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Analysis of the Environmental Impact of Sugarcane Cultivation on Ecotoxicity, Land Use Competition and Depletion of abiotic resources with Life Cycle Assessment
(Case Study: Madukismo Sugar Factory, Yogyakarta, Indonesia)

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Abstract

Madukismo Sugar Factory used Ametryn and 2,4 d.amine as herbicides, and Urea, NPK, and ZA fertilizers, in its sugarcane cultivation process. This study performed life cycle assessment to see its environmental impact and proposed sustainable improvement efforts. The factory's sugarcane cultivation was found to account for 1041.085927 kg 1,4-DCB- Eq of Freshwater aquatic ecotoxicity-FAETP 100a, 6.702603784 kg 1,4-DCB-Eq of Terrestrial ecotoxicity-TAETP 100a, 689.8995889 m2a of Land use– competition, and 171.1111422 kg antimony-Eq of Depleted abiotic resources. The improvement could be made by applying biological pest controls, such as trichogamma chilonis, Cotesia flavipes, Sturmiopsis inferens, Tetrastichus scoenobii and elasmus zehteneri. The NPK, ZA, and urea fertilizers should also be used according to the standard operating procedure set by the Ministry of Agriculture, particularly regarding its amount and duration (at least twice a year). Manure could also be used to decrease dependency on synthetic fertilizers. Filter cake should also be used as organic fertilizer in sugarcane cultivation.

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INTRODUCTION

Sugar is an important product inseparable from daily life. Sugar products vary and are not limited to food(Sirait, 2020).Sugar demand in Indonesia shows an increasing trend every year. In 2021, The country's national sugar production reached 2.35 million tonnes, consisting of 1.06 million tonnes from the state sugar factory and 1.29 million tonnes from the private sugar factory. Sugar demand increased to 6.48 million tonnes in 2022 (3.21 million tonnes for white sugar and 3.27 million tonnes for refined sugar). The state and private sugar factories produced 1.06 million tonnes and 1.29 million tonnes, respectively. The current sugar deficit is 850,000 tonnes of consumption sugar and 3,27 tonnes of refined sugar. This increased demand was accounted for by the increased domestic consumption due to population growth, increased citizen's income, and FnB industry's 5-7% annual growth (Anonim, 2022). Despite the positive impacts of the sugar industry (e.g., employment absorption, contribution to the state's revenue, and fulfilling the FnB industry's needs), this industry has been reported to have negative effects on the environment and human beings through the soil, surface water, and air pollution. Therefore, every element in sugar industry needs to implement a sustainable value concept, as depicted in the following figure.

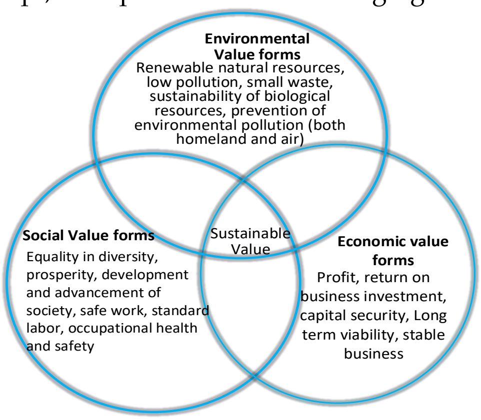

Figure 1. Sustainable Value Concept (Evans et al., 2017)

As displayed in the figure above, an industry should integrate economic, social, and environmental values in order to be sustainable. Sustainable value then represents not only environmental sustainability but also social and economic value(Ueda et al., 2009). Sustainability drivers, such as footprint reduction, poverty alleviation, fair distribution, waste reduction, and transparency, and their associated business strategies–understood as clean technology, sustainability vision, pollution prevention, and product stewardship–can take forward the creation of sustainable value for the business (Hart & Milstein, 2003). Sustainable value implemented in industry shares the similarity with the concept of life cycle assessment, as displayed in Figure 2 below.Industry should minimize environmental pollution due to its manufacturing process by improving the material and energy consumption efficiency, from raw material extraction, processing, and distribution to product recycling stages. Controlling environmental pollution may likely enhance public acceptance of the industry. Good environmental and social aspects may significantly affect the industry's long-term sustainability and benefits.

