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Implementation of Circular Economy in Peatlands to Support Sustainable Food Security in Post Covid-19 Era

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Abstract

The peatlands in Indonesia have changed quite a lot in recent years due to over-exploitation and climate change. The land-use change on peatlands resulted in soil infertility. The impacts of the degradation of peatlands are almost certain to worsen with the COVID-19 pandemic because the peatlands have an important role in providing food resources. Therefore, the peatlands restoration must be carried out considering the importance of the peatlands as food resources and carbon capture. One of the alternative solutions is to recycle the waste from agroforestry into organic fertiliser. This study aimed to investigate the application of organic fertiliser to restore soil fertility in the peatlands. The study also offered the circular economy scheme that can be applied in the peatlands to restore sustainability. The results showed that the degraded peatland that has been restored by adding organic fertiliser from local sources has a higher soil pH level than the one without adding organic fertiliser. The increase in pH level can decrease soil hydrophobicity and increase microorganism activities, encouraging biodiversity in the peatlands. In this study, the circular economy scheme by the integration between agroforestry and livestock was assessed economically and environmentally. Recycling cows' manure and leaf litter from peatlands into energy and recycling biogas sludge into biochar for biogas purification and soil enrichment benefit economically and contribute to mitigating greenhouse gas emissions.

Keywords: Peatlands, Agroforestry, Restoration, Circular Economy, Food Security, COVID-19

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1. Introduction

Climate change is real. The scientific data shows that its effects occur at an unprecedented rate and have observable consequences: the hottest temperature, the increase in global temperature, the increase in global sea surface temperature, the rise in sea level, and the iceberg melting in the Antarctic (Kaddo, 2016). On the other hand, the peatland forest has an important role as an environmental buffer against climate change. Peatlands can restore carbon balance through photosynthesis and respiration (decomposition), and decomposition is the second controlling factor of carbon accumulation (Harenda et al., 2018). However, the over-exploitation of natural resources and using fire for peatland clearing have contributed significantly to local and global climate change. Peatlands are potential farming areas, so the land-use change has increased over the last two centuries. In Indonesia, peatland forest fires in 1997/1998 started the most significant environmental destruction and the second largest contributor to carbon emission worldwide. The peatland fires in 1997/1998 emitted 0.19 – 0.23 gigatons of carbon into the atmosphere, equivalent to a 13 to 40% increase in carbon emission worldwide (Page, 2002). The increase in carbon emission has an impact on the global temperature. However, global temperature has risen steadily since 1880, and the 19 hottest temperatures have occurred since 2001 (IBERDROLA, 2020). Climate change has important implications for the quality of natural resources that are key to the food supply chain. This can lead to a food crisis. World Meteorological Organization (2019) reported that climate change and extreme weather events are the main drivers of the recent increase in world hunger.

Besides climate change, Indonesia also faces the COVID-19 pandemic that has been exacerbating the environmental degradation mentioned above. The COVID-19 pandemic has created a new era and consequences for humanity, the economy, and food systems (Galanakis, 2020). The food security issue arises when the world's population is on lockdown. The pandemic results in complicated interactions between the food system and the food supply. Ikhsan & Virananda (2021) reported that the COVID-19 pandemic could affect food security by disrupting food distribution, increasing transaction costs, and lowering the purchasing power of rural and urban households. More than 90% of Indonesia's food sources are obtained from the market. It means that only a very small portion of households is self-sufficient in food production. To avoid massive food shortages, it is important that countries should keep the food supply chains going.

These problems should be anticipated by strengthening the resilience of local communities, and agroforestry can offer a solution to support food security (Afentina, et al., 2021). Afentina, et al. (2021) reported that, on average, all agroforestry components are food sources, most of which are vegetables, fruits and tubers. It indicates that agroforestry has a large potential to supply food. Agroforestry not only provides staple food to overcome food shortages but also has various other types of food.

