Environmental Impact Assessment of Thai Banana Supply Chain

Cheerawit Rattanapan and Weerawat Ounsaneha

***Abstract*—The research of this study was to assess the environmental impact of banana supply chain in Thailand in accordance with the recommendations of the international standards ISO 14040 and 14044. The scope of this study was to determine banana supply chain located at Pathumthani province, Thailand with the production performance in 2018. One kilogram of banana plantation and Six hundred gram of banana product was used to the functional unit for farm and industrial sections, respectively. The seven clarifications including climate category, terrestrial acidification, freshwater eutrophication, human toxicity, terrestrial ecotoxicity, freshwater ecotoxicity, and fossil depletion of Thai banana supply chain was calculated. The results presented that the business to business of environmental impact category of banana plantation were the human toxicity from benzene consumption. The reason was partly that the long distance from farm to industry from the transportation. For the environment impact of banana product in the industry process, the result showed that the human toxicity was the main environmental impact from banana plantation as main raw material and electricity consumption in the ripening process. Hence, the alternative energy of fuel consumption and the reduction of banana waste should be proposed for the appropriate approach environmental impact reduction in Thai banana supply chain.**

***Index Terms*—Environmental impact, banana supply chain, life cycle assessment, Thailand.**

I. Introduction

Bananas are among the most consumed fruits in the world, and also the economical and nutritional important food crop in several areas of the world [1]. The banana consumption has been increased from the dietary behavior with the intake of fiber, resistant starch, total starch and some essential minerals, which are important to health [2]. The worldwide banana consumption is 9.51 kg/person/year on average, with Asian countries having a higher per capita consumption [3]. The main producers of bananas for the European market are Latin America [4], resulting in considerable transport distances for a fruit that is susceptible to spoilage. For Thai banana product, more than 234,000 tons was produced for demand of Thai and international consumption in 2013. Specifically, the central part of Thailand was the first main area of banana production with the advantage of low chemical contamination [5]. However, there are few published on the environmental impact studies of this product in Thailand [6].

Food production and consumption is an important contributor to environmental degradation, being responsible from 20% to 30% of the impacts of private consumption [7]. In developed countries, consumers start demanding food produced with minimal environmental burdens [8] and increasingly base their purchase decisions on environmental indicators [9]. Several methods, among them life cycle assessment (LCA) and carbon footprint (CF), have been developed and used to study a wide variety of goods including agricultural products. LCA can be used to study the entire life cycle of a product, beyond just the production phase, and summarize the environmental impacts of whole value chains, e.g. from production until consumption [10]. LCA studies have remained vital in providing detailed information for strategic planning and decision-making during product manufacturing so as to reduce on the environmental impacts. Through LCA, a product design can be improved by considering raw material, production technologies, and waste management strategies which emit less GHGs to the atmosphere [11]. The applications of LCA studies were found in the assessment of environmental impact of fruit production process [12]-[14].

Some reports [15]-[17] identified that environmental impact assessment of banana production. The calculated carbon footprint of Ecuadorian bananas, inclusive of the consumption point in Spain, was 1.28 tons CO_2e per tons of banana [18]. ADSAL *et al* [19] mentioned that the majority of the environmental impacts of banana production in Turkey was the plantation stage, and followed by the transportation stage. The minimum environmental impact of banana production in Turkey originated from the raw material supply stage. From this finding can be suggestions that the decreasing environmental impact of banana production in Turkey should be recommend. The improper disposal of the stem waste has a highly negative effect on the environment, causing impacts such as global warming potential or human toxicity potential. Moreover, Abdullah, *et al* [20] presented that each batch of banana production in Malaysia (during 10–12 months), four times of banana waste from plantation process (e.g., banana stem, leaves, fruit bunch, rotten fruit, and rhizomes) was emitted to environment.

Therefore, it is important to evaluate the environmental performance of the food production chain in order to identify possible hotspots and propose improvements aiming to reduce greenhouse gases (GHGs) and other emissions that contribute to various environmental impact categories, e.g. eutrophication, acidification, water use, etc. The aims of this work were to study the environmental impact of bananas from cradle to grave and to assess the potential of reducing environmental impact along the value chain.