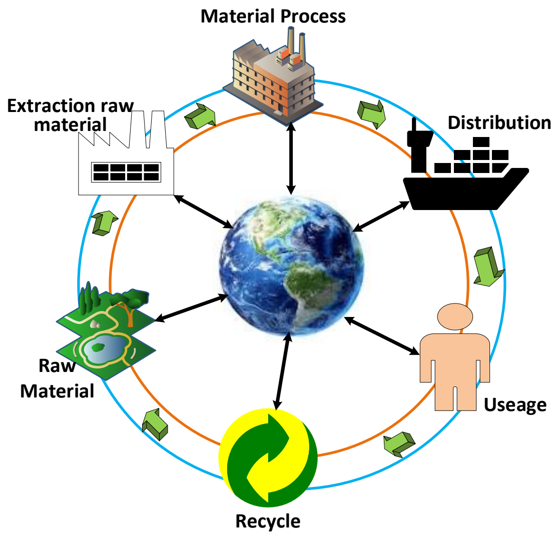

Figure 2. Life Cycle Assessment Concept (Hanafi et al., 2021)

Ref. (Mashoko et al., 2010) found that the sugarcane cultivation phase emits more greenhouse gas than other phases in the industry. Seabra (2011) also found that sugarcane cultivation accounts for 42% of greenhouse gas production in sugar production. In this regard, controlling and reducing energy and resource consumption is necessary to minimize environmental problems caused by sugarcane cultivation(Seabra et al., 2011).

One of the sugar factories in Yogyakarta Province is Madukismo Sugar Factory. Like other factories in the country, Madukismo Sugar Factory is demanded to produce high-quality sugar to meet the province's demands amid the declining trend of national sugar production while controlling environmental pollution caused by the sugar production process, especially in the cultivation stage. This study aimed to analyze the environmental impact of sugarcane cultivation on ecotoxicity, land use competition, and depletion of abiotic resources by performing the life cycle assessment in Madukismo Sugar Factory, Yogyakarta, Indonesia)

Figure 3. Madukismo Sugar Factory

METHOD

Unit Fungsional and Procedure LCA

This study was conducted through a literature review and field survey in Madukismo Sugar Factory. The field survey was performed to find out the crop arrangement, non-rainfall water source, transportation system, machines used for soil processing, and sugarcane harvesting. Interviews were conducted with employees and directors of Madukismo Sugar Factory in order to obtain data on sugarcane production and fertilizer and herbicide uses. OpenLCA was used to analyze the data and propose improvements. The functional unit used in this study was 1 ton of sugarcane produced in 1 year. LCA was performed in four stages, as illustrated in Figure 4, consisting of goal and scope setting, inventory analysis, impact assessment, and interpretation. It was done following LCA procedure described by ISO 14040. A quantitative descriptive approach was applied to assess the environmental aspects. Data were then processed and analyzed using OpenLCA 1.013, while the impact was calculated using CML method (baseline).

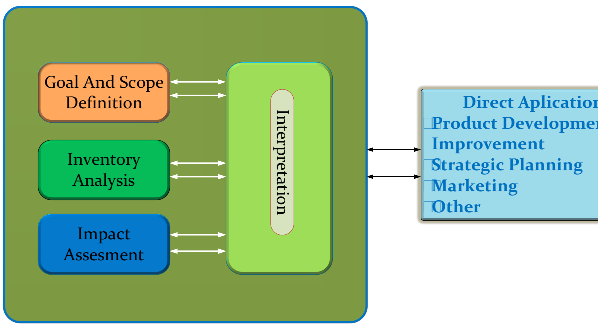

Figure 4. Lifecyle assessment framework (ISO 14044: 2006, Environmental Management,Life Cycle Assesment-Requirements Guidelines, 2006)

This study was conducted from September 2021 to June 2022 in Madukismo Sugar Factory. It was located in Jalan Padokan, Jl. Madukismo No.21, Rogocolo, Tirtonirmolo, Kecamatan Kasihan, Kabupaten Bantul, Daerah Istimewa Yogyakarta 55181.

Figure 5. Research Site location, Madukismo Sugar Factory, Yogyakarta (Map Data, 2023)

Software OpenLCA

OpenLCA 1.103, used in this study, is one of the latest software developed by Greendelta and is commonly used to assist Lifecycle Assessment (LCA) [11]. It is an open-source software that can be accessed freely. It helps assist in the analysis of an environmental aspect of a product or a service systematically and consistently. Databases used in this study were ELCD database 3.2, Agribalyse v3.0.1, and Bioenergidat-18, freely accessible in openLCA Nexus (Greendelta, 2019).

