CHEMICAL ENGINEERING TRANSACTIONS
VOL. 89, 2021

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Jeng Shiun Lim, Nor Alafiza Yunus, Jiří Jaromír Klemeš

ISBN 978-88-95608-87-7; **ISSN** 2283-9216

DOI: 10.3303/CET2189012

Impact of Reducing Food Wastage to the Environment and Economics: A preliminary Finding of Indonesia Case

Marissa Malahayati*, Toshihiko Masui

National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki, Japan
marissa.malahayati@nies.co.jp

More than 20 Mt of food in Indonesia are wasted every year without being consumed. Around 50 % of these foods are already wasted on-farm, even before they are processed and consumed further. The situation is very concerning because Indonesia also needs to ensure the national food stock, given the increasing population and decreasing agricultural land from year-to-year. The Indonesian government is trying to boost agriculture productivity, especially for food crops. Reducing on-farm food loss is believed to have helped the government overcome food insufficiency and increase income. The problem is that there is still limited research on this topic. As there is still limited economic modelling involved in all national reports, statistics, and research, there is still a lack of future projection on food wastage reduction impact. This study would like to assess the potential impact of on-farm food loss reduction on the economy and the environment by utilising the Computable General Equilibrium (CGE). This study compares two sets of policies introduced by the Indonesian government, such as improving yield and productivity for some agricultural products (cereals, food crops, horticulture, and dairy) and reducing food loss. The simulation results suggested that the combination of yield improvement and food loss reduction may increase Indonesia's Gross Domestic Product (GDP) by 0.17 % compared to the Business as Usual (BAU) by 2030. The policy is also able to lower the demand for cropland and reduce the GHG emission from agriculture. The simulation results also indicate that reducing food loss is more effective than focusing on increasing production and productivity. By comparing both the policies, reducing the food loss is potentially more economically profitable (increasing GDP by 0.93 % compared to BAU by 2030) than if the government is only concerned with yield improvement (increase GDP 0.74 % by 2030).

1. Introduction

Indonesia is anticipating a high increase in population, with more than 300 million people by 2045. It makes agricultural sustainability and food sufficiency important issues to be assessed. The importance of this issue is increasing because the country also faces a severe problem in managing and reducing its Food Waste and Loss (FWL). More than twenty million tonnes of food is wasted in Indonesia. Around half of these foods are wasted on-farm and during the post-harvest process (Yananto et al., 2021). This condition makes the government worried about the availability of food nationally, especially in the face of economic and population growth. Based on the Food Sustainable Index 2018, from the 67 countries surveyed, Indonesia was in the 53rd position for food loss and waste and 56th for sustainable agriculture. That rank indicates severe inefficiency in Indonesia's food supply chain, especially in the agriculture sector. It also captures the lack of appropriate waste management and monitoring systems, just like most developing Asia (Sakcharoen et al., 2021). The high level of conventional agricultural management practice and low penetration of advanced agricultural technology means that Indonesia's agricultural sector hasn't achieved its full potential yet (Sofiyuddin et al., 2021). This situation is also a reason behind a high level of food loss (food commodities that get spoiled, lost, or incur a reduction of quality before it reaches consumers) in the country.
The prevention of food loss is believed to positively impact the economy because it can increase income of the agricultural sector. It can also positively impact the agricultural sector because if the output produced can be optimised, Indonesia can reduce the amount of new agricultural land clearing and reduce the amount of agricultural input needed. The policy also can reduce the emissions from agricultural activities and land-use

Paper Received: 14 July 2021; Revised: 14 October 2021; Accepted: 5 November 2021
Please cite this article as: Malahayati M., Masui T., 2021, Impact of Reducing Food Wastage to the Environment and Economics: A Preliminary Finding of Indonesia Case, Chemical Engineering Transactions, 89, 67-72 DOI:10.3303/CET2189012