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II. Material and Methods

The International Standards, ISO 14040 and ISO 14044 [18], [19] were used to conduct the LCA study of Thai banana production. The more detail of methodology, data and the assumptions are the following:

A. Goal and Scope Definition

1) The environmental impact assessment of Thai banana supply chain consisted of the raw material acquisition, banana production, distribution, consumption, and waste disposals.
2) The process investigation of this study was following: 1) The main of material use for banana product such as banana, packaging etc. and 2) The process steps of banana product with 1 kilogram and 0.2 kilogram (1 banana) were banana plantation, cutting, cleaning, drying, separation, packaging, repining and transportation to consumer. The production diagrams of plantation and production are shown in Fig. 1 and 2, respectively.
3) The data from a one company and banana farms in the central parts was collected in this study. The primary data of all process including the type and value of material, fertilizer, chemical, water and electricity use was conducted by the input and output of mass balance.
4) The functional unit of this study was the banana product with the size of 1 kilogram and 0.2 kilogram (1 package).

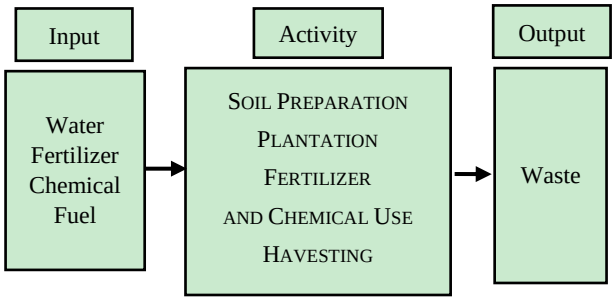

Fig. 1. Flow diagram of banana plantation.

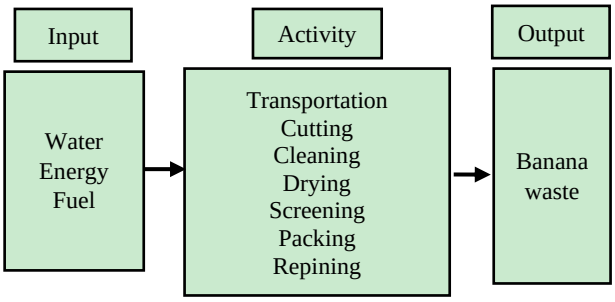

Fig. 2. Flow diagram of banana production.

B. Data Inventory

The inventory analysis in this study was mainly based on primary data from banana farm and factory collected in the period of 2018. The input and output of process was separated and identified according to the boundary scope of each unit. Secondary data for environmental impact assessment was obtained from the related study or report with strong in the academic reference.

C. Life Cycle Impact Assessment

The impact assessment includes the selection of impact categories, classification, and characterization based on ISO 14044 [19]. Seven impact categories considered in this study are climate category, terrestrial acidification, freshwater eutrophication, human toxicity, terrestrial ecotoxicity, freshwater ecotoxicity, and fossil depletion. The seven impacts were assessed as the potential of characterization. The allocation methods were chosen such that, where a market is already established, economic allocation was used, whereas in other cases system expansion was applied. Data storage and modeling were performed using the SimaPro 8.5.2.0.

III. Result and Discussion

A. Life Cycle Inventory of Banana Supply Chain

The results of this study obtained from bananas in farm gate and the bananas in industry process are presented in the whole year of 2018. Table I shows the main life cycle inventory inputs from banana plantation stage evaluated in this study taking into account 1 rai of banana orchard (1 rai = 0.16 ha). The inventory of banana plantation consisted of shoot, chemical organizer, organic fertilizer, pesticide, herbicide, benzene, water, diesel and electricity. The main input among a crop is the chemical fertilizers as 161.5 kilogram/rai or 1,009.375 kilogram/ha. This finding was lower than the report of Coltro and Karaski [21] with 1.2 ton fertilizers/plant applied in every year. Bananas have a high requirement for nitrogen and potassium and have the highest fertilization rate per hectare of all food crops [22]. Moreover, 1946.20 kg/rai was the output process in this farm.

From the result of life cycle inventory of banana production from industry, Table II shows the main life cycle inventory inputs from banana product evaluated in this study taking into account of an industry in 2018. The inventory of banana production consisted of banana, water, electricity, plastic bag, plastic tape, stringer and acetylene gas. The main resources input among a product is the electricity use because the electricity is used mainly for lighting and for operating pumps that extract water from wells and bananas are also transported within the facility on conveyor belts powered by electricity [17].