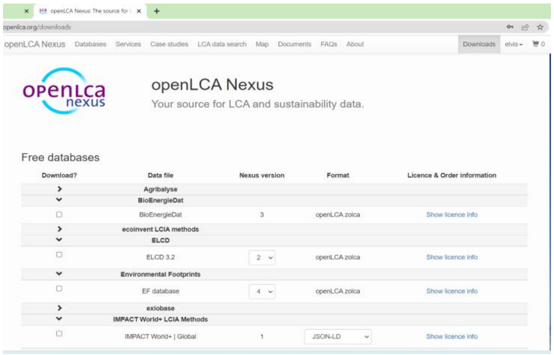

Figure 6. OpenLCA Nexus Database (GreenDelta GmbH, 2021)

RESULT AND DISCUSSION

Goal and Scope Definition

Prior to defining the goal and scope, it is necessary to determine the functional unit. Understanding the functional unit helps create and model a product system in LCA. It is a quantitative measure of a product function, which serves as the basis for calculating the impact (Arzoumanidis et al., 2019). The functional unit is vital in LCA and may affect the system comparison result. It represents the quantitative description of a system's function (Sillsa et al., 2020). The functional unit in this study is the production of 1 ton of sugar in 2021. This study aimed to describe the input and material impacts of sugarcane cultivation on environmental pollution. The scope of this study was cradle to gate method, which was done by examining the activities in sugarcane cultivation, as displayed in Figure 7

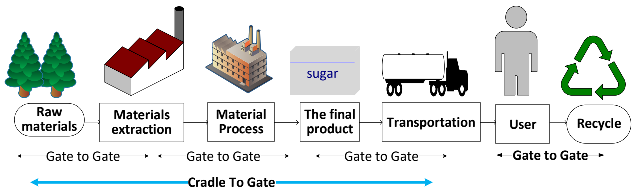

Figure 7. Scope of sugarcane cultivation LCA(Setiawan, 2020)

The inventory analysis of sugarcane cultivation comprised five stages: 1) soil processing, 2) crop planting, 3) maintenance (fertilizing and watering), 4) harvest-transporting process, and 5) postharvest waste burning. Postharvest waste is left in the sugarcane field after the harvest process. It includes dry leaves, litter, and sugarcane tops. Each process of sugarcane cultivation requires inputs (i.e., natural resources and energy), output (final product, waste, emission), and byproducts, as displayed in Figure 8.

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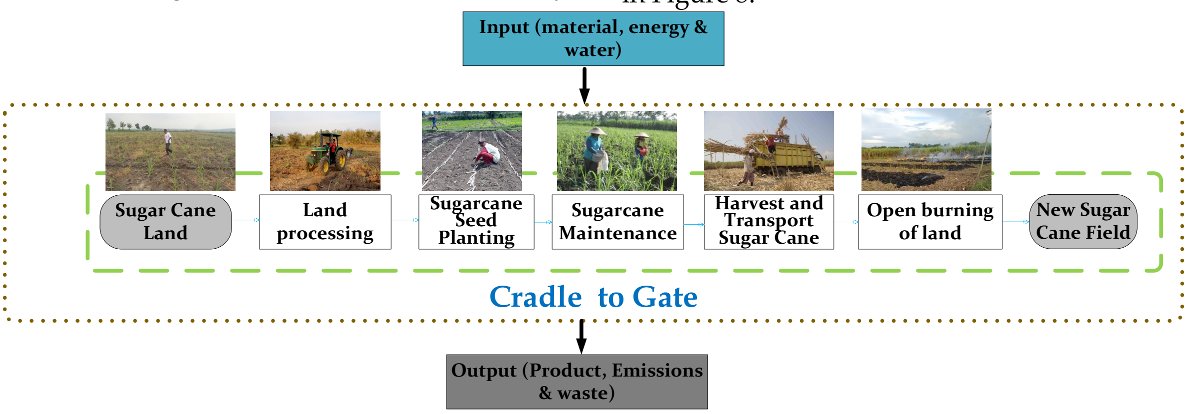