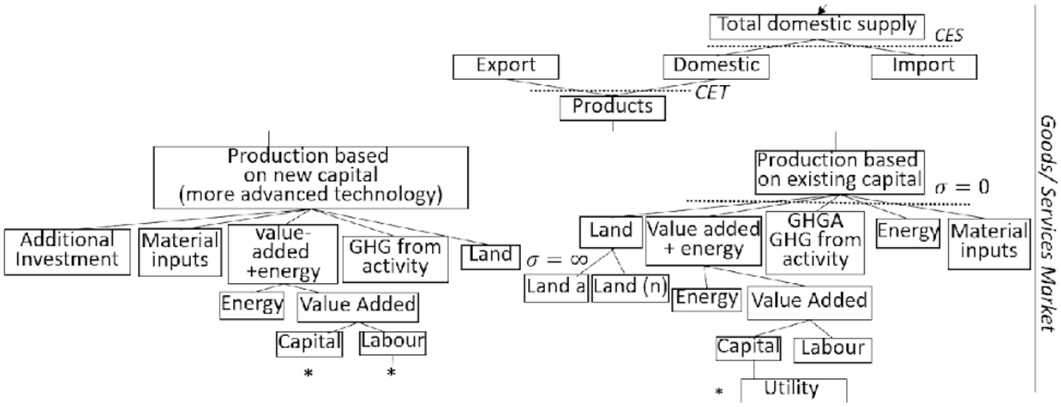
change (LUC). The policy will hold a very important role considering that most of the GHG emission in Indonesia comes from AFOLU (agriculture, forestry, and land use) sectors. In Indonesia, there is still a lack of research and information related to food loss. This condition is exacerbated by the lack of a monitoring system for the agricultural sector. The limited data and information also result in the lack of research related to the wastage of food. The lack of research and information related to food loss in Indonesia makes it difficult for the government to design and establish policies on this matter.

This study seeks to assess the potential impact of food loss reduction on the Indonesian economy and environment (especially cropland demand and GHG emission) by utilising computable general equilibrium (CGE). The CGE model is an economic model that describes the connections between each sector in the economy, which may help to represent the supply and demand relationship in the economy, including for agricultural commodities. This study is crucial to upgrade the research regarding the FWL in Indonesia, as the national FWL report and statistics in this country haven't involved dynamic economic modelling like the CGE model, which resulted in more limited projection. Using the CGE model, this study can project the impact of FWL reduction on the economy, GHG emission, and cropland demand. It is hoped that this study will be to reduce the research gap on food loss studies in developing Asia, especially Indonesia, and highlight the importance of food loss reduction in the country's economy and environmental sustainability.

2. Method and Data

As the initial step, a statistical assessment of the Indonesian food loss pattern was done before the simulation and then used to support the modelling process. The statistical information of food loss in Indonesia was gained from Indonesia's Food Balance Table (FBT) from 2000-2019. The information on food loss patterns is useful to decide which sectors are facing severe food loss problems. This information is then used to design the scenario and parameter setting in the Computable General Equilibrium (CGE) model.

The key analysis of this study is done by using AIM/CGE [Indonesia]. The AIM/CGE [Indonesia] is a Computable General Equilibrium (CGE) based economic model used to simulate any policy shock to the economy. The CGE model can be used for any scale of analysis, mostly on the global or regional scale. One limitation of the global or regional model is that it cannot describe one specific country. This study is focused on the Indonesia case, that the national scale CGE model is better to give more accurate simulation. The AIM/CGE [Indonesia] is a country-specific model designed to add more flexibility, to adjust the parameter depending on the Indonesian national statistics and assumptions. The model in this study will focus on several agricultural sectors facing the most severe food loss problem. After gaining all the information needed, the AIM/CGE [Indonesia] can be utilised for further policy analysis. As a general structure, there are three main blocks set up in the model: Production block, domestic final demand block, and international transaction (export and import) block. Each block is connected to the market and interacts with each other through the price mechanism. The relationship can be seen in Figure 1.



Note: CES: Constant Elasticity of Substitution, CET: Constant Elasticity of Transformation (substitution elasticity relation). The CES is often used to describe the relation between price and demanded-quantity (e.g., cheaper price means higher demand), while CET is used more to describe price and supplied volume relation (e.g., higher export price, higher export).