To manage agroforestry in peatlands, the circular economy approach becomes one of many solutions, especially for the long-term, to prepare for the transition into post-COVID-19 era. The circular economy approach differs from the linear economy, which uses a "take-make-dispose" model. In a circular economy, resources, waste, emissions, and energy can be minimised by re-use, re-manufacture, and recycling. In a circular economy system, resources need to be preserved for as long as possible, maximising the value of resources used and recovering and regenerating products and materials over the life of the products. Rizos, Tuokko, & Behrens (2017) also categorised circular economy into three processes: (1) minimising resources, (2) preserving resources as long as possible and maximising the value of resources used, and (3) recovering and regenerating products and materials over the life of the product by 5Rs (*reduce, re-use, recycle, refurbish, and renew)*.

Indonesia has adopted the circular economy in its vision and mission. Indonesia's vision for 2045 has outlined the concept of a circular economy as a long-term policy. Based on the Indonesia National Development Planning Agency's study (National Development Planning Agency, 2021), adopting a circular economy can potentially increase Indonesia's GDP from 593 to 638 trillion compared to business as usual. Currently, many studies have implemented recycling programs in the livestock sector by utilising livestock manure for electric generation, methane capture, organic fertiliser and biogas. The implementation of the circular economy by recycling livestock manure is widely conducted in Indonesia, but it still quantitatively neglects the economic and environmental benefits.

This paper underlined the application of the new circular economy to the largest peatlands in Central Kalimantan. The study measures circular economy indicators by economic and environmental analyses in agroforestry. We found that the circular economy is a promising practice and economically and environmentally beneficial. The application in this study can be replicated in other sectors and areas to increase the nation's welfare. We organised the paper as follows. After the introduction in section one, we discuss the methodology applied to the peatlands (namely the peatland treatment) and the circular economy in section 2. In section 3, we describe the peatland. Section 4 discusses the results of the circular economy application. Lastly, section 5 concludes.

2. Literature Reviews

Suppose the green economy focuses on economic growth to maintain the availability of the existing resources and ecological balance. In that case, the circular economy focuses on optimising the use of resources in a closed cycle. However, both promote sustainable development and improve the quality of life and human well-being.

The circular economy approach also differs from the linear economy, which uses a take-use-throw model. In a circular economy, the use of resources, waste, emissions, and energy is minimised by closing the production-consumption cycle and extending the product's life span, applying design innovation, re-use, and recycling. A simple circular economy model is shown in Figure 1. It showed that resources need to be preserved as long as possible, the use of resources needs to be maximised, and the product at the end of its life span needs to be recovered and regenerated (Cholifihani, 2018).

Rizos, Tuokko, & Behrens (2017) categorise three main processes in a circular economy: (1) using fewer primary resources, (2) maintaining and optimising the highest value of materials or products, and (3) changing the utilisation patterns. Each of the main processes consists of several elements that should be carried out to achieve the goals of a circular economy. Many of their elements are often interlinked, while in some cases, businesses can adopt a strategy that involves multiple circular processes. National Development Planning Agency (2021) divides circular economy elements into five principles: reduce, re-use, recycle, refurbish, and renew). Indonesia has adopted a circular economy concept in the national development vision in 2045 as a long-term policy.

The circular economy ensures the value of resources and makes human resources a priority to drive economic growth rather than natural resources as the main resource.

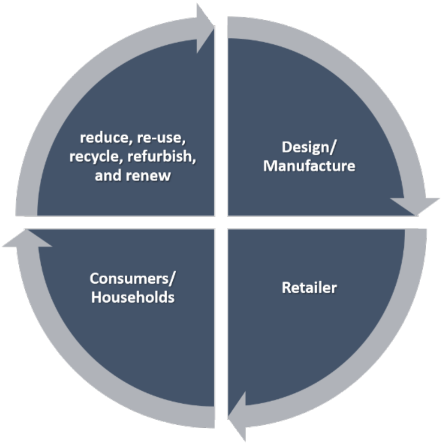

Figure 1- A Simple Circular Economy Model

Many developed countries such as Denmark, Finland, France, Belgium, and the Netherlands have implemented a circular economy to lead a green economy environment. For Indonesia, based on National Development Planning Agency (2021), the adoption of a circular economy in many sectors, in this case, study, food and beverages, textile, construction, wholesale, and trade, has the potential to increase the GDP from 593 to 638 trillion compared to business-as-usual approach.