Figure 8. Cradle-to-Gate scope of MSF's sugarcane cultivation

The sugarcane cultivation process begins with soil processing. The fossil fuel used as the input was 0.052 m^3 of diesel fuel and emitted diesel combustion products. Diesel consumption in the soil processing stage refers to the study (Izursaa et al., 2013), stating that the fuel consumption in this stage was 115 liter/ha/year. The filter cake is spread all over the field before planting a new crop and is one of the inputs needed in the planting stage. It refers to a residue removed during the sugarcane juice decantation during sugar and alcohol production(Rabelo et al., 2015).In 2021, Madukismo Sugar Factory planted 3293.21 tonnes of sugarcane seeds. The factory used 0.246 ha of land to produce 1 tonne of sugar. The next stage is the maintenance stage, consisting of fertilizing and watering activities. In this stage, non-organic fertilizers: urea, NPK, and ZA. It is assumed that 0.6 tonnes of ZA, 0.5 tonnes of NPK, and 0.5 tonnes of urea are used per hectare (Data from Madukismo Sugar Factory). Madukismo Sugar Factory also used herbicides, i.e., 2 liters of ametrine/ha and 2 liters of 2,4-d amine/ha. The diesel consumption in the crop planting stage was 164 liter/ha(Izursaa et al., 2013). Meanwhile, regarding the watering stage, most sugarcane fields owned by Madukismo Sugar Factory used a rainfed system and occasionally used diesel-fueled water pumps. Due to a rainfed system, the volume of water used during the cultivation is not recorded. However, (Farooq & Gheewala, 2019) as cited in (Qamar et al., 2018) states that sugarcane cultivation consumes 25.405.99 m^3/ha of water and 333 liter/ha of diesel (Izursaa et al., 2013). The output of this stage is the emission of non-organic fertilizer to the soil, air, and the nearest water body. This activity also potentially causes nutrient leaching, in which soil nutrients are moved away from the plant's root, making it unavailable for the plant. Some nutrients in non-organic fertilizers are known to be highly mobile and easily disappear through washing and evaporation activities. The next stage is the harvest, which was during the dry season between June-August 2021. During the dry season, sugar cane is in its optimal condition. Plants were cut and transported manually. Sugarcane cultivation produces a large amount of dry leaves, accounting for up to 40% of the total biomass. On average, each hectare of sugarcane field produces 15-20 tonnes of cane trash every harvest season (PRABHAKAR et al., 2010).

Post-harvest waste is usually left in the field and open burnt to Accelerate the field cleaning process and preparation for the next planting season. The open-burnt post-harvest waste is estimated to be 2.414 tonnes or 15% of the total harvest, as shown in(Astuti, 2019). According to (Sornpoon et al., 2014) 77% of the sugarcane field in Thailand was open-burnt, and only 23% of the total field was not burnt. Of this number, 82% of the field was burnt during the pre-harvest period, while 18% was during the post-harvest period. The harvested sugarcane is then transported to the factory using trucks. The diesel fuel consumption for sugarcane transportation in this study was assessed by referring to (Izursaa et al., 2013) i.e., 89 liters of diesel/ton of sugarcane. The result of the inventory analysis of the input and output of the sugarcane plantation subsystem is presented in Table 2.

Table 2. Input and output data of sugarcane cultivation in Madukismo Sugar Factory

Number	Input	amount	unit	Output	amount	Unit
1	Fuel /diesel	4500,45	liter	sugarcane	6.496,25	kg
2	Sugarcane field	0,246	ha	CO	8,181	kg
3	Sugarcane seeds	0,531	ton	CO_2	10,248,32	kg
4	water	7.177,06	M3	SO_2	42,66	kg
5	ZA fertilizer	600	kg	CH_4	137,24	kg
6	NPK fertilizer	500	kg	N_2O	1216,73	kg
7	Urea fertilizer	500	kg	NOx	25,819	kg
8	Ametryn	2	liter	PO_4^{3-}	4,015	kg
9	2.4 D amines	2	liter	CO_2 biogenik	2,585	kg
				NO_2	3,134	kg

Source: Research Result, 2022

Life Cycle Inventory (LCI)

Based on the analysis result, the scope was set to be cradle-to-gate. The sugarcane cultivation process comprises several stages: land preparation, seed planting, maintenance, harvest-transport, and open burning activities for the next planting season. Cradle-to-gate analysis is presented in Figure 8. Based on the input, process, and output presented in Figure 9, inventory data of the Madukismo Sugar Factory were obtained, as shown in Table 2

