Utilization of organic fertilizer in response to mitigate CO$_2$ emission

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Abstract. Food security and sovereignty are strategic policy agenda of national security. Accelerating the growth of sustainable food production and improving the welfare of farmers through optimization of land resources are the priority. One way to increase food production and enhance soil quality is through the utilization of organic fertilizers such as livestock waste. In addition, it is expected to reduce CO$_2$ emissions rather than leaving manure untreated. The purpose of this study was to determine the effect of solid manure and biourine application on increasing maize production and mitigate CO$_2$ emission. This study was conducted in Inceptisols Rasau Jaya II, West Kalimantan. A randomized complete block design trial was established from plots fertilized with solid organic fertilizer (PO), biourine (BIO), solid organic fertilizer+biourine (PO+BIO), and control, with five replications. Parameters observed in this study were CO$_2$ flux and agronomic performance of maize. CO$_2$ emission was measured using the static chamber method, placing chambers on the surface of the soil and taking measurements using an infrared gas analyzer for 125 days. CO$_2$ fluxes ranged from 59.93 to 106.07 Mg ha$^{-1}$ yr$^{-1}$ and there was no significant difference among the organic fertilizer treatments; nevertheless, the lowest CO$_2$ flux was illustrated in PO+BIO. Maize productivity was influenced by the organic fertilizer and PO+BIO had the greatest maize yield.

1. Introduction

Food security and sovereignty are strategic policy agenda of national security. To develop food security and sovereignty, accelerating the growth of sustainable food production and improving the welfare of farmers through optimization of land resources is a priority. Land resources become the priority due to increased food demand, increased food production through food crop extension area, and increased food crop productivity.

Tidal land is potential for developing food crops, since it comprises 12.95 percent (1.9 million ha) of the total area (14.7 million ha) in West Kalimantan [3]. The tidal land is a suboptimal land characterized by acidic soil, the toxicity of Al and Fe, pyrite, and salinity intrusion; therefore, the soil productivity is low. Despite these conditions, tidal land can still be utilized for food crops, such as maize.

Maize (Zea mays L.) is the second staple food in Indonesia. Nowadays, maize is also used as the main component of industrial animal feed [14, 15] and biofuel [8]. Maize production in Indonesia can be increased by intensification and extensification programs [10]. There is considerable land availability for developing maize in West Kalimantan, which is also supported by human resources. The local government of West Kalimantan sets maize as one of the superior commodities. Thus, increasing maize production and productivity will be established.
One way to increase food production and enhance soil quality is through the utilization of organic fertilizers such as livestock waste. Many farmers own livestock in addition to planting maize. The utilization of livestock waste for maize can be a good solution to enhance zero waste management. It can be processed as solid (manure compost) and liquid cow manure (bio-urine). Besides, it is expected to reduce carbon dioxide (CO₂) emissions rather than leaving manure untreated. As stated in Mikha et al. [12] that land applied with dairy manure compost had lower CO₂ fluxes (732.1–766.9 mg kg⁻¹) compared to no dairy manure compost (986.8 mg kg⁻¹).

Therefore, the purpose of this study was to determine whether the application of solid manure and bio urine can increase maize production and mitigate CO₂ emission.

2. Materials and methods

2.1. Study site description

A field study was conducted in 2019 in Rasau Jaya II Village, Kubu Raya Regency, West Kalimantan. The soil type is Inceptisols in tidal lands agro-ecosystem. The climate is tropical moist (IIIC and IVC) with average temperatures above 18 °C year-round and average relative humidity is 80.8%. The annual precipitation ranges from 2,000 to 4,000 mm yr⁻¹ [16].