Figure 1: General Structure of the AIM/CGE Indonesia model

In the production block, the nested production function is assumed. On the top of the nested production function, value-added with energy, land, material inputs and GHG from the activity is aggregated using the Leontief function. Value-added with energy consists of value-added and aggregated energy using the CES function.

Value-added is generated from capital and labour using the Cobb-Douglas function, and aggregated energy is generated from individual energy using the CES function. The produced commodity is supplied to the related commodity market.

The household sector provides production factors to the related market, and it gains income by providing those factors. Under this income constraint, the household decides each commodity's saving and final consumption to maximise its utility. Saving means investment, and it is added to capital in the next year. Another consumer is the government. Just like a household, the government also consumes goods through the market. The government also holds of "income redistribution" function to the household and receives taxes from other sectors. Each commodity market is also connected to the international blocks that consist of export and import. This connection means that Indonesia may be able to export some of its domestic products and at the same time import some products to be supplied in the domestic market. The assumption used in this model is a small open economy, which means any domestic activities do not affect the international market.

Another important treatment in the model is market equilibrium. The model always assumes the market equilibrium condition. That means total supply will be equivalent to total demand due to the price mechanism. The model always satisfied the assumption of total sales equal to the total cost in each production sector and total income equal to total expenditure in the final demand sector.

The simulation is conducted by applying several scenarios. There are four scenarios for this simulation that including the Business as Usual (BAU) scenario. Three other scenarios are depending on the combination of yield and food loss treatments. In the S1, only productivity/yield improvement in the agriculture sector is introduced. It is in line with the current Indonesian government's policy to boost the productivity of the crop, especially food crops. The yield improvement in Indonesia is made by the introduction of superior varieties and crop diversification. This study only introduces the policy to the cereals and food crops, horticulture, and livestock sector. The selection of the sector is based on statistical data from FBT. In scenario S2, only the food loss reduction policy is simulated without yield improvement. The introduction is done by assuming more intermediate input from the agricultural sector can be utilised by other sectors, especially the food industry sector. The food loss reduction for cereals crops (in this case, paddy) is set to be 1 %/y. Other crops and livestock at 0.5 %/y, considering that cereals experience the highest loss compared to other commodities. Scenario S3 combines both policies (Table 1). The policies' introduction for S1, S2, and S3 started in 2020.

Table 1: Scenarios Treatment of the Study

Scenario	Increasing Yield	Reducing Food Loss
BAU	No	No
S1	Yes	No
S2	No	Yes
S3	Yes	Yes

2.1 Data

2.1.1 Input-Output (IO) Table

The primary data used to construct the AIM/CGE [Indonesia] for this study is the Indonesia Input-Output (IO) Table 2010. The sector classification in the original Indonesia IO table is 185 sectors, and for this analysis, the sector is aggregated into 40 sectors. In this study, as the agricultural sector highlights, is classified into three sub-groups: 1) food crops sector, including all the main carbohydrate sources in Indonesia (paddy, maise, and cassava). 2) horticulture, consisting of all pulses, fruits, and vegetable crops, 3.) livestock, represents the meat and dairy sector. There is also the palm oil sector, as it is the main oil crop and an important plantation crop for Indonesia. For this study, the scenario treatment was only given to the primary food sectors, including cereals, horticulture, and livestock. Based on the IO Table and other statistics, the model is then calibrated to give the best description of the current economic condition during the dynamic process. This calibration is done by utilising several socio-economic data such as GDP growth, population, etc.

2.1.2 Future socio-economic condition

Socio macro-economic indicators are needed to support the model development. This study utilises economic growth statistics and economic growth projections published by the Indonesian Statistic Bureau. The economic growth projection is used as a benchmark in the model, so it will not deviate too far from the government's target and projection. It is also to add the level of confidence to the model. Based on the statistic, the average economic growth rate is 5.1% during 2019-2024, 5.2% during 2025-2029, and 5.5-5.7% during 2030-2039. And because there is also an international trade block inside the model, trade balance information is also needed. The trade balance is set using the national statistics from 2010-2018, and after 2018, it is assumed to change at the same rate as the GDP growth rate.