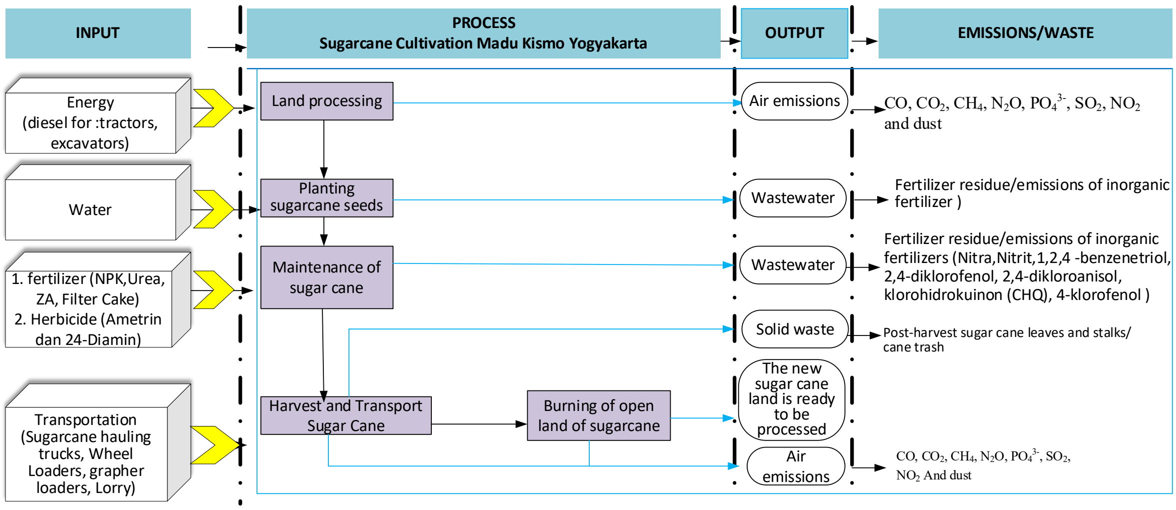

Figure 9. Input, Process, and output data of sugarcane cultivation in Madukismo Sugar Factory,

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Table 3. LCA data in Madukismo Sugar Factory

Materials and energy	Database	Provider database
Fuel/diesel	Agribalyse_v3_03062020	Light fuel oil/Ecoinvent
Sugarcane field	agribalyse_v3_03062021	Transformasi annual crop/Ecoinvent
Sugarcane seeds	agribalyse_v3_03062021	Sugarcane Ecoinvent
water	agribalyse_v3_03062021	Water, rain/Ecoinvent
ZA fertilizer	agribalyse_v3_03062021	Ammonium sulfat, as N(GLO)/Ecoinvent
NPK fertilizer	agribalyse_v3_03062020	Nitrogen fertilizer, as N (GLO)/Ecoinvent Phosphat fertilizer, as P2O5 (GLO)/ecoinvent
Urea ferlilizer	agribalyse_v3_03062020	Urea (with 46% N)/Ecoinvent
Ametryn	agribalyse_v3_03062021	Ametryn/ecoinvent
2.4 D amines	agribalyse_v3_03062022	
Transport	USDA	Transport, fright, lorry, unspecified (RER)/ecoinvent

Source : openLCA Nexus

Life Cycle Impact Assessment (LCIA) of sugarcane cultivation in Madukismo Sugar Factory

The environmental impact assessment aims to categorize and assess a system's environmental impact. The assessment was done using OpenLCA with CML-2001. Table 4 displays the impact when using CML, 2001 ecoinvent.

The inventoried data were quantitatively analyzed to determine the environmental impact of each stage in the process. This paper describes four environmental impacts of sugarcane cultivation: Freshwater aquatic ecotoxicity - FAETP 100a, Land use – competition, Depletion of abiotic resources, and Terrestrial ecotoxicity - TAETP 100a. The life cycle impact assessment (LCIA) analyzes five stages of sugarcane cultivation: soil processing, crop planting, maintenance, harvest-transportation, and cane trash open burning. The soil processing and harvest-transport stages emitted pollution from the use of diesel fuel in their processes, while crop maintenance emitted pollution due to the use of non-organic fertilizer, and the cane trash open-burning also emitted pollution from the combustion process. The following section describes the environmental.

Table 4. Effects of MSF's sugar cane cultivation

	Impact category	Reference unit	Result
1	Freshwater aquatic ecotoxicity - FAETP 100a	kg 1,4-DCB-Eq	1041.085927
2	Terrestrial ecotoxicity - TAETP 100a	kg 1,4-DCB-Eq	6.702603784
3	Land use - competition	m²a	689.8995889
4	Depletion of abiotic resources	kg antimony-Eq	171.1111422

a. Ecotoxicity

Environmental ecotoxicity is measured in three different categories: freshwater, saltwater, and land. Heavy metal emissions can affect the ecosystem. The toxicity is measured based on the substance's maximum tolerable concentration in the water. This method depicts the impact of toxic exposure on the environment, represented in 1,4 kg dichlorobenzene, and measures separately the freshwater aquatic ecotoxicity, marine aquatic ecotoxicity, and terrestrial ecotoxicity potential (Acero et al., 2015a).

