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Utilization of Bokashi composting and animal feed silage for sustainable agricultural waste management and environmental impact analysis

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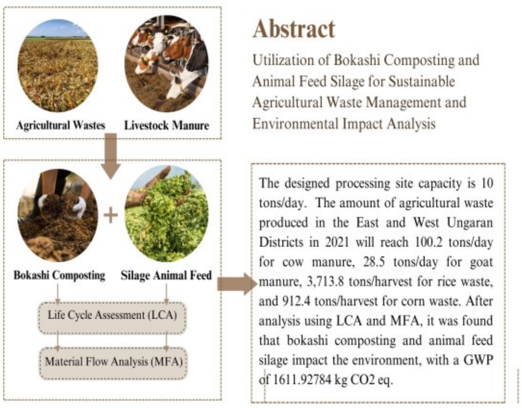
Graphical abstract



Abstract

Agriculture is a major driver of sustainable development in developing countries. However, with the increase in the global population, the amount of waste generated by agriculture has also increased, leading to environmental pollution. The increase in agricultural activity is proportional to the increase in livestock activity. As livestock production increases globally, increasing amounts of manure are produced. Out of the many methods for processing agricultural waste, only a few prioritize aspects of soil quality in the agricultural environment and can be used to improve crop quality. This paper presents a utilization and recycling method using bokashi composting and silage animal feed, and the environmental impact of these methods. The analysis was performed using Material Flow Analysis (MFA) and Life Cycle Assessment (LCA). The number of sites and site locations was calculated based on the number and location of existing farmer groups. Future bokashi composting and animal feed silage are expected to be utilized by more people, given their small environmental impact and improved soil and crop quality. In addition, further research needs to discuss this method to optimize the increased utilization of agricultural waste.

Keywords: Agriculture waste, Bokashi composting, animal feed silage, material flow analysis, life cycle assessment

1. Introduction

Agriculture is a major driver of sustainable development in developing countries (Agboola and Bekun, 2019). Among SDGs, agriculture is an essential tool for eradicating absolute poverty. Therefore, it is necessary to establish sustainable production, consumption, and distribution chains to increase agricultural productivity, ensure food supply security, and provide better nutrition (Ullah *et al.*, 2018). Agriculture can support economies by providing raw materials and food, increasing competition, and creating jobs for people (Gokmenoglu *et al.*, 2019). Agricultural activities such as fishing, forestry, and hunting are critical for prosperity, especially in developing countries (Zafeiriou and M. Azam, 2017).

However, with the increase in global population, the amount of waste generated by agriculture has also increased, which has led to environmental pollution (Isoda *et al.*, 2014; González-Sánchez *et al.*, 2014). Modern agricultural technology has been beneficial for increasing crop production. Nevertheless, it also has adverse effects, creating a long-lasting footprint in the environmental, social, and economic sectors (Puglia *et al.*, 2021; El-Ramady *et al.*, 2022). Waste generated from agricultural activities is also a major issue. Humans produce 150 billion metric tons of agricultural waste annually through intensive farming, harvesting, cultivation, and industrial processes (Patel *et al.*, 2022). Agricultural pollution is largely caused by agricultural wastes, such as straw, livestock manure, and vegetable waste. Without proper management, agricultural wastes pose environmental risks (Obi *et al.*, 2016; Wang *et al.*, 2016). Unfortunately, only a small proportion of agricultural waste is utilized, and most is disposed of through random burning or landfilling activities (Agapkin *et al.*, 2022; Elbasiouny *et al.*, 2020). The inappropriate use of resources and environmental pollution have become significant problems. Owing to the absence of cost-effective substitutes, a substantial portion of farm waste is dumped or burned in fields, causing significant environmental damage to urban and rural areas (Sangeetha and Govindarajan, 2023). Agriculture can cause an increase in water, land, and carbon footprints. Seventy percent of global water withdrawals are used for agricultural purposes, such as livestock and crop irrigation (Pellegrini *et al*., 2016). The increase in agricultural activity is proportional to the increase in livestock activity. As livestock production increases globally, increasing amounts of manure are produced, with ~25% not used as agricultural fertilizer but discarded and directly entering the environment (Wang *et al*., 2019). The emission of NH3 from the disposal of livestock manure accounts for 49% of total agricultural emissions, and more than 15% of the N in cattle feed is cleared into waterways through manure (Bai *et al*., 2016).