2.1.3 Food Loss for agricultural crops

Although the information on food loss of crops in Indonesia is still limited, some information can be gained from the Indonesian FBT Indonesia. Indonesia FBT is a database that estimates the national food commodities supply and demand based on the methodology constructed by Food and Agriculture Organization (FAO), and it is published annually by the Ministry of Agriculture and Indonesia Statistics Bureau (Hendriadi, 2019). This study utilises the FBT information of the last two decades, from 2000-2019. Indonesia's food balance state estimates the amount of food that is scattered. The calculation includes the number of missing or damaged foodstuff that cannot be consumed, which occurs intentionally and unintentionally, starting from harvesting, post-harvest processing, storage, distribution until market availability. From this dataset, the food loss trend in Indonesia can be assessed.

2.2 Study Limitation

There are several limitations in this study that needs to be addressed in further studies, such as this study only considers limited crops and only considers food loss, while food wastages also consist of wastage that accumulated at the consumer and retail level. There are also some plantation products utilised by the food industry (e.g., palm oil). The reduction of food loss itself is more complex than described in this simulation. In the real world, to improve the storage system, the government may need to supply more electricity. The government might also need to add more advanced agriculture machinery, improve the transportation system and the infrastructure. A more comprehensive analysis of the supply chain and more advanced modelling is needed to further assess the energy use in each stage of the supply chain. Another limitation of this study is that there is still no introduction of Indonesia's GHG emission mitigation targets.

3. Result

3.1 General Pattern of Food Loss in Indonesia

The trend of FWL quantity, especially for developing countries, is usually accumulated more on-farm (food loss (FL)) than at the consumer and retail level (food waste) (Vila et al., 2018). The same applies to Indonesia. The pattern can be seen by utilising the Indonesian FBT 2000-2019. The table consists of around 140 agricultural commodities. For simplification of analysis, all commodities in the FBT have been categorised into several food groups: cereals and starchy foods, pulses and oilseeds, fruits, vegetables, dairy products, fish, and oil and fats. After summing up all the listed commodities in Indonesia's FBT 2000-2019, the general pattern of FL in the country can be seen. In the last two decades, around 5-10 Mt of food has been wasted on-farm and during the post-harvest process, with a significant amount of carbohydrate source commodities (cereals and starchy foods) (Table 2).

Table 2: Descriptive Statistics of total FWL for each food group based on Indonesia FBT 2000-2019 (kt)

Statistic Descriptive	Carbohydrate		Horticulture			Dairy	Others	
	Cereals	Starchy foods	Pulses & oilseeds	Fruits	Vegetables	Dairy	Fish	Oils and Fats
Min	3,985.0	423.0	481.0	221.0	284.0	74.0	91.0	0.0
Max	5,265.8	2,431.0	915.0	1,206.1	689.6	453.0	355.0	631.0
Mean	4,594.9	907.8	576.2	845.3	513.5	222.0	233.2	210.2
Standard Deviation	428.5	506.5	131.6	321.5	125.9	122.5	72.6	163.3

More than 50 % of Indonesia's food loss comes from cereals products. Around 4.6 Mt of cereals are wasted each year, mostly as unhusked rice (paddy). As the standard deviation for cereals is so much lower than the mean, it suggests that there is not much variation from this value. It makes the cereals sector the most important sector that needs to be assessed in food loss studies. Carbohydrates also can be gained from starchy foods (e.g., cassava, potato, etc.), which are also experiencing high annual losses. Every year, around 907.8 kt of starchy foods are wasted without being consumed by the Indonesian people.

Other commodities experiencing high FL are horticulture commodities (pulses, fruits, and vegetables). On average, 845.3 kt of fruits, 576.2 kt of pulses and oilseeds, and 513.5 kt of vegetables are wasted every year. In terms of proportion, fruits contribute to around 10-24 % of total FL. Pulses and vegetables contribute to around 4-6 % of the total FL. Another food group that experiences high food loss is dairy products (including meat, egg, and milk). Around 222 kt of dairy products never reach the consumer. Although this value is not as big as the carbohydrate food crops and horticulture, this food group gains special attention from the Indonesian government, considering the need to increase the national animal protein consumption. Considering the importance of carbohydrate food groups, horticulture, and dairy, the simulation in this study focused on these commodities.