According to (Chakraborty et al., 2017) urea, phosphate, and nitrogen in agricultural fields account for faster algae growth and lower Dissolved Oxygen concentration in the freshwater. This condition is often known as Algae bloom, an immediate significant increase of microorganisms causing decreased oxygen concentration and toxic release. It often results in the organism's death, especially fish. Nitrogen within the fertilizer can also create a dead zone in the freshwater and saltwater ecosystem (Ward, 2009). Bedog River is located near the Factory's sugarcane field. It receives water runoff from the sugarcane field contaminated by 2,4 d.amine and wastewater from the Factory's wastewater management process (Novayanti & Poedjirahajoe, 2014).The factory also used ametryn to control monocotyledonous and dicotyledonous weeds in sugarcane cultivation (Simoneaux & Gould, 2008).], which may spread and pollute the surface water, such as river and water body sediment near the water body (Moura et al., 2018).

1.Freshwater aquatic ecotoxicity - FAETP 100a.

The freshwater ecosystem undoubtedly contributes to people's life and welfare by, among others, providing food and drinking water, cultural development, recreation, and ecotourism. It also plays a role in maintaining water quality by degrading organic materials and recycling nutrients (UNEP, 2017). Due to its central role, the freshwater ecosystem should be well-protected from pollution, including the one from sugarcane cultivation activities.

Freshwater aquatic ecotoxicity represents the potential effect of toxic chemicals such as phenol, Hg, As, Cd, Cr,Cu, Pb, Ni, Vanadium, and Zn on creatures living in freshwater, stated in kg 1,4 DCB Eq (Jessica Hanafi et al., 2021). In this study's context, one of the toxic chemicals is phenol, which is one of the materials to make 2,4 d.amine. Madukismo Sugar Factory used this herbicide during the cane planting and maintenance to kill pests. 2,4 d.amine is commonly used in the agricultural sector, including sugar cane cultivation. It contains an active substance of 2,4-dichlorophenoyacetate made from phenylacetic acid chlorination. 2,4 d.amine disposed directly to open water or the surrounding environment may take 12.9 to forty days to degrade, depending on the water quality. The substance concentration decreases through microbial activity, water's offsite flow, and small particle adsorption in muddy water. Once degraded, 2,4 d.amine may turn into 1,2,3-4 n benzeneditriol, 2-4 dichlorophenol, 2,4-dichloroanisole, chlorohydroquinone (CHQ), 4-chlorophenol, and volatile organic compounds.(Wisconsin Department of Natural Resources, 2012). The compounds are toxic for fish and other living organisms in the river.

Table 4 and Figure 10 display the relationship between freshwater aquatic ecotoxicity and the material and energy input during the sugarcane cultivation at Madukismo Sugar Factory. Figure 10 shows that the materials and energy, including nitrogen, phosphate, ammonium sulfate fertilizers, transportation, ametryn, and 2,4 d.amine, were related to a 1041.085927 kg 1,4 DCB eq of freshwater aquatic ecotoxicity. More specifically, nitrogen, phosphate, ammonium sulfate, diesel fuel, ametryn, and 2,4 d.amine was found to account for 388; 219.4; 202.5; 96.397; 68.166; 66.637 kg 1.4 DCB eq of freshwater aquatic ecotoxicity, respectively.

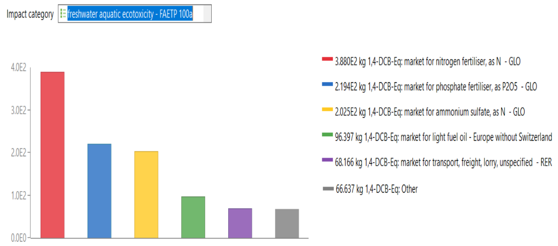

Figure 10. Relationship between Material-Energy Input and Freshwater aquatic ecotoxicity

2.Terrestrial Ecotoxicity - TAETP 100a.