Agricultural waste has significant ecological service and economic values, which can not only alleviate ecological and environmental pollution but also reduce the agricultural production demand for limited resources. Many physical, chemical, and biological processes have been developed to treat or minimize livestock manure. Composting is the most popular method for disposing of extensive manure waste (Zhang *et al*., 2022; Li *et al*., 2022; Li *et al*., 2020; Wu *et al*., 2020). Composting is an effective technology that transforms agricultural organic solid waste, such as manure, into fertilizers that are harmless to the environment (Awasthi *et al*., 2019; Yang *et al*., 2019). Other common agricultural waste treatments include anaerobic digestion (for bioenergy production) (Wang and Lee, 2021), thermochemical processes (for the production of high-value-added products) (He *et al*., 2022), and other integrated treatment pathways (Zhang *et al*., 2018). These methods provide opportunities to close the biogeochemical cycle of waste nutrients while controlling the public health risks posed by the increased production of organic waste (He *et al*., 2022). However, of the many methods for processing agricultural waste, only a few prioritize aspects of soil quality in the agricultural environment that can be used to improve crop quality (Arumdani *et al*., 2021). This study provides a solution to this problem using the bokashi composting and animal feed silage methods.

Bokashi refers to the decomposition of organic matter using an effective microorganism (EM) culture (Budihardjo *et al*., 2022). In EM-bokashi, bokashi serves as a growth medium for microorganisms and provides a suitable microenvironment for EM in the soil (Nikitin *et al*., 2018). According to Shin, *et al*. (2017), the positive effects of EM application enhance the growth, yield, and quality of crops, including beans, corn, grass, peas, peanuts, rice, tomatoes, and wheat. Silage is made of forage, crop residues, or agricultural or industrial byproducts that are preserved naturally or artificially for use as animal feed (Doelle *et al*., 2009)]. Using the silage method, the problems associated with agricultural waste and animal feed can be solved.

Given the impact and potential utilization of agricultural waste, special attention should be paid to determining strategies for managing large quantities of agricultural waste so that environmental problems that can arise due to poor management can be minimized, and waste utilization can be maximized. This study consists of four parts: introduction, methods, results, discussion, and conclusion.

2. Methodology

2.1. Materials

Agricultural solid waste was collected from agricultural locations in the East Ungaran and West Ungaran Sub-district. West Ungaran and East Ungaran Sub-districts are included in the Ungaran City. Agricultural locations based on data from farmer groups were obtained from the Agricultural Extension Center of each Sub-district. There were 160 farmer groups in the East Ungaran and West Ungaran Sub-districts, spread across each Sub-district. The agricultural wastes used in this study were rice waste, corn waste, cattle waste, and goat farm waste.

The materials used in this study were selected based on the existing conditions of the solid waste generated at the research location. Material Flow Analysis (MFA) was used to determine the flow of solid waste materials produced in the East and West Ungaran Sub-districts. The analysis was carried out using the STAN (an acronym for substance flow analysis) software originating from Austria. Calculations were made every four months following the farmers' harvest frequency in the East and West Ungaran Sub-districts.

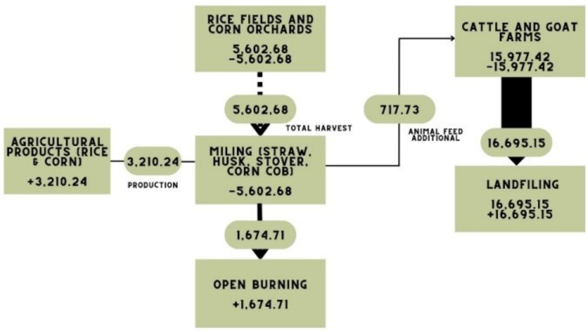


Figure 1. Existing Material Flow

The material flow is illustrated in Figure 1 in tons every four months. It can be seen that the total production of paddy and corn from rice fields and corn orchards is 5602.68 tons/harvest. All production results were included in the miling process, so the agricultural production of rice and corn is 3210.24 tons/harvest. Out of total crop residue obtained (2392.44 tons), 30% (717.73 tons), was reused as additional animal feed, while 70% (1674.71 tons) was burned. The manure produced by cow and goats for four months amounted to 16695.15 tons, the stockpiled openly. Farmers need transportation in existing agricultural solid waste processing, considering the absence of the necessary facilities; therefore, the processing is carried out on their respective agricultural lands.