3.2 CGE Simulation Result

The CGE simulation assesses the impact of yield improvement and food loss reduction policies on the economy, agricultural land, and GHG in agriculture (Table 3). The simulation indicates that all scenarios will positively impact the economy, as indicated by the GDP value. Reducing food loss (S2) brings a greater impact than S1. This is because when the food loss policy is reduced, with the same amount of agricultural capital used, more agricultural outputs can be utilised as inputs to other sectors, especially for the food industries. The result indicates that the food loss reduction is economically more efficient than only increasing the yield, as more agricultural outputs can be utilised. The combination of adding yield and reducing the food loss (S3) brings the biggest impact.

The simulation shows that scenario S1 increases the GDP by 0.03 % by 2030, while it is 0.15 % and 0.17 % for scenarios S2 and S3 respectively. The result shows that the impact on the GDP is five times higher when food loss reduction is introduced. The impact value is small because this study only considers the agriculture sector, focusing on the cropland for carbohydrate food crops, horticulture, and livestock. The simulation also suggested that the food loss reduction may lower the land demand more effectively than when only the yield improvement was introduced. The simulation shows that the land demand when the food loss reduction is implied (S2) may reduce around 0.93 % by 2030, double compared to the S1 scenario that will only reduce the land demand by around 0.36 %. Although the percentage seems insignificant, the cropland area under the BAU scenario, around 200,000 ha cropland under the S1 scenario and 270,000 ha cropland under the S2 scenario, can be saved. This land can be utilised for other activities or land conservation. The impact will be bigger if both the scenarios are combined (S3). Under the new scenario, the demand for cropland can be reduced by around 0.38 Mha (1.28 %) than the BAU by 2030.

Table 3: Summary of Simulation Result for GDP, cropland area, and GHG from agriculture activity

Year	Scenarios						
	BAU	S1	%	S2	%	S3	%
			GDP (Trillion IDR)				
2010	6,712.77	6,712.77		6,712.77		6,712.77	
2015	9,021.58	9,021.58		9,021.58		9,021.58	
2020	11,642.04	11,642.04		11,642.04		11,642.04	
2025	14,977.11	14,977.83	0.01 %	14,988.77	0.08 %	14,989.45	0.08 %
2030	19,198.95	19,203.87	0.03 %	19,226.71	0.15 %	19,231.44	0.17 %
			Cropland (Mha)*				
2010	21.11	21.11		21.11		21.11	
2015	23.47	23.47		23.47		23.47	
2020	25.73	25.73		25.73		25.73	
2025	27.59	27.58	-0.06 %	27.45	-0.51 %	27.44	-0.56 %
2030	29.65	29.54	-0.36 %	29.37	-0.93 %	29.27	-1.28 %
			GHG Agriculture (Mt CO_2-eq)				
2010	96.09	96.093		96.09		96.09	
2015	107.42	107.42		107.42		107.42	
2020	117.97	117.97		117.97		117.97	
2025	125.96	126.27	0.25 %	125.58	-0.30 %	125.89	-0.06 %
2030	134.35	135.35	0.74 %	133.69	-0.50 %	134.63	0.21 %
			GHG Energy (Mt CO_2-eq)				
2010	460.36	460.36		460.36		460.36	
2015	607.70	607.70		607.70		607.70	
2020	756.86	756.86		756.86		756.86	
2025	966.10	965.62	-0.05 %	965.45	-0.07 %	964.98	-0.12 %
2030	1238.11	1,236.75	-0.11 %	1,236.58	-0.12 %	1,235.26	-0.23 %

Note: * Cropland including agricultural land for paddy, corn, cassava, horticulture, and pasture for livestock

This study also estimates the GHG emissions from agriculture. GHG emissions from agriculture come from the land management for agricultural production consisting of croplands, managed grassland and permanent crops. The simulation indicates that if a crop's yield increases, it will increase crop production on-farm, which will demand more input. The simulation shows that it will increase the GHG emission from agricultural activity. Under the S1 scenario, the emission from agriculture may rise by 0.74 % by 2030.