To support the circular economy, the ability to measure circularity is important. However, the measurements of circular economy are still at the development level and rare (Kristensen & Mosgaard, 2022). The concept of circular economy relates to sustainability and balances the three dimensions of economy, environment, and society. Therefore, so far, simple measurements related to sustainability are often carried out using the life cycle assessment. Ghisellini et al. (2014) and Toniolo, Mazzi, Niero, Zuliani, & Scipioni (2013) evaluated a circular economy practice in the integration of agriculture, dairy production, and the use of plastics for food packing, respectively. Many studies about life cycle assessment in industry, agriculture, and livestock sectors measure the sustainability of circular economy practices. However, such studies are still rare in agroforestry. Forest plays a fundamental role in the transition from linear to circular economy. The circular economy provides opportunities for the forest sector, environmental protection, new job creation, and economic growth. So far, the measurement of the circular economy implementation in the forest is conducted by a descriptive and cluster analysis (Lazaridou, Michailidis, & Trigkas, 2021).

3. Methods

The Peatland Treatment

Sampling and data collection were done in Kawasan Hutan Lindung dengan Tujuan Khusus (KHDTK) or Forest Area with Special Purposes Tumbang Nusa, Banjarbaru, Central Kalimantan. The peatland observed in this study was the ex-fired peatland in 2015 treated with and without organic fertiliser. The organic fertiliser was composed of many weeds that grow in the peatland, for example, kelakai (*Stenochlaena palustris*), eupatorium, grass, karamunting (*Melastoma malabaricum*), and *Colopogonium mucunoides*. Other local materials such as cow and goat manure served as raw materials in the organic fertiliser composting process. The organic fertiliser application was carried out following Cahyono's method in patent number P00202101996. The parameters for the observation of vegetation (total number and type of tree, land cover, peat thickness, pH and soil conductivity) were recorded. Dead trees were also included in the parameter of number and type of trees. Soil samples were collected from 3 plots; each 1 m x 1 m in 20 m x 20 m peatland was observed at 0-10 cm soil depth and further mixed among subplots to finally weigh about 1 kg. The soil samples were analysed in the Soil Laboratory of the Faculty of Agriculture, Universitas Gadjah Mada. Both the pH and soil conductivity analysis used the electrometer method.

The Method for Calculating the Impact of Circular Economy Scheme

A circular economy scheme for agroforestry has been formulated. We made the scheme of circular economy in agroforestry by recycling livestock and plantation waste into energy and recycling the side-product of biogas into adsorbent for biogas purification. We also calculated the economic and environmental benefits of this scheme.

In this study, biogas from cow dung (30 heads of cows) and plantation waste had biogas yield of 0.31 m^3/head/day (Bond & Tempeton, 2011). Biogas was passed into an adsorption column containing natural zeolite and biogas sludge-based biochar (1:1 w/w) under the air pressure between 5-7 bar. The packed bed column had a diameter of 4 cm and a length of 20 cm for carbon dioxide adsorption. The purified biogas samples were analysed using Gas Chromatography to determine the methane content and the calorific value of biogas.

The economic aspect of biogas was determined by comparing the total investment cost of biogas purification (I_{total}) and the saving cost of purified biogas power that displaced coal-fired power (ΔC). The deviation between the total investment and the saving cost was expressed as potential profit (P). The electrification potential of purified biogas (kWh/year) was calculated using the scheme in Figure 2 and the calculation described in Equations (1), (2), and (3).