2.2. Analytical methods

Life Cycle Assessment (LCA) analysis was carried out using the SimaPro application to study and determine the environmental impact of the agricultural solid waste processing method using the bokashi composting and animal feed silage methods. Data analysis was performed using the CML-IA baseline/World 2000 method, and the processing results were interpreted. The data input process used secondary and primary data from observations and interviews. The limitation used in this environmental impact analysis was cradle-to-gate; therefore, the calculation was limited to the environmental impact of the processing of agricultural solid waste.

3. Results and discussion

3.1. Bokashi composting

The first processing alternative used in this plan was composting technology using the bokashi system. Bokashi fertilizer is obtained from composting and fermenting agricultural solid waste in rice straw, husks, and livestock manure, and starter compound consist of EM4, molase, and water.

The main types of microorganisms are lactic acid bacteria, photosynthetic bacteria, yeast, actinobacteria, and fermenting fungi (Luo *et al*., 2022). However, bokashi is prepared by decomposing organic materials using an EM culture. EM is a mixed culture of inoculated microorganisms produced during the fermentation of organic materials. The bokashi production process takes three to fourteen days. Bokashi stock can be stored and produces little odor (Zaman *et al*., 2023). Bokashi is suitable for organic materials with high or low carbon-nitrogen ratios (Aziz *et al*., 2019). This process is also very straightforward to perform and does not require special tools; therefore, it is not costly.

Bokashi is an alternative for integrating livestock and horticulture and reducing environmental pollution (Patriani *et al*., 2022). This method can also reduce the continuous use of inorganic fertilizers by decreasing the balance of soil properties (Budihardjo *et al*., 2023). Efforts have been made to increase crop productivity using Bokashi (Pangaribuan *et al*., 2012). Other research has been shown that this composting can increase plant nutrient uptake, growth, and yield via different basic mechanisms such as changes in soil structure, nutrient solubility, root growth and morphology, plant physiology, and symbiotic relationships (Iriti *et al*., 2019; Pandit *et al*., 2019). It is an amendment to soil fertility technology in farming systems. This technology can improve soil properties and provide better conditions for plant growth and production (Iriti *et al*., 2019; Ginting, 2019). The other benefits is to replace chemical fertilizers to increase soil fertility and improve the soil's physical, chemical, and biological properties (Imban *et al*., 2017). Applying organic materials plus EM, or as a combination in the EM bokashi fermentate, is most advantageous for improving crop yield. Evidence exists that EM bokashi inoculation/fertilization leads to significantly greater increases in yield than other growth promoters Olle *et al*., 2021).

The effects of reusing, recovering, and recycling highly nutrient-rich organic wastes in agricultural systems are shown in Figure 2. For example, waste manure can be treated using the bokashi composting technology to reduce the pollution caused by manure in the surrounding environment and reduce soil compaction. Such a technique will prevent the long-term degradation of soil quality caused by the excessive use of chemical fertilizers in agriculture. Diversity reduction, soil quality degradation, and other issues can be resolved to varying degrees by adopting this strategy (Gravuer *et al*., 2019).

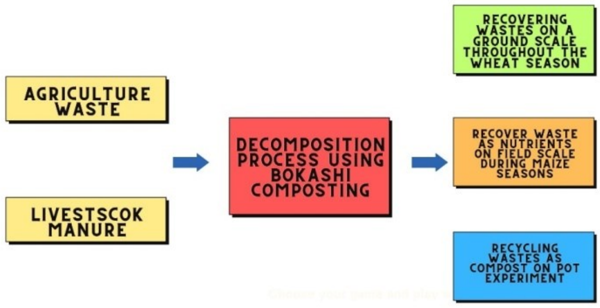


Figure 2. Schematic Process of Recycling Wastes to Bokashi Composting as an Organic Fertilizer

Various types of agricultural waste are generated in East Ungaran and West Ungaran Sub-districts; some are liquids, while others are solids. The agricultural waste included in this plan was solid waste originating from rice, corn, cattle, and goat farming activities. Agricultural activities have a high potential for waste production in Ungaran. Therefore, the processing of agricultural solid waste using the bokashi composting scenario uses crop residues in the form of chopped rice straw and rice husks as well as livestock manure consisting of cow and goat manure, all of which are composted.

