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SAGO AS AN ENVIRONMENTALLY SUSTAINABLE FOOD RESOURCE IN THE CLIMATE CHANGE ERA

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Abstract

This current study is focused on measuring the life cycle assessment of the sustainability of sago palm cultivated on peatlands. A previous theory suggested that while food production tends to increase arithmetically, population tends to increase naturally at a faster geometric rate that may cause hunger and/or starvation in the future generation. Land is a limited resource, and to address the rapidly increasing population, peatland cultivation has become popular as a result in the recent times. Rice is the main staple food in Indonesia with a consumption of >90 kg/capita/year. Sago palm is an indigenous plant that abundantly grows in both mineral soils and peatlands all over Indonesia. The aim of this research was to recommend the sustainability of sago palm as a staple food resource in order to ascertain if it is a contributor to climate change. The method of life cycle sustainability assessment (LCSA) that consists of Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (SLCA) was used through the dashboard tool. Our results suggest that sago palm cultivated on peatlands falls in the “sustainable” category when assessed based on the social, economic, and environmental aspects of sustainability.

Keywords: climate change; environmentally friendly food resource; life cycle assessment; peatland

1. Introduction

Rising global temperatures in the last four centuries has resulted in climate change, also termed as global warming. It is caused as a consequence of increased emissions of greenhouse gases (GHGs) such as carbon dioxide (CO₂), methane, and nitrous oxide (Intergovernmental Panel on Climate Change (IPCC), 2007).

Anthropogenic CO₂ emissions are exacerbated due to the ever-increasing population. Malthus (1798) stated that while food production tends to increase arithmetically, population tends to increase naturally at a faster geometric rate, which may cause hunger and/or starvation in the future generations due to a greater demand for food and energy.

According to the Department of Forestry (2008), the most important sources of GHG emissions consist of Land Use, Land Use Change, and Forestry (LULUC; 46%), energy (24%), peatlands (12%), waste (11%), agriculture (5%), and industries (2%). Based on size, Indonesia has 14.9–26.5 million ha of peatlands (Noor, 2011) which makes it the fourth biggest in the world after Russia, Canada, and America (Barchia, 2006). Peatlands have been

used for agriculture and plantation in recent times to fulfill the requirements of food and biofuel that are continuously increasing and constrained due to limited land and resources.

Agriculture is most significantly impacted by climate change since it causes prolonged drought periods, floods, and inconsistent rainfall patterns. Climate change influences the productivity of paddy, which forces the government to import rice from other countries to fulfill the needs of the country's population. Indonesia has a huge population of sago palm, which is an indigenous and underutilized plant that naturally grows in the wild all over Indonesia, especially in Papua and Maluku. Sago palm contains sago starch rich in carbohydrates that can serve as an ideal staple food. Sago has been consumed as a staple food in the eastern parts of Indonesia since a long time even though those regions are being converted for rice cultivation.

The sago palm trees thrive both on mineral soils and on peatlands that have lower levels of nutrients and are highly acidic. The sustainability of sago palm must be recognized in order to assess the potential impacts of its cultivation and plantation on peatlands to the environment, society and economy.

2. Methods

We used three methods to identify the sustainability of sago plantation on peatlands, a) life cycle assessment (LCA) to evaluate the environmental aspect; b) environmental life cycle costing (Env. LCC), to measure the economic aspect; and c) social life cycle assessment (SLCA), to evaluate the social aspect. These methods represent the three pillars of sustainability development that include the environmental, economic, and social aspects, however to determine the overall sustainability, the method of life cycle sustainability assessment (LCSA) was used (Finkbeiner, Schau, Lehmann, & Traverso, 2010; Schau, Traverso, & Finkbeiner, 2012).

Figure 1. Dimension of (a) sustainability development and (b) life cycle sustainability assessment (LCSA)

(Source: Schau et al., 2012)

The formulation of the LCSA method is as follow:

$$\text{LCSA} = \text{LCA} + \text{Env. LCC} + \text{SLCA} \quad (1)$$

The following sections assess the state of the art with regard to the sustainability of sago palm start from the steps of seedling, plantation, maintenance, transportation from plantation to the factory, and at the factory process with the environmental dimension (see section 2.1),

the economic dimension (see section 2.2), social dimension (see section 2.3), and LCSA using Dashboard tool (see section 2.4).

2.1 Environmental Dimension

The LCA method adopts the well-known international standard of ISO 14040 and 14044 (Finkbeiner et al., 2010; Schau et al., 2012) that assess the impacts on the environment, sources of pollutants, and GHG emissions which causes increase in global temperatures, change in global climate pattern, eutrophication, acidification, and adverse effects to humans (Pleanjai, Gheewala, & Garivait, 2007).