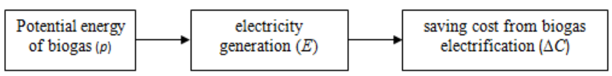

Figure 2- The calculation scheme of the potential energy, electricity generation, and saving cost from biogas electrification

$$p = n\,CH_4\,x\,\Delta H^o c \qquad (1)$$
$$E = \eta\,x\,p \qquad (2)$$
$$\Delta C = E\,x\,L \qquad (3)$$

p in Equation (1) represents the potential energy from purified biogas (MJ), $n\,CH_4$ is CH_4 composition of biogas (mole), and $\Delta H^o c$ is combustion calorie of 1 mole of CH_4 (kJ/mole). The calculation in Equation (2) is the calculated electricity generated from purified biogas (E) in MWh, with η representing the electrification efficiency of biogas. In this study, the electrification efficiency was 40% for large turbines and 25% for smaller generators (Cuellar & Webber, 2008). The saving cost from the use of purified biogas power that displaced coal-fired power (ΔC) was calculated in

Equation (3), with L representing the electricity cost of USD 0.09/kWh.

The total investment cost to establish biogas purification technology (I_{total}) was calculated by totalising the initial investment cost (I_i) and operational cost/year (OC). Thus, the profit gained from the biogas purification adoption and sales unit of the used biochar

(P) can be calculated in Equation (4):

$$P = \Delta C - (I_i + OC) \quad (4)$$

The increase in the energy efficiency of biogas will improve combustion efficiency. It means that GHG emissions produced during electricity generation will decrease and give a positive impact to the environment. The positive environmental aspect of biogas power plant ($\Delta CO_{2\,total}$) is calculated by reducing of total CO_2 emissions produced during the electricity generation before biogas purification ($eCO_{2\,i}$) with biogas after biogas purification ($eCO_{2\,f}$), as shown in Equation (5), following the calculation done by Cuellar & Webber (2008):

$$\Delta CO_{2\,total} = eCO_{2\,i} - eCO_{2\,f} \quad (5)$$

However, the total biogas energy is not all converted into electricity in the implementation, so the CO_2 emission factor should be considered. The CO_2 emission combustion from biogas ($eCO_{2\,comb}$), the CO_2 emission factor, the amount of CO_2 emissions in kg from 1 kWh electricity-based biogas power (zCO_2), and the total CO_2 emissions of biogas power (eCO_2) are determined in Equations (6), (7) and (8), respectively:

$$eCO_{2\,comb} = 1\, m^3 x\, [\,(\%CH_4 x \rho\, CH_4\, x 2.75) + \rho\, CO_2 (1 - \%CH_4)\, (6)$$

$$zCO_2 = \frac{e\,CO_{2\,comb}}{E\%\, x\, \eta} \quad (7)$$

$$eCO_2 = E\, x\, zCO_2\, x\, V_{biogas} \quad (8)$$

$\boldsymbol{\rho}$ **CH_4** and $\boldsymbol{\rho}$ **CO_2** in Equation (6) represents mass density from CH_4 (0.68 kg/m^3) and CO_2 (1.08 kg/m^3), respectively, and $\boldsymbol{E}\%$ is energy density (kWh/m^3) that was calculated by dividing biogas energy ($\boldsymbol{E}$) with the volume of biogas ($\boldsymbol{V_{biogas}}$).

4. Results

The Peatland Characteristics

Peatland fires and explorations cause a decrease in soil quality, as well as soil physical, chemical and biological changes. The peatland fires have changed the function of peats from an absorber to a source of greenhouse gas emissions. In this study, the environmental engineering by organic fertiliser application (microbial agents of the best local biotechnology) was conducted on ex-fired peatlands in Central Kalimantan. The characteristics of the ex-fired peatland with and without organic fertiliser are shown in Table 1. These observed peatlands are used for rubber, eucalyptus (agroforestry system), and horticulture.