Rice agricultural waste produced in East Ungaran and West Ungaran Sub-districts consists of straw and husks. According to Nappu, (2013), the potential for waste generated from rice production, such as straw, is as much as 55.6% of the total rice and grain yield (44.4%). Out of the unhusked rice, only 65% becomes rice, while 35% is in the form of husks; therefore, the amount of each component of the remaining harvest in the form of straw and husk can be obtained from the total production each year. Straw and husk have many uses that can be applied to the sustainability of the agricultural sector in the East and West Ungaran Sub-districts; therefore, calculations were made to determine the amount of each component in the remaining rice harvest to maximize utilization.

The projected straw and husk production trends in East Ungaran and West Ungaran Sub-districts show a positive linear graph and an annual increase. Straw and chaff production in Ungaran in 2012 reached 11973.84 tons/year, with 6657.46 tons/year of straw and 1860.73 tons/year of chaff. The projected weight of straw and husk in 2031 reached 19197 tons/year, or an increase of 60% in weight. The projected weight of straw reached 10673.64 tons/year, and the husk weight reached 2983.24 tons/year.

Beside rice, corn is the highest commodity among the food crops in East Ungaran and West Ungaran Sub-district. Corn in East Ungaran and West Ungaran Sub-district is primarily used as fodder for livestock and as a food source for the community. During harvesting, corn produces waste in the form of stover. During the post-harvest process, namely corn shelling, the waste produced is corncobs. According to Nappu (2013), 30% of the potential waste generated by corn plants is obtained in the form of stover, 44% in the form of cobs, and 26% in the form of dry-shelled seeds, namely, the product.

The projected trend of maize waste production in East Ungaran and West Ungaran Sub-district also shows a positive linear graph. The total waste generated in East Ungaran and West Ungaran Sub-district in 2012 reached 2853 tons/year, with 855.873 tons/year of stover and 1255.28 tons/year of cobs. The projected waste generated in 2031 reached 4258 tons/year, or a 60% increase in weight. The projected straw weight reached 1277.49 tons/year, and the husk weight reached 1826.616 tons/year. Corn has the same harvest age as rice, which is four months. Based on production data for the past 10 years, the solid waste from rice plants produced in East Ungaran and West Ungaran Sub-district is 668 tons/harvest, with 271 tons/harvest of stover and 397 tons/harvest of cobs.

In animal husbandry, cows produce daily solid waste in the form of cow dung. According to Zumaro and Arbi (2017), one adult cow produces as much dung as 25 kg/day. In reality, breeders have yet to consider further processing and utilization of cow dung; many cattle breeders immediately dispose of cow dung and allow it to accumulate in several fields without any processing. When utilized, cow dung has the potential to be used as compost because of its high nutrient content.

The projected trends of one of kind livestock waste production, cattle waste, in East Ungaran and West Ungaran Sub-district show a positive linear graph and an annual increase. The total cow dung waste generated in East Ungaran and West Ungaran Sub-district in 2022 reached 101 tons/year, and the projected waste generated in 2031 reached 105 tons/year. Suppose that the average cow produces 25 kg of manure per day. In that case, the agricultural solid waste generated from cattle breeding activities per day in Ungaran reaches 103.868 kg/day or 103 tons/day. Beside cows, goats also have a reasonably high population in Ungaran District, Goats produce droppings daily. According to Amaranti, *et al*. (2012), goat manure produced per day from one goat is 1.4 kg (Figure 3 and Table 1).

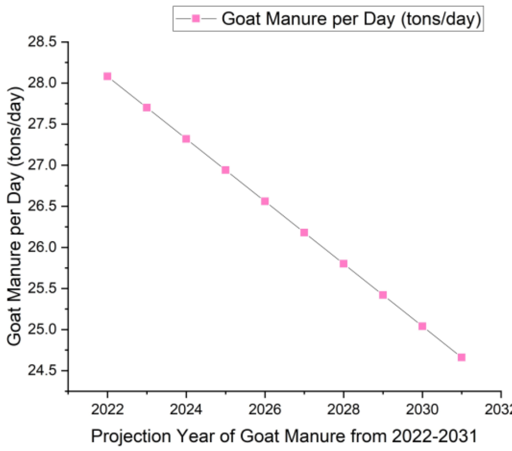


Figure 3. Graph of Goat Manure Generation 2022 – 2031

Table 1. Incoming waste amount

Agriculture Solid Waste	Input Waste (tons/day)	Input Waste (tons/4 months)	Waste Weight (kg/day)	Waste Weight (tons/4 months)	Waste Volume (m^3/day)
Livestock Manure (Goat and Cow Manure)	129.26	-	129.26	-	114.37
Crop Residue					
Rice Straw	-	3557.88	29.65	2616.09	21.80
Chaff	-	994.41	8.29	1343.8	11.20
Stover	-	425.83	3.55	376.84	3.14
Corncobs	-	624.55	5.20	650.57	5.42
Total	129.26	5602.7	175.95	4987.31	155.93