Terrestrial ecotoxicity refers to the effect of toxic compounds on terrestrial ecosystems (Dincer & Bicer, 2018). Various chemical types and properties may be released to water, air, and soil during a life cycle. Inventorizing chemical compounds of various products may result in hundreds of substances potentially causing terrestrial ecotoxicity and damaging the ecosystem quality.(LC Impact, 2019). The main route of nitrogen exposure to humans is polluted drinking water. Nitrate is the final product of nitrogen that may be accumulated in the groundwater under the agricultural field.(Nolan & Stoner, 2000). Nitrate concentration could be very high in rivers and groundwater due to large amounts of nitrogen fertilizer runoff from the field. Groundwater is also used for drinking by 90% of people in rural areas in the USA, where most people have private wells not regulated by the EPA. Public tap water companies should meet the maximum limit of 10 mg/l of nitrate-nitrogen concentration (N) to avoid methemoglobinemia, usually known as a blue baby syndrome. Nitrate-contaminated water also potentially causes cancer, diabetes, and thyroid (Ward et al., 2005). Nitrate concentration in the groundwater could be very high due to the nitrogen fertilizer runoff from sugarcane fields. The field survey shows no regulation regarding the minimal distance between the local community's well and the MSF's sugarcane field, putting local people's wells at risk of infiltrating nitrate compounds from the nitrogen fertilizer used during the planting period. In Indonesia, nitrate's drinking water quality standard was 50 mg/l as NO_3^- (Peraturan Menteri Kesehatan Republik Indonesia No.492/MENKES/PER/IV/2010, 2010). The pest control could be done biologically usingTrichogamma chilonis, Cotesia flavipes, Sturmiopsis inferens, Tetrastichus scoenobii and elasmus zehteneri. Trichogramma is available commercially and common in lepidopteran pest control in horticultural plants.(Sharma et al., 2020). In other words, MSF could implement biological pest control to minimize the environmental impacts.

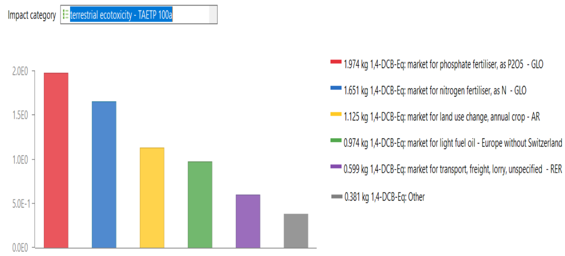

Figure 11. Relationship between Material-Energy Input and terrestrial ecotoxicity

Table 4 and Figure 11 display the relationship between terrestrial Ecotoxicity - TAETP 100a and the material and energy input during the sugarcane cultivation in Madukismo Sugar Factory. Figure 11 shows that the materials and energy, including nitrogen, phosphate, ammonium sulfate fertilizers, transportation, ametryn, and 2,4 d.amine were related to a 1041.085927 kg 1,4 DCB eq of terrestrial ecotoxicity. More specifically, nitrogen, phosphate, ammonium sulfate, diesel fuel, ametryn, and 2,4 d.amine was found to account for 1,651; 1,125; 0.974; 0.599 and 0.381 kg 1.4 DCB eq of terrestrial ecotoxicity, respectively.

b.Land Use - Competition

Land use competition refers to the effect of agricultural, residential, and natural resource extraction activities on the land. Changes in the land area may lead to biological diversity changes, which are indicated by species loss, land loss, and dry organic matter. The damage could be viewed from the decreased renewable and non-renewable natural resources. The damage was measured in m2a (square meters per year)(Acero et al., 2015b). Table 4 and Figure 12 display the relationship between land use competition and the material and energy input during the sugarcane cultivation in Madukismo Sugar Factory. As shown in Figure 12, nitrogen, phosphate, ammonium sulfate, diesel fuel, Ametryn, and 2,4 d.amine is linked to the 689.8995889 m²a decrease in the sugarcane field area. More specifically, nitrogen, phosphate, ammonium sulfate, diesel fuel, ametryn, and 2,4 d.amine accounted for 182.9; 171.9; 136.7; 117.5; 53.483; and 27,500 m²a, respectively. The area of sugarcane fields owned by MSF continued to decrease due to land use changes for residential, hotel, and ecotourism purposes. The decrease could be noted from the decrease in sugarcane fields in Yogyakarta province, from 3,134 ha in 2021 to 2, 920 in 2022. (Directorate General of Estates, 2021).