The results in Table 1 show that the ex-fired peatland has changed from its natural characteristics. The average pH fell in the category of extremely acid to ultra-acid, comparable to previous findings of soil pH in Central Kalimantan with an average pH level of 3.25-3.6 (Shimada et al., 2001). However, the degraded peatland that had been restored by adding organic fertiliser from local sources (P4 and P5) had higher pH than the one without adding organic fertiliser. Adding organic fertiliser neutralises the pH and makes the land more suitable for intensive cultivation.

The addition of organic fertiliser also increases microorganisms' activity. Many soil microorganisms play an essential role in nutrient cycling and environmental interactions. The diverse microorganisms in the soil are essential for decomposing and recycling plant organic matter into humus. It has been recognised that, aside from being decomposers, soil microorganisms also help plants absorb more nutrients for their growth. Moreover, organic fertiliser can also serve as a compact growing medium, saving water, reducing heat and evaporation, providing sustainable nutrients, and improving root systems (Agus et al., 2021). Related to low pH levels (P1, P2, and P3), it can be explained that the peatland fires increase the hydrophobicity of the peat soil so that its capacity to retain water decreases and the flood potency is directly proportional to the high level of the humic acid represented by pH (Agus, et al., 2020). The level of soil conductivity in P1, P2, and P3 reflect that the peatland gets the water supply from the region it is located in, while in P4 and P5, the water supply only comes from the precipitation. The values are directly proportional to a high level of organic matter, high soil negative charge, low soil pH, and high lignin content in the soil.

Table 1- The Ex-fired Peatland Characteristics

Parameters	P1	P2	P3	P4	P5
Vegetation	Natural rubber agroforestr y	Natural rubber agrofor estry	Natural rubber agrofor estry	Mix agroforestry (eucalyptus, natural rubber)	Vegetables and horticulture
Number of trees	24	27	20	Many trees	-
Land cover	50-65%	50-65%	40-65%	30-45%	0%
pH	3.54	3.72	3.68	4.44	5
Soil conductivity	112	107	108	57	55

From this study, we concluded that the peatlands ecosystem has beneficial biodiversity potential, although it is low. Biodiversity and quantity of trees are classified as low-medium categories (Agus, et al., 2020). It is caused by limiting factors such as low pH and soil conductivity. Even so, the invention of organic fertiliser application has the potency to improve soil quality which is indicated by an increase in pH level.

A Circular Economy Implementation in Agroforestry Integrated with Livestock

This study offers a circular economy approach and closed-loop ecosystem management to manage the ex-fired peatlands for agroforestry. Agroforestry is defined as a combination of woody plants/forest components, such as trees, shrubs, palms, bamboos or other woody plants, with agricultural plants (annual crops) and/or animals (livestock).

A circular economy promotes better harmony in environmental, social and economic aspects. Agus et al. (2021) implemented a circular economy approach through an integrated bio-cycle organic farming system (IBFS) by (1) integration of the agricultural and non-agricultural sectors, (2) harmonisation of the economic, environmental, aesthetic, and socio-cultural values, (3) crop rotation and diversity systems, (4) artificial functional biotechnology, (5) integrated crop management, pest management, soil moisture management and nutrient management, and (6) integrated landscape ecology. A circular economy approach that can be implemented in agroforestry and integrated with the livestock sector has been made by recycling livestock manure and leaves litter as a source of energy (Figure 3).

In this study, we made a circular economy scheme in agroforestry by recycling livestock and plantation waste into energy and recycling the side-product biogas into adsorbent for biogas purification. We also calculated the economic and environmental benefits of this scheme, using 30 cows. The potential energy of biogas from 30 cows' manure mixed with leaf litter was assessed. Biogas sludge, the side-product from biogas energy production, was also recycled into biochar as carbon dioxide adsorbent in biogas purification.