The first site was planned as the required paddy and corn waste storage area. For each harvest season, four months in one season, 5602.7 tons of waste or 294.8 tons of waste is generated for 19 sites. The data shows that the volume of incoming waste per site for 19 sites, consisting of rice straw, chaff, stover, and cob, is 267.49 m^3. The planning height of the waste pile is 1.5 m, so the area for the waste pile is 175 m^2. With a ratio of length and width = 1:1, the waste pile area's length and width is 13.23 m. For mobility, it is planned that the actual height and width will be added to the length and width are around 16 m. The storage area needs to be 256 m^2.

Agricultural solid waste is pretreated by enumeration. Agriculture waste pre-treated is rice straw, corn stover, and corncobs. Rice husks and livestock manure do not need to be pre-treated in the form of chopping for rice husks because of their small shape. The total rice straw weight per site for 19 sites is 1560 kg.

Since corn waste is used as animal feed, it is planned that the amount of waste processed into animal feed per day is

1000 kg, consisting of 500 kg of stover and 500 kg of corncobs. With waste density is 1360 kg/m^3, the incoming waste volume is 1.15 m^3. The corn bran waste density is 1130 kg/m^3 then corn bran volume is 0.44 m^3, and the corncobs volume with waste density is 720 kg/m^3 is 0.69 m^3. Thus, the total volume is 2.28 m^3. It is planned that the waste pile height is 1 m, so the required area is 2.28 m^2. With a length-width ratio of 1:2, the length of the shredding place is 1.07 m, and the width is 2.14 m. For mobility, it is planned that the actual height and width will be added so the length is 2 and the width is 3 m. The required area is 6 m^2.

There will be 2 locations for laying the waste, consisting of waste before and after being chopped, in the same area. The dimensions of the area after chopping are 2 × 3 m. At the pre-treatment site, there is a chopping machine with a capacity of 1000–1500 kg/hour. The length is 1.8 m, the width is 0.9 m, and the tool height is 1.5 m. The total length used in planning the pre-treatment site was obtained from the sum of the lengths for the enumeration and storage of waste before and after enumeration. The calculation length of the pre-treatment site is 5.8 m, yet for planning. The pre-treatment length is 6 m. Just as with the length, the width is obtained by adding up all the components of the planning width so that the width is 6.9 m, and for planning, the pre-treatment length is 7 m. The site's height is set to 3 m, and the required area for the pre-treatment site is 42 m^2.

The next site is the processing site of the bokashi fertilizer. In this area, bokashi fertilizer processing occurs. The waste processed into bokashi fertilizer is livestock manure, chopped rice straw, and husks. The weight of manure in each site is 6.8 tons, the rice straw weight is 1.56 tons, and the rice husk weight is 0.44 tons. The volume of manure in each site is 6.02 m^3, the rice straw volume is 1.15 m^3, and the rice husk volume is 0.59 m^3. Therefore, the total volume is 7.76 m^3.

For the composting tub, the planning height is 0.5 m, so with the total volume of waste being 7.76 m^3, the required area for the composting tub is 15.51 m^2. With a length-width ratio of 1:1, the length and width of the tub are 3.9 m. For mobility, it is planned that the actual height and width will be added to the length and width of the tub are 6 m, the height is 0.5 m, and the area is 36 m^2. It is planned that there will be 14 to 14 days fermentation time. Therefore, the bokashi fertilizer processing area is 504 m^2.

Bokashi fertilizer products are packaged in sacks. Assuming the product is produced daily, the result of bokashi fertilizer would be the same as the amount of bokashi fertilizer processing waste. The result of bokashi fertilizer is 8800 kg/day. Assuming the sack capacity of each unit would be 250 kg/unit, the number of sacks per day would be 35. It is also important to plan the sack dimensions. The sack's length is 1.2 m, the width is 1.8 m, and the height of the sack, if it is full, is 0.2 m, so the volume is 0.43 m^3/unit. If the number of sacks per day is 35, the total volume is 15.12 m^3. If the sack pile height is 2 m, the storage area of the sacks is 7.56 m^2. The length-width ratio is 1:1; therefore, the length and width are 2.75 m. The required storage area with a capacity plan for seven days of product output is 52.92 m^2. Therefore, with the same length-width ratio, the required length and width is 7.27 m. The number of sacks per seven days is 245 units. For mobility, it is planned that the actual height and width will be added so the length is 10 m, the width is 10 m, and the height is 3.5 m. Thus, the required area is 100 m^2.