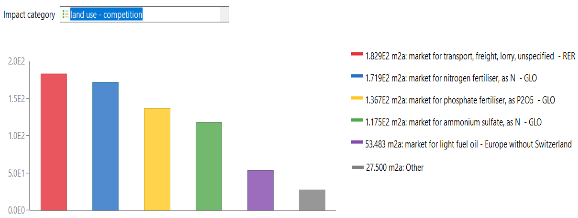

Figure 12. Relationship between Material-Energy Input and Land use Competition

c.Depletion of Abiotic Resources

Depletion of abiotic resources refers to the consumption of non-biological resources, such as fuel, minerals, metal, and water. Abiotic resource use may serve as the parameter of the scarcity of a resource in nature. Thus, it highly depends on the amount of resources and the extraction level. This parameter reflects the number of depleted resources measured and presented in antimony, water consumption, kg of mineral depletion, and MJ of fossil fuel (Acero et al., 2015b). Table 4 and Figure 13 display the relationship between the depletion of abiotic resources and the material and energy input during the sugarcane cultivation in the Madukismo Sugar Factory. As shown in Figure 13, nitrogen, phosphate, ammonium sulfate, diesel fuel, ametryn, and 2,4 d.amine were linked to the 171.1111422 kg antimony eq. of natural resources and ecosystem damages. More specifically, nitrogen, phosphate, ammonium sulfate, diesel fuel, ametryn, and 2,4 d.amine accounted for 112.7; 17.539; 15,913.8; 582.8; 8.250; and 8,085 kg antimony eq, respectively. Depletion of abiotic resources appears to be caused by significant fuel and water consumption during the cultivation, i.e., 4500.45 liters of diesel and 7,177.06 liters of water.

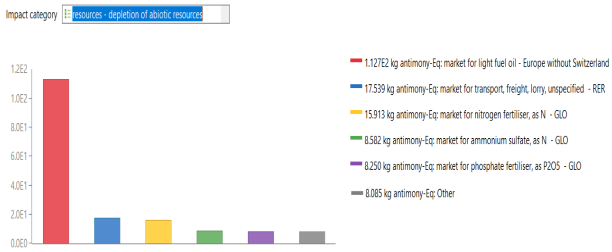

Figure 13. Relationship between Depletion of Abiotic resources and Materials and energy input

Interpretation

Interpretation was the last stage in this study. It was done to improve MSF's sugarcane cultivation, thus minimizing negative impacts on freshwater aquatic ecotoxicity, terrestrial ecotoxicity, land use competition, and depletion of abiotic resources.

Improvement Analysis

The factory needs to applied Resource Efficiency and Cleaner Production program, an integrated, sustainable concept of environmental practice during the process, production, and services, to enhance the efficiency and minimize human and environmental risks (Anonim, 2020). Efforts for improving MSF's cultivation performance are described as follows:

a. Lifecycle assessment result shows that the most significant environmental lies in the considerable uses of fertilizer and herbicides. Therefore, the improvement could be made as follows:
   Input change, which could be done by determining an efficient input that brings minimal damages to the environment and human:
   1. Instead of using 2,4. D amine and ametryn, pest control could be done biologically using trichogamma chilonis, Cotesia flavipes, Sturmiopsis inferens, Tetrastichus scoenobii and elasmus zehteneri.
   2. The use of NPK, ZA, and urea fertilizers should comply with the SOP set by Ministry of Agriculture.
   3. Using organic fertilizer could lower the dependence on synthetic ones, Filter cake could also be used as the organic fertilizer in sugarcane cultivation.
b. Another problem is related to the large amount of water consumption. In this regard, equipment could be modified to

provide more efficient and effective irrigation system. It is suggested to use the technical irrigation to enhance the water efficiency and increase the sugar cane and sugar production. The irrigation system may also anticipate the fluctuating water needs during rain season.

CONCLUSION

This study concludes that MSF's sugarcane cultivation is responsible for 1041.085927 kg 1,4-DCB- Eq of Freshwater aquatic ecotoxicity-FAETP 100a, 6.702603784 kg 1,4-DCB-Eq of Terrestrial ecotoxicity-TAETP 100a, 689.8995889 m2a of land use– competition, and 171.1111422 kg antimony-Eq of depletion of abiotic resources. The lifecycle assessment result shows that the most significant environmental lies in the use of fertilizer and herbicides. Therefore, the improvement could be made as follows: - Input change, which could be done by determining an efficient input that brings minimal damages to the environment and human, for instance: 1. Using biological pest controls such as trichogamma chilonis, Cotesia flavipes, Sturmiopsis inferens, Tetrastichus scoenobii dan elasmus zehteneri; 2. Compliance with the Ministry of Agriculture's SOP regarding NPK, ZA, and urea fertilizers; 3. Using the proper amount of organic fertilizers to decrease dependence on synthetic ones, in addition to using filter cake as the organic fertilizer, and 4) Implementing technical irrigation to improve water consumption efficiency and increase production. The irrigation system may also anticipate the fluctuating water needs during rainy season.

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