The LCA method assesses the potential of ecological influences caused due to the activities starting from the gathering of the raw materials until returning the waste to the “grave”, the overall phases of the life cycle of a product are referred to as “cradle to the grave” (Finkbeiner et al., 2010; Curran, 2006).

According to the ISO 14040 standard, LCA consists of the collection and evaluation the inputs, outputs, and the potential environmental impacts of a product. It consists of four phases: goal and scope definition, life cycle inventory analysis, life cycle impact assessment, and interpretation.

2.2 Economic Dimension

Environmental LCC is an assessment of all costs associated with the life cycle of a product that is directly covered by any one or more of the factors (e.g., suppliers, manufacturer, user or consumer, or the final end of product). The meaning of cost is all the money value of staffs and services that are bought by producers or consumers. Environmental LCC works parallel and consistent with the LCA method. Hunkeler, Lichtenwort, & Rebitzer (2008) suggested that in environmental LCC with the complementary inclusion of externalities that are anticipated, should be internalized in the decision-relevant future (Ciroth, Hunkeler, Klöpffer, Swarr, & Pesonen, 2011). In this research, Environmental LCC is counting the amount of production cost, mostly in using fuel, fertilizer, pesticide, herbicide, ameliorant; and external cost that consist of carbon stock (rupiah/ton) and social cost (ton/ha). Then, the total income of selling sago starch is calculated (ton/ha/year) in Rupiah.

2.3 Social Dimension

Social LCA assesses the social impacts on the workers, the local communities, the consumers, the society and all the other value chain factors (UNEP & SETAC, 2013). In this current research, the emphasis was on the stakeholder worker within the impact category of human rights. Our research also emphasizes on the sub-category related to the current main issues of the workers that include fair salary, working hours, and health and safety (UNEP & SETAC, 2013).

2.4 Life Cycle Sustainability Dashboard (LCSD)

After counting the result of the LCA, the Environmental LCC and SLCA, then to assess the sustainability is using Life Cycle Sustainability Assessment (LCSA) method. LCSA method is the total amount of LCA, Environmental LCC, and SLCA. As a result, to weighing the sustainability of this sago starch product is using dashboard tool. Life Cycle Sustainability

Dashboard (LCSD) is a specific application of the dashboard of sustainability to the LCSA and to evaluate the sustainability by incorporating social, economic, and environmental pillars. In the dashboard program, a certain number of indicators and their values can be added. The result of LCSD can be shown as graphical representation (a cartogram). The performance is presented within a seven-color code ranging from dark red that represents the “critical” conditions over yellow “average” conditions to dark green representing the “best” conditions. An additional feature is the dashboard arrow at the top of each graph, which can be used to demonstrate the overall result of sustainability.

The LCA of sago palm cultivated on peatlands consist of all the phases from seedling, cultivation (maintenance and harvesting), carrying (from plantation to factory), and the production process in a factory as shown (Figure 2). The inputs of each phase involve fertilizer, fuel, water, and chemicals while the outputs of each phase include GHG emissions, solid waste, and effluent.

The LCA data was primarily obtained from on site. The data of sago palm (plantation and factory) was taken from the national plantation company on peatland in Selat Panjang, Meranti district, Riau Province. Environmental LCC was estimated using the available literature and national data. The data for SLCA was collected at the site the company and the plantation on the peatland. The sago palms that are cultivated on the peatland were investigated using LCA, environmental LCC, and SLCA.

Figure 2. Inventory of the inputs and outputs from the seedling to the production process

3. Results and Discussion

The environmental, economic, and social aspects are presented in the following sections. The results of the LCSA are summarised at the end of this section by compiling the total of the results of LCA, Environmental LCC, and SLCA.

3.1 Environmental Dimension: LCA of Sago Palm on Peatland

Figure 3 represents the overall LCA of sago palm from seedling to the factory production phase. Sago palm (*Metroxylon* spp.) is an indigenous, neglected and underutilized plant species of Indonesia that has received little attention of agricultural researchers and government policy makers (Padulosi, Thompson, & Rudebjer, 2013).

Sago starch is the plant's food reserve in the form of carbohydrates that is preserved inside the trunk which can be consumed as human food similar to rice, corn, and tubers. Sago can grow in both muddy land (that is rich in minerals and carbon) and equally well in peatlands without any disturbance to the natural ecosystem (Bintoro, Purwanto, & Amarillis, 2010).