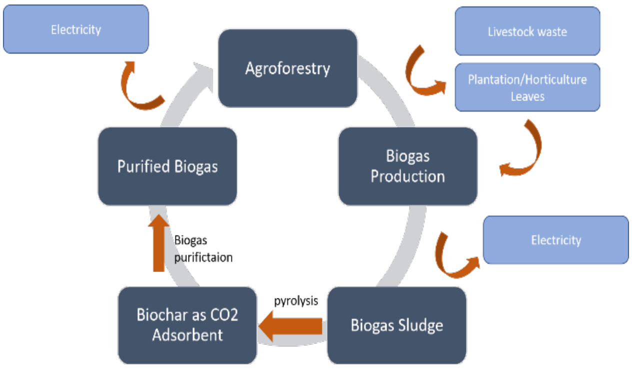

Figure 3- The Circular Economy Scheme in Agroforestry that Integrated with Livestock Sector

The mixing of cow manure and leaf litter has a potential energy of 70,767.85 MJ (with a total methane content of 32.68%). The biogas was then used to generate electricity. With 25% and 40% electrification efficiency, the purified biogas generated 4,918.37 and 7,869.39 kWh/year, respectively. The purified biogas power plant displaced the electricity supplied by the national electricity company in Indonesia (PLN), so it can save the electricity cost for PLN. The saving cost of electricity displaced by the purified biogas power plant is shown in Table 2.

The calculation in this study used the currency conversion value following the exchange currency rate when the study was conducted in 2020. The result showed that the purified biogas power plant reduced the electricity cost from USD 465.47 to 744.76 annually.

Table 2. Saving costs by recycling livestock waste into biogas energy

Cows (heads)	The potential energy (p) (MJ)	Electrification (E) (kWh)	Saving cost (ΔC) (USD)
Electrification efficiency (η) = 25%			
30	70,767.85	4,918.37	465.47
Electrification efficiency (η) = 40%			
30	70,767.85	7,869.39	744.76

The total investment cost consists of the initial and operational costs, as described in Tables 3 and 4. The initial investment cost is USD 546.35 (see Table 3), while the operational cost is USD 2,152.57 per month (see Table 4). In Table 4, the adsorption unit and pyrolysis reactor have a lifespan of 10 years, so the depreciation cost every year can be calculated.

From this study, we can calculate that the total investment cost of biogas purification was USD 4474,19.

In this scheme, there was no profit gained from biogas purification because the total investment cost was higher than the saving cost from the purified biogas power plant (Table 2). Therefore, in this study, we recommend an alternative scheme where the biogas purification unit will be integrated with the sale unit of the used biochar. As an effective adsorbent, biochar also has agronomic benefits such as soil amendment and fertiliser. Kung, et al. (2013) also claimed that biochar has economic value as a soil amendment. After being used in CO2 adsorption, biochar was sold at USD 0.42/kg. Assuming that biochar production and biochar yield is 100 kg/day and 41,7%, respectively, the sale of used biochar will be USD 6,392.61/year. Therefore, the profit gained from biogas purification integrated with the sales unit of used biochar is USD 2,384.57/year and 2,665.86/year at 25% and 40% electrification efficiency, respectively.

Table 3. Total investment cost of biogas purification using waste-based adsorbent

Needs	Amount	Unit	Price/ unit ($)	Total price ($)
Adsorption unit cost				
Adsorption column	1	Set	56	56
Plastic pipe ½ mm	1	meter	0.63	0.63
…Plastic pipe 3/8 mm	1	meter	0.42	0.42
Clamp ½ mm	4	Unit	0.17	0.68
Clamp ¾ mm	4	Unit	0.17	0.68
Tape	2	Unit	0.14	0.28
Auto sealer	1	Unit	1.22	1.22
Nepel pipe	4	Unit	0.56	2.24
Flowmeter	2	unit	9.1	18.2
Compressor	1	unit	297.5	297.5
Digital scale	1	unit	7	
Total				384.89
Biochar production cost				
Pyrolysis reactor	1	unit	525	525
Digital scale	1	unit	7	7
Tool kit keys	1	unit	14.35	14.35
Total (I_i)				546.35

