

Sustainability assessment in crude palm oil production: A review

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Abstract. Palm oil is important commodity for the world since it is a raw material for various important products such as cooking oils, cosmetics, and foods. Moreover, palm oil is found as a source for renewable energy such as biodiesel and biogas. As the result, the demand of palm oil is projected to jump in the future. To fulfil this demand, the increasing of palm oil production is unavoidable. Crude palm oil process is one substantial process to produce palm oil. This process becomes source of income for countries and citizen of those countries where crude palm oil are produced such as Indonesia, Malaysia and Thailand. Despite of these positive impacts, the environmental impacts of crude palm oil process such as greenhouse gas emission, waste, high water and energy consumption are identified. Thus, to maintain sustainability in palm oil production, several standards such as Indonesia Sustainable Palm Oil (ISPO) and Roundtable Sustainable Palm Oil (RSPO) are introduced. One main requirement from these standards is to monitor sustainability impacts of crude palm oil production. Sustainability assessment is a procedure to evaluate sustainability impacts of products, process and policies. This paper aims to review sustainability assessment process applied in crude palm oil production.

1. Introduction

The increasing of palm oil demand is projected to occur in the future. This is caused by the increasing demand for palm oil based products such as cooking oils, cosmetics and foods. Furthermore, Palm oil is announced as one alternative to replace non-renewable fossil fuel. This trend must be followed by the enhancement of palm oil production. Palm oil is produced through several processes. It is started by cultivating palm oil trees in plantation. From the plantation, fresh fruit bunch are harvested and delivered to crude palm oil processor. At this stage, fresh fruit bunch are transformed into crude and kernel palm oil. These oils are then later used to make various final products. These processes are run by different organizations and companies that configure palm oil industry supply network. Figure 1 displays palm oil industry supply network.

One critical process in producing palm oil is crude palm oil process. In this process, fresh fruit bunch are transformed into crude and kernel palm oil. Indonesia, Malaysia and Thailand produce more than 80% of palm oil in the world. These countries are dominated by organizations and companies that operate crude palm oil production. This activity becomes source of income for citizen and local governments in these countries. However, this activity also brings environmental impacts such as greenhouse gas emission, waste, water and energy consumption. With increasing the environmental awareness in these countries, several standards such as Indonesia Sustainable Palm Oil, Malaysia Sustainable Palm Oil and

Roundtable Sustainable Palm Oil are introduced. These standards have the main objective to maintain sustainability in palm oil industry.

One main requirement to maintain sustainability is to monitor sustainability impacts of crude palm oil production. 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 [1,2]. This process can be used to evaluate sustainability impacts of products, processes and policies. This paper aims to review sustainability assessment processes that have been applied by academics and practitioners for assessing crude palm oil production.

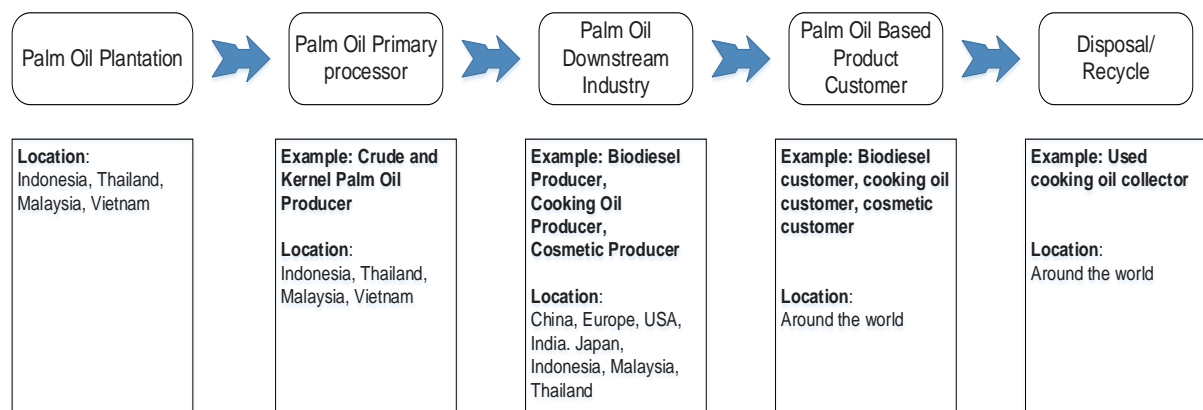


Figure 1.Palm Oil Industry Supply Networks

2. Research Methods

The purpose of our research is to review and to analyze sustainable assessment research in palm oil industry supply network 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 construction industry from different Journals and Sources were reviewed.

2.1. Research Process

To achieve the aim of the research, the research process is divided into two steps. First step focuses on searching and selecting journal papers. The keywords used for searching and selecting the papers were sustainability assessment and palm oil 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. First theme is object of assessment that presents activities, processes or policies assessed in the literature. Second theme is tools for assessment that displays 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.