Sago palm is believed to originated from Papua, Maluku, Sulawesi, Sumatera, Kalimantan, and Java (Djoefri, Syafruddin, Dewi, & Ahyuni, 2013), however, it can also be found in Aceh, West Sumatera, Riau, West Kalimantan, West Java, Bali, North Sulawesi, South Sulawesi, and in majority in Papua (Bintoro, 2008). A company in Indonesia has cultivated sago palm in approximately 14,000 ha of peatland plantation in Tebing Tinggi island, in Meranti District, Riau Province (Bintoro et al., 2010). This national company has also built a sago mill factory with a capacity of 100 ton dried sago starch/day.

Sago palm is beneficial in several aspects such as has high carbohydrates content, gluten-free (ideal for autistic individuals), low glycemic index (appropriate for diabetic people), high resistance starch (suitable for people with celiac disease), organic product, no bleaching and no artificially added flavors and colors colour (Wulan, 2015). Sago palm has a high productivity of approximately 150–250 kg/bark that is equivalent to ± 22.36 ton/ha/year. Even in the wild forest of Papua, it can be found the productivity of sago palm was approximately 800–900 kg dried sago starch/trunk (Flach, 1996).

Sago palm thrives well in the forest in both polyculture and monoculture forms. Even though the tropical rain forest vegetation in Indonesia is predominantly of the polyculture form, the monoculture form is not uncommon. Previous studies show that fertilizer application did not affect the growth characteristics of sago palm. Sago trees propagate via buds/suckers, which develop around the main plant. The propagation of sago palm is different from oil palm, which requires replanting at 20–25 years. Sago palm is resistant to pests and diseases, prolonged droughts, floods and storms. The buds are able to propagate even after a fire event when followed by rain. It can also serve as a water catchment species. Almost all plant parts of sago are useful for human needs such as the leaves, trunk, solid waste, and even the high-protein worms that live inside the trunk. Sago starch processing can be carried out in integrated ways with zero waste. Sago is scattered all over the western and eastern parts of Indonesia with the highest population in Papua and Maluku. Indonesia has the world's biggest population of sago that is scattered over 5.5 million ha (Bintoro, 2018).

The density of tree arrangement in sago and oil palm plantation is similar. Sago has about 156 trees/ha with an annual harvesting period. Sago has the highest productivity (22.36 tons/ha/year) compared to that of oil palm (4.11 tons/ha/year) and paddy (6.15 tons/ha/year) cultivation (Wulan, 2015). In terms of productivity per unit area of land, sago requires 0.005 ha compared to that of oil palm (0.24 ha), and paddy (0.10 ha).

Sago palm does not require any special treatment, fertilizers or ameliorations meaning that the indigenous plant is well suited to the soil and peatland ecosystems of Indonesia.

Moreover, there are no transportation fuel costs associated with sago because the logs are transported to the mill factory via the water canal. However, the fuel consumption is higher (31.2 liter/ha) during harvesting of the logs. The sago starch production process at the mill factory requires 210 liter/ton sago starch. Sago falls under the low yield category of 14.88% because of higher solid wastes (854.89 kg/ton sago logs) and effluents (29,464.2 liter/ton/year), and extremely high water requirements (28,612 liter/ton sago starch).

The use of fuel, fertilizer, ameliorations, and waste output causes GHG emissions. Higher fuel consumption during sago harvesting and starch processing at the mill is the biggest source of GHG emissions in the case of sago; however, the total emissions are still lower than that of oil palm and paddy. Total emissions produced from sago starch product, crude palm oil, and rice product was 214.75 ± 23.49 , 406.88 ± 97.09 , and 322.03 ± 7.57 kg CO₂ eq, respectively (Wulan, 2015).

Material Input	Sago Palm
Area	1 ton logs need area: 0.00007 ha 1 ton Sago Starch needs area: 0.05 ha
Productivity ton/ha/year	Logs: 156 trees Sago Starch: 22.36
Yield	14.88%
Seedling Fertilizer kg/ha/Year Fuel l/ha/year	There is no special treatment, no additional fertilizer/pesticide/herbicide.
Maintenance and Harvesting Fertilizer kg/ha/year Fuel l/ha/year	Fuel: 1/50 logs 1 ha: 156 trees 1 tree: 10 logs 1560/50 31.2 l/year
Transportation Fuel l/ton	Using canal.
Production process	Fuel: 210 l/ton Sago Starch
	Water: 28612 l/ton Sago Starch
	Solid waste: 854.89 kg/ton logs Barks are fired for thermal heating power
	Effluent: 400 m ³ /day 29,464.2 l/ton/year
Total Emission Ton/ha/year	Emission: 214.75 ± 23.49 kg CO ₂ eq

Figure 3. Summary of LCA sago palm

3.2 Economic Dimension: LCC

The economic dimension of the three commodities from seedling, plantation, transportation, to the production process consists of the production cost comprising of the cost of fuel and fertilizers, the externalities cost (EC) comprising of the carbon stock and social costs, while the income (Rupiah/ton/ha/year) is the selling price of the product (Figure 4).