TABLE I: Life Cycle Inventory Analysis of Thai Banana Plantation

Order	Inventory	Quantity	Unit
Input			
1.	Shoot	300	Shoot/Rai
2.	Chemical Fertilizer	107	Kilogram/Rai
	60-0-0	2.5	Kilogram/Rai
	0-0-46	6.5	Kilogram/Rai
	15-15-15	28.5	Kilogram/Rai
	21-0-0	7	Kilogram/Rai
3.	Organic Fertilizer	10	Kilogram/Rai
4.	Pesticides	1.2	Liter/Rai
5.	Herbicide	0.4	Liter/Rai
6.	Benzene	54.75	Liter/Rai
7.	Water	1,228.46	Liter/Rai
8.	Diesel	85.98	Liter/Rai
9.	Electricity	6.79	Kilowatt/Rai
Output			
1.	Banana	1946.20	Kilogram/Rai

TABLE II: LIFE CYCLE INVENTORY OF THAI BANANA PRODUCTION

Order	Inventory	Quantity	Unit
Input			
1.	Banana	808.27	Kilogram
2.	Water	913.55	Liter/Product
3.	Electricity	271.52	Kilowatt/Product
4.	Bag	0.86	Kilogram/Product
5.	Tape	7.11	Kilogram/Product
6.	Stringer	0.01	Kilogram/Product
7.	Acetylene gas	0.02	Kilogram/Product
Output			
1.	Banana Product	6434.72	Kilogram
2.	Waste	1.23	Kilogram/Product

B. Environmental Impact of Banana Supply Chain

The business to business result in this study for environmental impact of banana supply chain divided two section following 1 kilogram of banana plantation from farm gate and 0.2 kilogram of banana product from industry.

For the banana plantation, the environmental impact categories in this study were climate change, terrestrial climate change, terrestrial acidification, freshwater eutrophication, human toxicity, terrestrial ecotoxicity, freshwater ecotoxicity and fossil depletion. The result was shown in Table III. The human toxicity was the main environmental impact of banana plantation from diesel use (Fig. 3, 4). The reason was partly that the distance from farm to industry is long distance around 40 kilometer of round-trip. Hence, the secondly environmental impact of banana production was the fossil depletion from the fuel consumption of transportation between farm and industry. Mfitumukiza *et al*. [23] reported that most of the energy in the agricultural stage was from fossil fuel (diesel). The patterns of energy use as quantified during the study further points to the need to explore options for reducing environmental impacts and costs associated with using fossils fuels. The apparent option is resorting to renewable energy sources which are available in Thailand. This will include utilization of gasoline of biodiesel in the level of agriculture production.

TABLE III: ENVIRONMENTAL IMPACT FOR 1 KILOGRAM OF THAI BANANA PLANTATION

Impact category	Life cycle Inventory									
	Potassium chloride	Urea, as 100% $CO(NH_2)_2$	NPK compound	Ammonium sulphate	Manure	Cypermethrin	Glyphosate	Diesel	Benzene	Electricity, high voltage {TH}
Climate change	2.77495E-08	1.70137E-07	1.06169E-06	1.95954E-07	0	3.50356E-11	8.98309E-07	1.56605E-06	0.001517395	1.49103E-07
Terrestrial acidification	1.13445E-08	1.08888E-07	2.35289E-06	7.28988E-08	0	4.71497E-11	1.2415E-06	6.30807E-06	0.001302941	1.12944E-07
Freshwater eutrophication	4.375E-09	5.22156E-08	3.40062E-06	2.82971E-08	0	2.54005E-11	2.82189E-07	0	0.00090007	3.86373E-06
Human toxicity	6.25955E-09	9.82423E-08	5.21324E-07	1.48691E-07	0	7.27455E-11	1.944E-06	0.002494769	0.011615338	1.04069E-05
Terrestrial ecotoxicity	2.94241E-10	3.60113E-09	3.76103E-08	9.82846E-09	0	2.22085E-11	2.25927E-07	7.88978E-08	0.000260446	1.6976E-08
Freshwater ecotoxicity	7.02881E-10	1.04495E-08	4.04592E-08	1.10668E-08	0	1.07818E-11	2.50183E-07	4.99697E-05	0.001154872	2.31333E-06
Fossil depletion	6.49634E-08	1.11072E-06	2.20001E-06	6.5528E-07	0	6.43023E-11	1.56771E-06	2.72685E-05	0.009202226	2.85717E-07

TABLE IV: ENVIRONMENTAL IMPACT FOR 0.2 KILOGRAM OF THAI BANANA PLANTATION

Impact category	Life cycle Inventory			
	Banana	Oriented polypropylene film	Acetylene	Electricity, high voltage {TH}
Climate change	3.249728	0.001388	3.31E-06	0.026539
Terrestrial acidification	0.011111	7.28E-06	1.53E-08	7.96E-05
Freshwater eutrophication	8.29E-05	4.75E-08	1.65E-09	2.94E-05
Human toxicity	13.87103	2.73E-06	5.61E-05	0.851759
Terrestrial ecotoxicity	0.000804	2.69E-09	9.22E-10	4.36E-06
Freshwater ecotoxicity	0.0031	1.13E-09	4.28E-08	0.000495
Fossil depletion	3.15985	0.000976	8.82E-07	0.008146