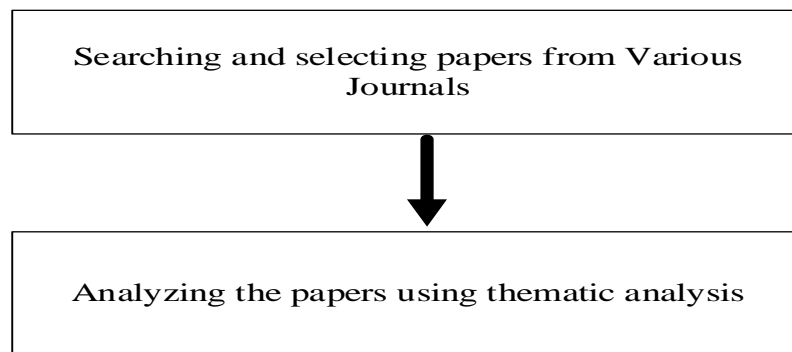


Figure 2.Research Process

3. Result and Discussion

3.1. Statistic of Reviewed Papers

In the first step of research process, 35 papers from various journals have been selected. These papers were published between 2009 until 2019. From the literature, it has been found the articles focused to review sustainability in palm oil industry including [3] that focused to identify sustainable practices, [4] that focused to identify future sustainable implications in Indonesia, Malaysia and Thailand palm oil industries, [5] that focused to review the potential use of residual palm oil biomass and effluent and [6] that focused to review trend of sustainability research in palm oil industry. However, none of these papers focused on sustainability assessment. This paper focuses to review current sustainability assessment processes for crude palm oil production. Figure 3 displays more than 80% of reviewed papers were published by four journals including: Journal Cleaner Production, energy, Biomass and Energy, and Renewable and Sustainable Energy Reviews.

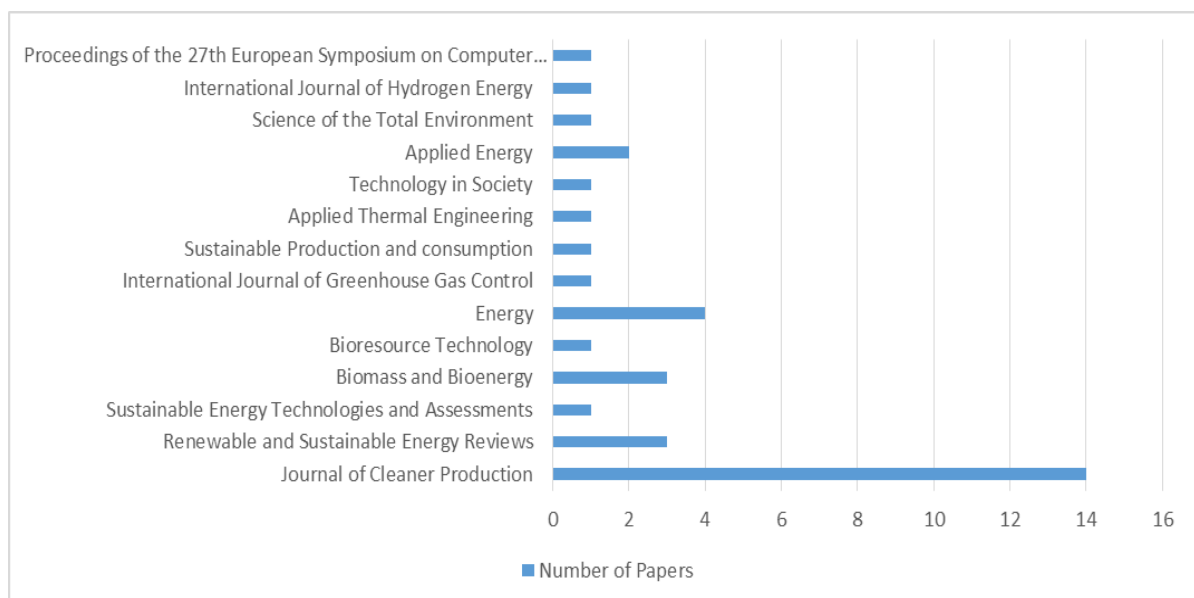


Figure 3.Distributed Reviewed Papers Based on Journal

3.2. Objects of Sustainability Assessment

The central issue in crude palm oil production is the environmental impacts caused by the production processes. There are several processes to transform fresh fruit bunch into crude palm oil and kernel palm oil including sterilisation, stripping, digestion, clarification, oil drying (for making crude palm oil) and depericarping, nut craking, winnowing and kernel drying (for making kernel palm oil) [7]. Furthermore, there are additional processes to treat palm oil effluent, fibre and shell. Those are wastes produced by crude and kernel palm oil process. These processes consume water and energy as well as produce greenhouse gas emission. All of these processes become the main objects of sustainability assessment.