Table 4. The total operational cost of biogas purification using waste-based adsorbent

Needs	Amount	Unit	Price/unit ($)	Total price ($)
CO_2 adsorption				
Depreciation cost Adsorption unit	1	year	38.84	38.84
Natural zeolite	321.2	kg	0.42	134.90
Labor's salary	1	month	101.39	1,216.64
Total				1,390.38
Biochar production				
Depreciation cost Pyrolysis reactor	1	unit	53.93	53.93
Fuels @12kg	90	unit	9.8	882
Labor's salary	1	month	101.39	1,216.64
Total (OC)				2,152.57

Based on the economic analysis, the circular economy scheme in agroforestry has a positive impact. Recycling agroforestry waste for biogas production and selling the used biochar as soil enrichment can reduce the initial cost of biogas purification. The positive benefits from the circular economy scheme will encourage and improve the enthusiasm of social capitalists to enter the biogas power generation industry. In this case, the government also has an important role in making the implementation of the circular economy scheme sustainable. Xu, et al. (2018) reported that the subsidy policy for organic fertiliser producers and users would improve the positive aspects of organic fertiliser use in the market.

Table 5- Carbon dioxide emissions from biogas power plant

Condition	Emissions factor (zCO_2) (kg/[kWh/m^3])	Total eCO_2 (eCO_2) (kg)	Mitigation of CO_2 emissions ($\Delta CO_{2\,total}$) (kg)
Electrification efficiency of 25%			
Before biogas purification	5.28	67,035,600	34,150
After biogas purification	4.46	67,001,450	
Electrification efficiency of 40%			
Before biogas purification	2.06	41,897,250	21,379
After biogas purification	1.74	41,875,871	

The mitigation of CO_2 emissions from the purified biogas power plant was also assessed to determine the impacts of circular economy implementation on the environmental aspect. The result in the environmental aspect is shown in Table 5. It can be concluded that the use of waste as an adsorbent in biogas purification reduced CO_2 emissions by 34,150 and 21,379 kg/year at the electrification efficiency of 25% and 40%, respectively. Biogas purification contributes positively to mitigating CO_2 emissions. Moreover, the utilisation of biogas sludge as biochar has benefits in carbon sequestration and can capture carbon in a more stable form for thousands of years (Kung, 2013).

As for the long-term impact, if the market accepts the circular economy scheme, it will offer strong job creation prospects (Longo, et al., 2016). It means a higher job potential will be obtained if the agroforestry and livestock waste is properly managed. The socialisation of local people also needs to be considered so that they have a good perception of the great potential of waste management for the economy. Thus, for further study, better public communication must be included as an important factor in improving the implementation of a circular economy by helping people understand the benefits of this scheme.

5. Conclusions

The paper underlined the application of the circular economy scheme on the largest peatland in Central Kalimantan. The research was taken in Forest areas with Special Purposes Tumbang Nusa, Banjarbaru, and Central Kalimantan. This paper examined the soil characteristics of the peatland with organic fertiliser application compared to the one without organic fertiliser application. The results showed that the implementation of organic fertiliser on the degraded peatland caused the increase in pH level. The peatland fires cause degradation in soil characteristics such as low pH and electrical conductivity. Bio-engineering through organic fertiliser implementation enhanced soil properties in the peatlands. In this scheme, the circular economy practice of using organic fertiliser from waste can be an alternative solution to restore peatlands.

The specific circular economy practice was conducted and assessed in this study. The recycling of cows' manure and leaf litter into energy, and biogas sludge into adsorbent for biogas purification, giving benefits, both in economic and environmental aspects. In the environmental aspect, the circular economy implemented in the agroforestry reduced carbon dioxide emissions by 21,379 to 34,150 kg/year, while in the economic aspect, the circular economy scheme gives a profit by USD 2,384.57/year to 2,665.86/year. The circular economy scheme also has a higher job potential for recycling and managing waste, such as in biogas and its purification, biochar production, and selling units.

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