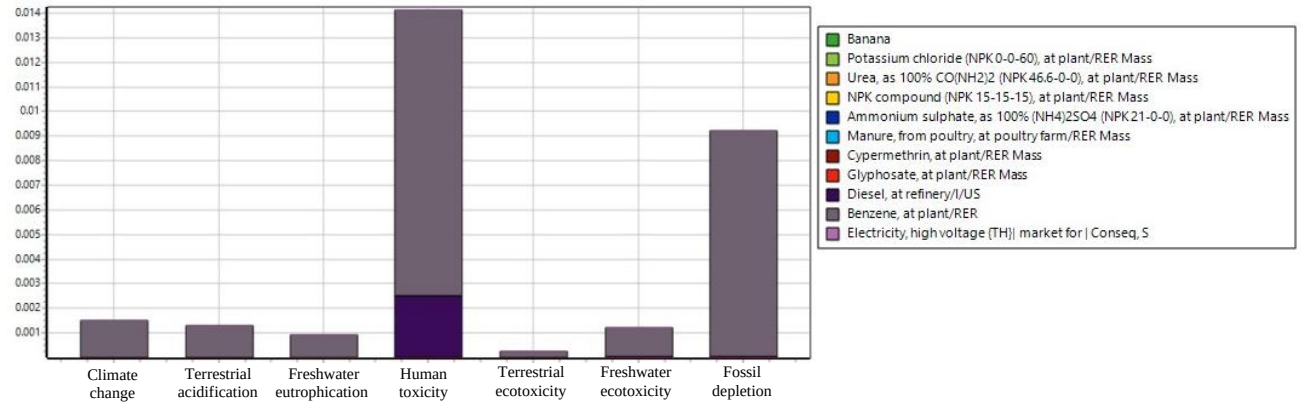

Fig. 3. The impact classification of banana plantation.

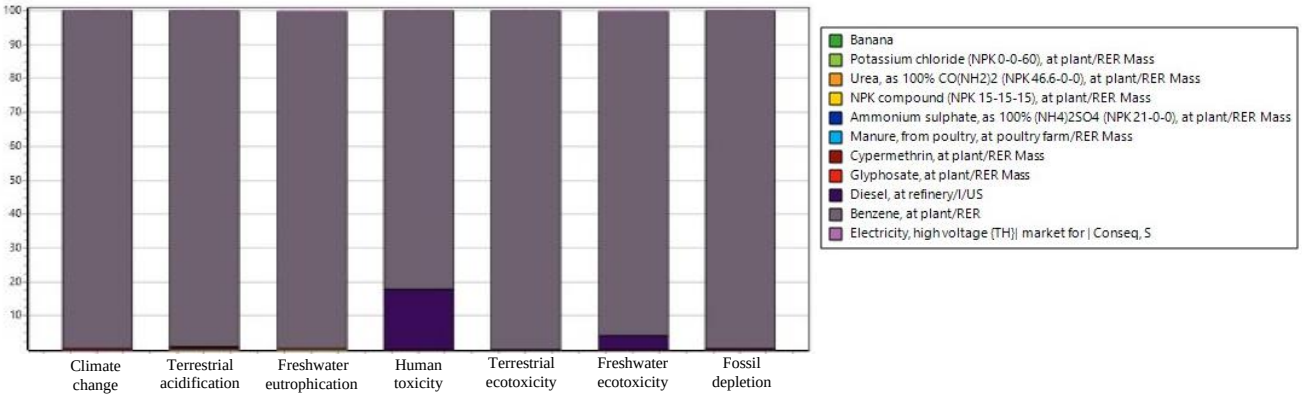

Fig. 4. The impact percentage of banana plantation.