Table 1. Classification of Papers Based on the Object of Sustainability Assessment

| Object of Sustainability Assessment | Reviewed Papers |
|--|--|
| Crude and Kernel Palm Oil Process | [8] [9] [10][11][12][13][14] [15][16][17][18][19][20][21][22][23][24][25][26] |
| Palm oil effluent treatment process | [27][28][29][30][31][32][33][34][35][36] |
| Fibre and Shell Treatment Process | [37][28][38][39][29][33][34][35][36] |
| Crude and Kernel Palm oil Technology | [40][41] |

From the crude and kernel palm oil process, [42] identified greenhouse gas emission are emitted from the use of chemical, the use of energy and waste water management. Furthermore, [25] calculated the consumption of water by palm oil mills. They found that in Thailand, to produce one-ton crude palm oil, 5083 m³ water were required. The water can be classified into two types: direct and indirect water. Indirect water is found in fresh fruit bunch production while direct water is sourced from boiler that produces hot and steam. Other environmental impacts are identified by [24,30]. [24] found that the process emit heavy metals and nitrogen oxides which are categorized as human toxic potential while [30] identified liquid and solid waste resulted from this process. Palm oil mills also identified to produce emissions that cause eutrophication [23]. Moreover, [11,12,29] investigated economic impacts of palm oil mills. They found that profit of palm oil mills depends on oil extraction rate.

Although palm oil mill produce significant liquid and solid wastes, these wastes are biomass that can be transformed into variety of products [5]. Hence, palm oil effluent, fibre and shell treatment processes become the other popular objects of sustainability assessment in reviewed papers. These processes could produce electricity and mineral fertilizer as well as reduce greenhouse gas emission [30]. [28] Evaluated the economic and environmental impacts of alternative processes such as composting of empty fruit bunches (EFB) and fibre, Biomass combustion for high pressure steam combined heat and power and production of biogas from Palm oil mills effluents.

3.3. Tools and Indicators for Sustainability Assessment

Life cycle assessment, multi criteria, mathematical model and simulation are tools used for assessing sustainability in reviewed papers. Life cycle assessment appears to be used in majority of reviewed papers. [24,25,43,44] are example of reviewed papers that used life cycle assessment. Some authors combined life cycle assessment with other tools such as life cycle costing to expand the scope of assessment. For example, [28,29,34] combined life cycle assessment with economic assessment. Multi criteria indicators become second popular tool used in reviewed papers. This tool opens opportunities for researchers to assess three

dimension of sustainability (economic, social and environmental) simultaneously. [12,27,40] are example of reviewed papers used multi criteria indicators. Furthermore, [45] demonstrated the use of simulation model to assess environmental impacts of palm oil mills and bio refinery. In term of indicators, several indicators have been identified in reviewed papers to present the sustainability impacts of crude palm oil process. Table 2 shows those indicators.

Table 2. Sustainability Indicators Used in Reviewed Papers

| Sustainability Dimensions | Indicators Used in Reviewed Papers |
|----------------------------------|---|
| Environmental | Net energy ratio Global warming potential Mass balance GHG emission Eutrophication potential Acidification potential Human toxicity potential Photochemical oxidant Energy consumption Water consumption |
| Economic | Production Cost Maintenance cost Revenue Interest Rate Ratio Net Present Value Payback Period Total capital investment Oil Yield Extraction efficiency |
| Social | Risk factor poisoning disease Accident case Health and safety Education public acceptance |

3.2.3. *Presentation of Sustainability Assessment Result*

The result of assessment is presented in different formats that depend on tools used for assessing. [23,24] presented their result in different units based on indicators used. For example for indicator CO₂ emission, they present the result using Kilogram unit. On other hand, [12,27,40] presented the result of assessment in form of scoring and ranking. These scores were calculated using several equations that consider reference value and weight for each criterion. Some reviewed papers demonstrated the use of assessment result to support decision-making. For example, [12,29,30] used the assessment result to support decision related selection of alternatives process for treating liquid and solid wastes from crude palm oil production.

4. Possibility for Future Research

Based on the analysis of reviewed papers several possibilities for future research are identified:

- Further research is required to assess social impacts from the crude palm oil in developing countries.
- The opportunities are widely open to use different sustainability assessment tools such as simulation and composite indicators.
- 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.

5. Conclusion

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

- The review of sustainability assessment process for crude palm oil production indicates that different indicators are required to support the assessment process.
- The review indicates that majority of reviewed papers are focused to assess economic and environmental impacts of crude palm oil production. The evaluations of social impacts are rare in reviewed papers.
- The review indicates that life cycle assessment and multi criteria indicators are dominant tools used in review papers to assess sustainability.

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