Under scenario S2, food loss reduction is treated as an efficiency improvement. It means that more agricultural output can be absorbed and utilised by other sectors as an intermediate input with the same or lesser capital input in the agricultural sector. This efficient treatment might be able to reduce the emission. At least around 0.50 % of emissions can be reduced under the S2 scenario by 2030. This result still has a limitation: to reduce the food loss, there are also more complicated processes and more capital that might be involved, which have not been considered yet in this study. The result under the S3 scenario varies. After the scenario is introduced, the emission is reduced by around 0.06% compared to the BAU by 2025. The emission is then gradually increased by 0.21 % by 2030.

Another interesting finding is that any improvement in the agricultural sector, although not very significant, can reduce emissions from the energy sector to some degree. This reduction is generated by the efficiencies created by technological improvements in the agricultural sector. With increased yield and decreased food loss, other sectors that use inputs from the agricultural sector can process more inputs with the same amount of energy. The efficiency of the agricultural sector can bring efficiency to the energy sector. The emission reduction from the energy sector is not very significant considering that the agricultural sector does not consume large amounts of energy. Based on our simulations, the reduction in energy emissions between scenarios is varied. The largest decrease occurred in the S3 scenario (-0.23 % compared to BAU level y 2030), while the lowest was in the S1 scenario (-0.11% compared to the BAU level by 2030). The result shows that efficiencies under reduced food loss are greater than under yield-enhancing policies alone.

4. Conclusion

Indonesia is struggling in managing its on-farm food loss due to its poor supply chain management. The government also has a concern to increase agricultural production to ensure food sustainability in the country. To maximise food sustainability, the government has committed to increased agricultural productivity. Given the high level of food loss in Indonesian agricultural commodities, increasing agricultural productivity alone can’t be very effective if it is not balanced with actions to reduce food loss. This study tried to simulate the policies. Using the CGE model, this study estimates the impact of the Indonesian government’s policies by increasing the yield and reducing the on-farm food loss. The simulation result shows that combining the policy of yield improvement and food loss reduction may positively impact the economy by increasing the GDP (0.17 % compared to the BAU by 2030), reducing cropland demand, and GHG emission from the agriculture activity. By comparing these two policies, reducing food loss is more effective than boosting productivity as it may increase GDP and reduce more emissions and cropland demand. This result still needs to be improved by considering more capital and technologies that need to be introduced when the food loss reduction occurs. The result shows that any agricultural intensification and diversification policies will not be effective without reducing food loss. It is recommended that the government give more concern to food loss reduction and improve agricultural supply chains' efficiency.

Acknowledgments

This research was performed by the Environment Research and Technology Development Fund JPMEERF20192008 of the Environmental Restoration and Conservation Agency of Japan.

References

Hendriadi, A (Ed.), 2019, Analisis Ketersediaan Pangan: Neraca Bahan Makanan Indonesia 2017-2019, Report, Jakarta, Indonesia (in Indonesian).

Sakcharoen, T., Ratanatamskul, C., Chandrachai, A., 2021, Environmental sustainability assessment of zero-waste system for wastewater recycling and food waste management in building, Chemical Engineering Transactions, 83, 343–348.

Sofiyuddin, M., Suyanto, S., Kadir, S., Dewi, S., 2021, Sustainable land preparation for farmer-managed lowland agriculture in Indonesia, Forest Policy and Econonomic, 130 (102534), DOI:10.1016/j.forpol.2021.102534.

Vila, J.L., Cebolla, J.C.G., Vidar, M., Bucatariu, C., Pasa, A., Juanatey, A.G., Steible, B., Capodiferro, D., Blondeau, S., 2018, Food loss and waste and the right to adequate food: Making the connection Right to Food, FAO Discussion Paper, Rome, Italy.

Yananto, I.D., Amalia, A., Putri, A.P., Siregar, M.T.J., Mustikasari, N., Rahmadita, K., Putri, K.H., Putri, D.E., Junerosano, M.B., Putri, A.R., Martianto, D., Rahardyan, B., Tasrif, M., Hanafi, J., Adiwijaya, D., 2021, Ringkasan Bagi Pembuat Kebijakan: Food Loss and Waste di Indonesia, Report, Jakarta, Indonesia (in Indonesian).