Figure 4. Graphic of the production cost, externality cost, and income of sago palm

Apart from the high fuel costs during the harvesting (logs and trunks) process, the production process also incurs higher fuel costs. The EC of sago palm falls in the lower category (Rp. 29,929,200) compared to that of oil palm and paddy (Rp. 40,329,450) because land clearing of oil palm plantation and paddy field requires higher land destruction and peatlands drain which results in serious land damage and produces higher GHG emissions (Wulan, 2015). The value of carbon stock and social cost can be found in the study of (Chew, Md. Isa, & Mohayidin, 1999).

3.3 Social Dimension: SLCA

The main social factors of sago palm on peatland can be identified according to the methodological sheets for sub-categories in the SLCA (UNEP & SETAC, 2013) and use data of plantation and the factory by observing and interviewing the management and staff at the site. This exercise revealed high risk in terms of 1) fair salary, 2) working hours per week, and 3) health and safety.

Figure 5. Graphic of the social aspect of sago palm

These risks have been placed on a scale of 1 to 3 where 1 means very good, 2 means good, and 3 means average. Fair salary had a rating of 1 for oil palm among sago palm and paddy because the salaries of oil palm laborers can reach 2–7 times than those of other agricultural areas (Budidarsono, Rahmanulloh, & Sofiyuddin, 2012). The average number of working hours per week is almost the same for those three crops (sago pal, oil palm, and paddy) because all companies are required to follow the regional and national labor regulations. Oil palm had the best health and safety rating because that company has good regulations for health and safety at the site areas. Both the plantation and factory side of this company was given the “zero accident” award by the Ministry of Labor. The best total average of social aspect was oil palm, followed by sago palm, and paddy. This is because the oil palm company was established in 1911, and since then it has continuously improved its performance through research and development. In addition, the oil palm company has always had a high demand in the world. Figure 5 shows a screenshot of the sustainability dashboard for the three different commodities on peatlands.

3.4 Life Cycle Sustainability Assessment: LCSA

The life cycle sustainability dashboard (LCSD) is used for summarizing the results from the LCSA in a consistent way to the decision makers. The LCSD is a Microsoft Excel spreadsheet tool in which a specific application of “Sustainability” is used to compare different products or scenarios (Finkbeiner et al., 2010). The LCSD uses a color scale ranging from red (bad) via yellow (intermediate) to green (good) to present the comparison of the three dimensions of sustainability (Traverso, Finkbeiner, Jørgensen, & Schneider, 2012). Figure 6 shows the screenshot of the sustainability dashboard for sago cultivation on peatland. The value of the color in the dashboard is as follows:

Figure 6. Life cycle sustainability assessments of sago palm on peatlands

According to the policy valuation, the sustainability from the environmental (LCC), economic (LCC), and social aspects (SLCA) of sago palm showed a light green color indicating it is sustainable.

4. Conclusion

By applying LCA, LCC, and SLCA methods, we were able to quantify the indicators of the sustainability of sago palm cultivated on peatland. Our results show that sago palm falls in the sustainable category (OK) with a light green indicator meaning that it is sustainable. Sago palm also showed a good performance in the LCA (environmentally friendly category) with a green indicator, because it does not require additional fertilizer and ameliorations. It also showed a light green indicator in the LCC because of zero cost for fertilizers and ameliorations, lower carbon stock emissions, and almost no social costs. In addition, the income from selling the product (Rupiah/ton/ha/year) is also very good because of its high productivity and fair market price. However, the social aspect of sago palm cultivation falls under the pink category indicating that there is scope for improvement, for instance, from the oil palm industry, in its social aspect (fair salary, working hour, health, and safety).

Sago palm as an indigenous plant of Indonesia is suitable for tropical rain forest vegetation with evidence no additional fertilizer and ameliorant during cultivation. There is no destructive land during the preparation of land for growing sago palm, low externality cost, low carbon emission (214.75 ± 23.49 kg CO₂ eq) and high productivity (22.36 ton/ha/year). Therefore, sago palm is recommended as an environmental friendly food resource in climate change era.

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