2.2. Materials

The maize variety used for this field study was Lamuru from Cereal Crops Research Institute. Organic fertilizer (bulk) (PO) was cow manure that was composted with a bioactivator to accelerate the decomposition process of cow waste. Whereas, bio-urine (BIO) was liquid cow waste (urine) that was fermented and added with a bioactivator. The result of organic fertilizers analysis was shown in Table 1.

| Parameter  | Organic fertilizer (bulk) | Bio-urine     |
|------------|---------------------------|---------------|
| pH         | 7.34                      | 7.75          |
| Organic C  | 29.73 %                   | 1.29 %        |
| Total N    | 2.97 %                    | 3.06 %        |
| C/N ratio  | 10.01                     | 0.42          |
| P          | 0.74 %                    | 12.14 mg kg⁻¹|
| K          | 1.51 %                    | 2,385.24 mg kg⁻¹ |
| Ca         | 4.31 %                    | 71.23 mg kg⁻¹ |
| Mg         | 1.43 %                    | 378.72 mg kg⁻¹ |

2.3. Cultivation

Minimum tillage was used for soil cultivation. Dolomite was applied 0.75 t ha⁻¹ after tillage to increase soil pH. Maize was planted using a 75 x 40 cm planting distance. Organic fertilizer (PO) was applied after planting. Meanwhile, bio-urine (BIO) was applied three times at 14, 35, and 49 days after planting. Urea was applied twice at 7 and 42 days after planting. SP-36 and NPK were all applied at 7 days after planting. Maize was harvested at 126 days after planting.

2.4. Experimental design, data collection and analysis

A randomized complete block design trial was established with four treatments as solid organic fertilizer (PO), bio-urine (BIO), solid organic fertilizer + bio-urine (PO+BIO), and control. Each treatment was replicated five times. The complete fertilizer treatments were as follows (table 2).
Table 2. Treatment of fertilizer.

| Fertilizer treatment                        | Fertilizer composition                                   |
|---------------------------------------------|----------------------------------------------------------|
| Farmer technology (control)                 | cow manure 0.6 t ha$^{-1}$, urea 200 kg ha$^{-1}$, and NPK 15-15-15 200 kg ha$^{-1}$ |
| Organic fertilizer (bulk)                   | cow manure 0.6 t ha$^{-1}$, urea 100 kg ha$^{-1}$, NPK 16-16-16 350 kg ha$^{-1}$, and SP-36 50 kg ha$^{-1}$ |
| Bio urine                                   | Bio urine 150 L ha$^{-1}$, urea 100 kg ha$^{-1}$, NPK 16-16-16 350 kg ha$^{-1}$, and SP-36 50 kg ha$^{-1}$ |
| Organic fertilizer (bulk) + Bio urine       | cow manure 0.6 t ha$^{-1}$, bio urine 150 L ha$^{-1}$, urea 100 kg ha$^{-1}$, NPK 16-16-16 350 kg ha$^{-1}$, and SP-36 50 kg ha$^{-1}$ |

The parameters measured in this study were agronomic performance on yield, plant height, and leaf number. CO$_2$ emission was measured using the static chamber method, placing chambers on the surface of the soil and taking measurements using an infrared gas analyzer (IRGA, LI-COR 820 model) on 125 days after maize planting [2, 4, 6, 11, 17].

Data were analyzed using SAS (SAS Institute Inc., Cary, NC). Analysis of variance (ANOVA) was performed on the data by using the Mixed procedure (Proc Mixed). Treatment means were compared using the Duncan’s Multiple Range Test (DMRT) post hoc tests ($n=5$, $P<0.1$).

3. Results and discussion

CO$_2$ fluxes ranged from 59.93 to 106.07 Mg ha$^{-1}$ yr$^{-1}$ from all fertilizer treatments. There were no significant differences in CO$_2$ fluxes among the organic fertilizer treatments. Nevertheless, the lowest CO$_2$ flux was illustrated in PO+BIO. Farmer’s fertilizer technology as a control showed higher CO$_2$ flux than the combination of organic fertilizer (bulk) + bio-urine. Interestingly, CO$_2$ fluxes were higher in the treatment of organic fertilizer or bio urine application solely (figure 1).