3.2. Silage animal feed

According to Nappu (2013), the potential waste generated from corn production, namely stover and cobs, produces as much as 30% and 44% of the total corn production, respectively. The corn kernels produced from the total production represent only 26%; therefore, each component of the remaining harvest in the stover and corncobs can be obtained from the total production each year. However, stover and corncobs have the potential to be reused. The examples of stover and corncobs utilization that can be done are used as animal feed.

Figure 4 presents the data on stover and cob waste generated from total production per year in the form of existing data from 2012 to 2021 and projected data from 2022 to 2031.

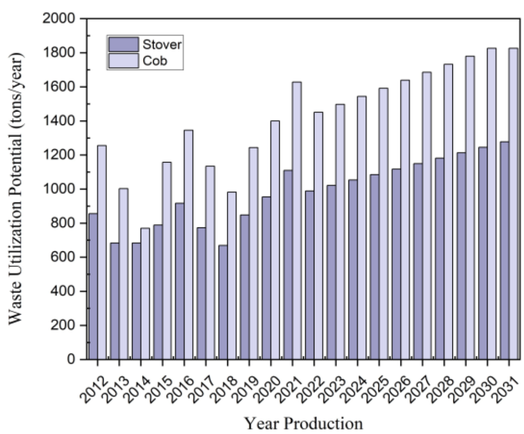


Figure 4. Composition of The Remaining Corn Harvest

The waste processed for silage consists of corn stover and chopped corncobs. The planned 1000 kg/day of processed animal feed at each site would be achieved by adjusting the capacity of the silage ponds as airtight silos. The corn weight is 500 kg, while that of the cob is 500 kg; the corn stover volume is 0.27 m3 and that of the corncobs is 0.42 m3. The total waste processing volume is 0.69 m3.

The waste heap height is 0.5 m for livestock feed silage processing, so the area is 1.38 m2. With a length-width ratio of 1:1, the site's length and width are 1.16 m. Because the silage processing site for animal feed is one building with pre-treatment, the length of the silage processing area is the same as that of the pre-treatment area. The site's width plan is 2 m, and the required silage processing area is 12 m2.

A place for animal feed silage products is where animal feed silage products are stored in a tarpaulin silo bag. The silage is stored for 14 days according to the fermentation time, the total yield of animal feed is 1000 kg/day, and the capacity of the tarpaulin silo bags is 1000 kg. The number of tarpaulins per day is one unit, the diameter and height are 1.5 m, the area of the tarpaulin is 1.76 m2, and the volume is 2.65 m3. The capacity of the product container can accommodate 14-silage ponds according to the silage fermentation time. The product area is 24.72 m2, and the length and width of the area are 4.97 m. Because the place for animal feed products is one building with bokashi fertilizer products, the length of the place for animal feed products is the same as that for bokashi fertilizer products, and the width of the place for animal feed products is added for mobile access in and out of the silage pond. The length for animal feed products is 10 m, the width is 9 m, and the height area is 3.5 m.

3.3. Life cycle assessment

A comparison of environmental impacts between management methods was carried out on existing agricultural solid waste in East Ungaran and West Ungaran Sub-district and the management technology for agricultural solid waste in composting using the bokashi method with an LCA using Simapro software. Data analysis was performed using the CML-IA baseline/World 2000 method and the processing results were interpreted. The data input process used secondary and primary data from the observations and interviews. The limitations of this environmental impact analysis are cradle-to-gate; therefore, the calculations are limited to the environmental impact of the processing of agricultural solid waste.

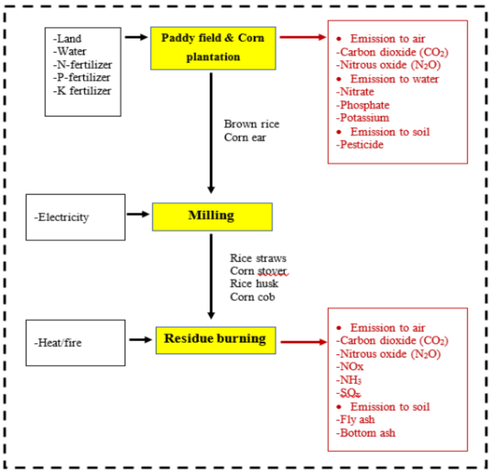


Figure 5. System Boundaries of Existing Treatment Systems: Open Combustion

3.4. Goal and scopes

In goal and scope, system boundaries of the bokashi composting and silage systems were analyzed and visualized using diagrams containing information about the materials used, the process used, the products made, and the emissions resulting from the process.