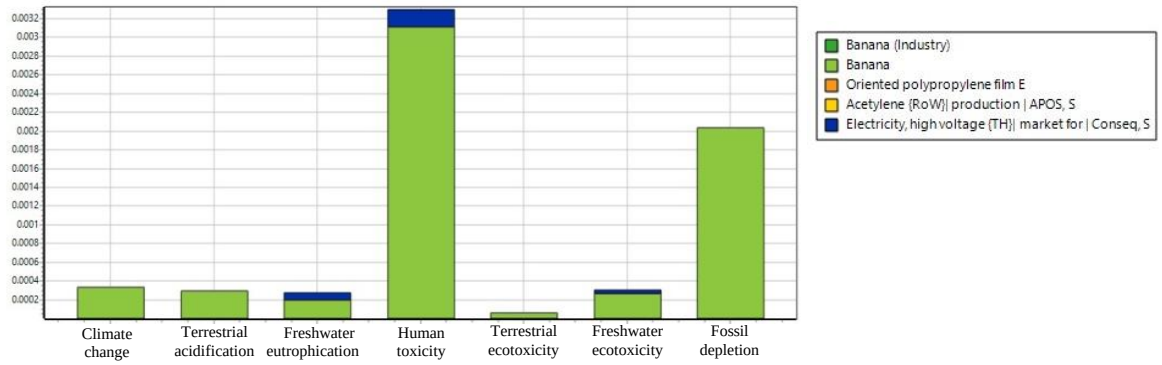

Fig. 5. The impact classification of banana production.

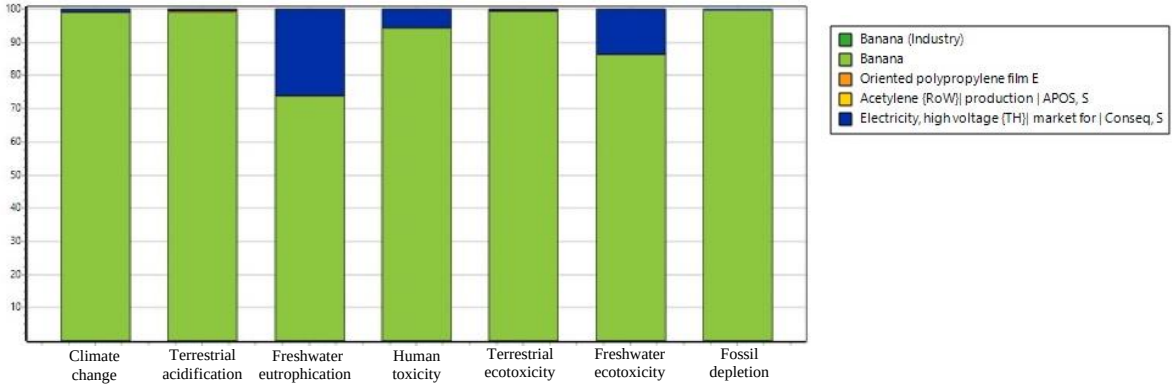

Fig. 6. The impact percentage of banana production.

Table IV shows the environment impact of banana product in the industry process. The human toxicity was the main environmental impact of banana product from banana plantation as main raw material (Fig. 4, 5). The reason was mainly that the highest category potential of banana plantation is human toxicity. In additional, the secondly material for high impact of human toxicity was electricity use. At the ripening stage, banana is placed in special chambers, in which maturation is induced under controlled temperature through the use of ethylene. The air

conditioning of these rooms requires electricity consumption, and its production implies water use, mainly for cooling [24].

C. Finding Implementation for Banana Supply Chain

Form the environmental impact performance of banana farm indentified that the fuel consumption was the main source of environmental impact because of the high volume. Hence, the optimization plan or alternative energy of fuel consumption should be proposed. The liquefied petroleum gas (LPG) consumption in the banana farm should be recommend for reducing the environmental impact and operation cost than diesel and benzene consumption. Besides, the second source of environmental impact for banana farm was the fertilizer consumption because of the famer awareness and behavior. Therefore, the organic fertilizer consumption should be proposed for reducing the environmental impact and operation cost in the banana farm. Concerning the environmental impact from banana production in industry, the raw material (babana from farm) was the highest environmental impact because of the rotten and failed standard bananas. Thus, the reduction of banana waste in the production process with transformation from waste to production should be offered. The failed standard bananas peeled for delivering for bakery production should be proposed for reducing the environmental impact and operation with the banana industry.

IV. Conclusion and Recommendation

From the finding of this study, the fuel consumption is the high environment impact of banana plantation because of the high demand. Hence, the plan of fuel consumption should be proposed for the reduction of environmental impact in the farm level. The alternative energy such as natural gas and LPG for fuel consumption during plantation was the suitable option. Moreover, the banana as the main raw material was the highest contribution of environmental impact in the industry process. Then, the reduction of waste from banana is the appropriate approach with the low cost and the increase the productivity. Besides, the determination of banana size for banana farmer should be the alternative option for reduction of environmental impact in banana process.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization, and methodology, C.R., ;data collection and data analysis, W.O.; and writing, W.O.

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