![Figure 1](image_url)  
**Figure 1.** Mean CO$_2$ emission under different fertilizer treatments.  
*Values followed by a different letter indicate significant difference based on Duncan’s Multiple Range Test (DMRT) ($n=5$, $P<0.10$). Bars indicate standard deviation.*
The result is following Mikha et al. [12] that measured lower CO$_2$ fluxes (732.1 to 766.9 mg kg$^{-1}$) on land applied with 11.2 and 22.4 t ha$^{-1}$ dairy manure compost compared to no dairy manure compost (986.8 mg kg$^{-1}$). In addition to that, Xu-bo et al. [18] also stated that long-term manure application had a greater economic benefit on maize yield with the less environmental impact of greenhouse gas emissions (soil CO$_2$ and N$_2$O fluxes per unit yield).

Based on ANOVA with coefficient variance of 9.79, organic fertilizer (bulk) + Bio-urine had significantly the highest yield compared to Bio-urine alone. Nevertheless, there were no significant differences in yield among farmer’s technology, organic fertilizer (bulk), and the combination of organic fertilizer (bulk) + Bio-urine (figure 2).

![Figure 2. The average maize yield under different fertilizer treatments.](image)

Values followed by a different letter indicate significant difference based on Duncan’s Multiple Range Test (DMRT) ($n=5$, $P<0.10$). Bars indicate standard deviation.

The agronomic performance of maize which was measured on plant height and leaf number per plant were not influenced by the fertilizer treatment. There were no significant differences in plant height and leaf number per plant among those fertilizer treatments (figures 3 and 4).

![Figure 3. The average of plant height under different fertilizer treatments.](image)

Values followed by a different letter indicate significant difference based on Duncan’s Multiple Range Test (DMRT) ($n=5$, $P<0.10$). Bars indicate standard deviation.
This study indicated that organic fertilizer (bulk) + Bio-urine can increase maize yield. The balance composition of inorganic fertilizer (N, P, and K) in the PO+BIO treatment also played a role in enhancing yield. This can be shown in the fertilizer composition of farmer’s technology as a control treatment. The organic fertilizer (bulk) dosage was the same as the PO and PO+BIO treatments; however, the inorganic fertilizer composition and dosage of farmer’s technology was different. This study finding was supported by Baghdadi et al. [1], Gomaa et al. [5], Kandil et al. [7], Körschens et al. [9], Nur et al. [13] that observed the combined application of organic fertilizer (manure) and mineral (inorganic) fertilization enhanced grain yield of maize, compared to solely inorganic fertilization treatment. The combination of organic fertilizers (cow manure and Bio-urine) as implemented in the PO+BIO treatment influenced soil quality by adding more nutrients to the soil (table 1). Besides, by adding more organic fertilizers, it also improved soil physical properties such as water-holding capacity, soil structure, and aggregate stability, that could promote nutrient absorption by plant and managed plant under abiotic stress.

Furthermore, the application of organic fertilizer (bulk) + Bio-urine also had a benefit to the environment that was able to reduce CO$_2$ emission (figure 1). Therefore, the balanced combination of organic and inorganic fertilizers was an important part of intensifying yield and reducing adverse environmental impact due to greenhouse gas emission.

4. Conclusions
There was no significant difference in CO$_2$ flux among the organic fertilizer treatments; however, the lowest CO$_2$ flux was indicated in organic fertilizer (bulk) + Bio-urine treatment. Whereas, fertilizer treatment influenced maize yield; in which the PO + BIO treatment generated the significantly highest yield due to more nutrient enrichment and soil quality improvement.