The specified boundaries are shown in Figures 5 and 6 to determine the environmental impact of the bokashi composting and silage methods that farmers in the west and east Ungaran districts can carry out.

Figure 5 shows system boundaries of existing waste treatment in East Ungaran and West Ungaran Sub-district, open burning. It is shown that with this treatment, waste from milling activity of brown rice and corn ear such as rice straws, corn stover, rice busk, and corncobs will just throw off to open burning without any further treatment and will give bad impact to air and soil because of the emission.

Figure 6 shows system boundaries of the planning waste treatment in East Ungaran and West Ungaran Sub-district using bokashi composting and silage. It is shown that with this treatment, there are few steps must followed before the agriculture waste and livestock manure is treated, such as collection and pre-treatment

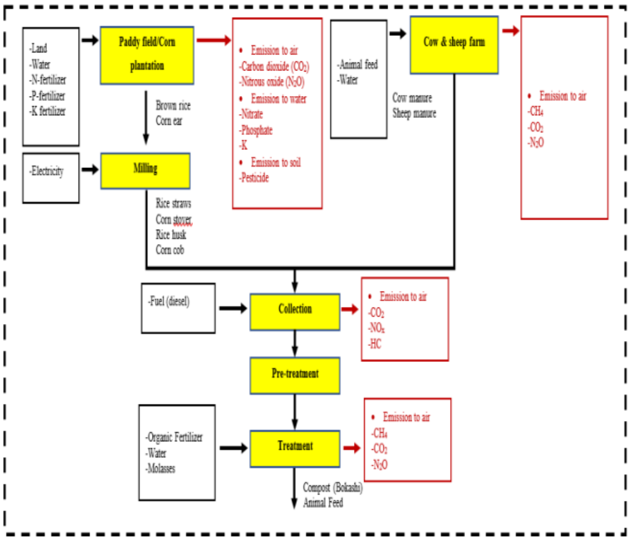


Figure 6. System Boundaries of Composting Planning System (Bokashi Fertilizer) and Silage

3.5. Life cycle inventory

Primary and secondary data were obtained during observation activities. Furthermore, the interviews were grouped into tables so that the writer and the reader could understand them. The data were divided into three main groups: input, output, and emissions. Details regarding the sources of the materials used in each process were provided in the input group. The results or outcomes of the process used as inputs in the next process are entered into the output menu. In contrast, the emissions resulting from the process are detailed in the emission group and divided into emissions to air, water, and soil.

The agriculture waste treated using the open burning method is rice straw, rice husk, corn stover, and corncobs. For the environmental impact, the samples tested were calculated based on one ton of crop residue. The rest of the harvest (30 %) is used by farmers as additional animal feed, and the remaining 70% is burned. Livestock manure derived from cows and goats is the main input used for processing agricultural solid waste via open stockpiling. The environmental impact of the livestock manure was tested on a ton basis.

For composting scenario (bokashi fertilizer) and animal feed (silage), the remaining crop residues in the form of chopped rice straw and rice husks, as well as cow and goat manure, were used as compost. Stover and corncobs are chopped and reprocessed into animal feed using the fermentation method to produce silage animal feed. The amount of waste is assumed to be 2 tons, with an allocation of 1.5 tons for compost and 0.5 ton for animal feed (Table 2).

