through Life Cycle Assessment in Crumb Rubber Processing Procedia - Soc. Behav. Sci. 195 2475–84

[12] Vidanagama J and Lokupitiya E 2018 Energy usage and greenhouse gas emissions associated with tea and rubber manufacturing processes in Sri Lanka Environ. Dev. 26 43–54

[13] Sharib S and Halog A 2017 Enhancing value chains by applying industrial symbiosis concept to the Rubber City in Kedah, Malaysia J. Clean. Prod. 141 1095–108

[14] Jawjit W, Pavasant P and Kroeze C 2015 Evaluating environmental performance of concentrated latex production in Thailand J. Clean. Prod. 98 84–91