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References
[1] Baghdadi A, Halim R A, Ghasemzadeh A, Ramlan M F and Sakimin S Z 2018 Impact of organic and inorganic fertilizers on the yield and quality of silage corn intercropped with soybean *PeerJ* **6**: e5280
[2] Butnor J R, Johnsen K H and Maier C H 2005 Soil properties differently influence estimates of soil CO$_2$ efflux from three chamber-based measurement systems *Biogeochemistry* **73**: 283–301
[3] Central Bureau of Statistics 2017 *West Kalimantan in number Central Bureau of Statistics for West Kalimantan Province*
[4] Dariah A, Marwanto S and Agus F 2013 Root- and peat-based CO$_2$ emissions from oil palm plantations *Mitig. Adapt. Strateg. Glob. Change* **MASGC**(2013)
[5] Gomaa M, Kandil E, Zeid A A and Salim B M 2016 Response of some faba bean to fertilizers manufactured by nanotechnology *J. Adv. Agric. Res.* **21**: 384–399
[6] Husnain H, Wigena I G P, Dariah A, Marwanto S, Setyanto P and Agus H 2014 CO$_2$ emissions from tropical drained peat in Sumatra, Indonesia *Mitig. Adapt. Strateg. Glob. Change* **MASGC**(2014)
[7] Kandil E E, Abdelsalam N R, Mansour M A, Ali H M and Siddiqui M H 2020 Potentials of organic manure and potassium forms on maize (Zea mays L.) growth and production *Sci. Rep.* **10**: 8752
[8] Koçar G and Civaş N 2013 An overview of biofuels from energy crops: Current status and future prospects *Renew. Sust. Energ. Rev.* **28**: 900–916
[9] Körschens M *et al.* 2013 Effect of mineral and organic fertilization on crop yield, nitrogen uptake, carbon and nitrogen balances, as well as soil organic carbon content and dynamics: Results from 20 European long-term field experiments of the twenty-first century *Arc. Agron. Soil Sci.* **59**: 1017–1040
[10] Margaretha S L, Azrai M and Aqil M 2012 The impact of cropping intensity on maize marketing in rainfed area. p 242-246 Agribusiness of Maize-Livestock Integration, *Proceedings of International Maize Conference* (Gorontalo, Indonesia. November 22–24, 2012)
[11] Marwanto S and Agus F 2013 Is CO$_2$ flux from oil palm plantations on peatland controlled by soil moisture and/or soil and air temperatures? *Mitig. Adapt. Strateg. Glob. Change* **MASGC**(2013)
[12] Mikha M, Widiantuti D P, Hurissso T T, Brummer J E and Davis J G 2017 Influence of composted dairy manure and perennial forage on soil carbon and nitrogen fractions during transition into organic management *Agriculture* **A07**(2017)0037
[13] Nur M, Islami T, Handayanto E, Nugroho W and Utomo W 2014 The use of biochar fortified compost on calcareous soil of East Nusa Tenggara, Indonesia: 2. Effect on the yield of maize (Zea mays L) and phosphate absorption *Am. -Eurasian J. Sustain. Agric.* 105–112
[14] Pasuquin J M, Witt C, and Pampolino M 2010 A new site-specific nutrient management approach for maize in the favorable tropical environments of Southeast Asia. Soil Solutions for A Changing World, *Proceedings of 19th World Congress of Soil Science* (Brisbane, Australia. August 1–6, 2010)
[15] Reddy Y R, Ravi D, Reddy C H R, Prasad K V S V, Zaidi P H, Vinayan M T and Blümmel M 2013 A note on the correlations between maize grain and maize stover quantitative and qualitative traits and the implications for whole maize plant optimization *Field Crops Res.* **153**: 63–69
[16] Rejekiningrum P *et al.* 2012 *Atlas sumberdaya iklim untuk pertanian di Indonesia skala 1: 1000.000* (In Bahasa) (Balai Penelitian Agroklimat dan Hidrologi Bogor)
[17] Vac S-C, Popita G-E, Frunzeti N and Popovici A 2013 Evaluation of greenhouse gas emission from animal manure using the closed chamber method for gas fluxes *Not. Bot. Horti. Agrobo.* **41**(2): 576–581
[18] Xu-bo Z, Lian-hai W, Nan S, Xue-shan D, Jian-wei L, Bo-ren W and Dong-chu L 2014 Soil CO$_2$ and N$_2$O emissions in maize growing season under different fertilizer regimes in an upland Red Soil region of South China J. Integr. Agric. 13(3): 604–614