Table 2. Bokashi Technology Planning Data Inventory

Categories	Parameter	Unit	Paddy field & Corn plantation	Miling	Cow & Goat Farm	Collection	Pre-treatment	Animal Feed	Composting
Input material, fuel, and energy	Land	Ha	0.478	-	0.25	-	-	-	-
	Water	m^3	71.664	-	-	-	-	0.01	-
	N-fertilizer	kg	6.424	-	-	-	-	-	2.059
	P-fertilizer	kg	0.852	-	-	-	-	-	0.000042
	K-fertilizer	kg	0.068	-	-	-	-	-	1.5505
	Diesel	kg	-	0.962		0.21958235	-	-	-
	Electricity	kWh	-	-	-	-	30.4	-	-
	Animal feed	kg	-	-	2500.429	-	-	-	-
	Animal (Cow & Goat)	kg	-	-	29510.71	-	-	-	-
	Brown Rice	tons	0.312	-	-	-	-	-	-
	Corn ear	tons	0.473	-	-	-	-	-	-
	Corn stover	tons	-	0.203	-	-	0.203	0.203	-
	Rice straws	tons	-	0.391	-	-	0.391	-	-
	Rice husk	tons	-	0.109	-	-	0.109	-	-
	Corncobs	tons	-	0.297	-	-	0.297	0.297	-
	Cow manure	tons	-	-	-	0.5	0.5	-	-
	Sheep manure	tons	-	-	-	0.5	0.5	-	-
	Organic fertilizer	tons	-	-	-	0.203	-	0.5	-
	Molasses	tons	-	-	-	0.391	-	0.5	-
	Brown rice	tons	0.312	-	-	0.109	-	-	-
	Corn ear	tons	0.473	-	-	0.297	-	-	-
Output product and co-product	Cow Manure	tons	-	-	0.5	-	-		-
	Sheep manure	tons	-	-	0.5	-	-		-
	Corn Stover	tons	-	0.203	-	-	0.203	-	-
	Rice straws	tons	-	0.391	-	-	0.391	-	-
	Rice husk	tons	-	0.109	-	-	0.109	-	-
	Corncobs	tons	-	0.297	-	-	0.297	-	-
	Processed Animal Feed	tons	-	-	-	-	-	0.5	-
	Compost	tons	-	-	-	0.076	-	-	-
	Emission to air								
	CO_2	kg	730.53	23.400	-	1.48	1.48	-	-

	N_2O	kg	0.348	-	0.038	0.011	0.011	-	-
	CH_4	kg	-	-	1.551	0.180	0.180	-	-
Emission	SO_2	kg	-	0.958	-	-	-	-	-
	NO_x	kg	-	0.294	-	-	-	-	-
	NH_3	kg	-	0.126	0.076	-	-	-	-
	Emission to water								-
	Nitrate	kg	0.3774249	-	-	-	-	-	-
	Phosphate	kg	2.17444148	-	-	-	-	-	-
	Emission to soil								
	Pesticide	kg	0.025	-	-	-	-	-	-

3.6. Life cycle impact assessment

LCA analysis using the CML-IA baseline/World 2000 method is conducted to assess the waste treatment's environmental impact using the bokashi composting and animal feed silage method. This method uses Global Warming (GWP100a) as a parameter in the SimaPro application. First, the existing waste treatment in East Ungaran and West Ungaran Sub-district using open dumping and open burning is assessed as a comparison. Next, the planning waste treatment, bokashi composting, and animal feed silage are being analyzed too. The result shows that open dumping and burning contribute to 2004.86 kg CO2 eq. Meanwhile, bokashi composting and animal feed silage contribute 161,192 kg CO2 eq. to global warming (GWP100a).

From the results of calculations carried out on the SimaPro application above, the bokashi composting and silage processing methods have a smaller global warming impact when compared to existing processing methods. Moreover, bokashi composting is straightforward and does not require special tools; therefore, alternative processing does not need high costs.

4. Conclusion

With the condition of agriculture waste and livestock manure in West Ungaran and East Ungaran Sub-district, Ungaran City, bokashi composting, and animal feed silage is planned for the handling method. This study provides a strategy planning for implementing the bokashi composting and silage method in East Ungaran and West Ungaran Sub-district. Based on the calculation, it is obtained that agriculture waste in East Ungaran and West Ungaran Sub-district in 2021 reached 100.2 tons/day of cow manure, 28.5 tons/day of goat manure, 3713.8 tons/harvest session for rice waste and 912.4 tons/harvest session for corn waste. This strategy planning includes processing site design. The designed processing site capacity is 10 tons/day. One processing site serves eight to nine farmer groups and is spread across the East and West Ungaran Sub-districts. After analysis using LCA, it was found that bokashi composting and animal feed silage impact the environment and cause global warming with a GWP value of 1611.92784 kg CO2 eq. If we compare this result with this LCA analysis for the open-burning method, bokashi composting, and animal feed, silage has a lower environmental impact. So, implementing these methods has a good effect on the environment. However, for further implementation, it is important to have thorough research regarding the composition and characteristics of each waste of the agriculture sector and suitable waste handling for the waste. Therefore, the waste handling strategy is more solutive.

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