

The Application of Biochar on Intercropping System of Cassava and Maize, and the Effects on Soil Quality and Land-Use Efficiency

Eny Dyah Yuniwati
University of Wisnuwardhana Malang
nieyuniwati@gmail.com

Karyanto
University of Wisnuwardhana Malang

Abstract. Degraded land occurs due to the decrease in soil quality, which is often resulted from continuous planting without considering the quality of the soil. This study aims to reduce damage to soil fertility, control soil degradation, and increase the production of cassava and maize crops. The research was conducted in Junrejo village, Batu. Two types of biochar (chicken manure biochar and corn cob biochar) were used on cassava and maize intercropping. This study used three treatments: control, biochar chicken manure, and corn cob biochar. The study used a randomized block design with two factorials with a 5% analysis of variance and the smallest significant difference (LSD). The results showed that the application of biochar chicken manure and corn cob biochar significantly improved soil quality and increased the production of maize and cassava crops. Also, it proved effective for land use, thus controlling and reducing soil degradation. The soil quality was improving, and so was the cassava and maize yield. The highest yield was from cassava and maize intercropping with the application of chicken manure biochar (cassava 18.33 Mg ha⁻¹, maize 3.89 Mg ha⁻¹), while monoculture cropping system with the application of corn cob biochar production was 4.07 Mg ha⁻¹ for maize, and 32.81 Mg ha⁻¹ for cassava. The highest land use efficiency of cropping system intercropping cassava and maize after application of corn cob biochar was 1.03 and 0.72. It shows that the improvement of soil quality in intercropping of cassava and maize system after the application of corn cobs biochar was very effective so that land degradation could be avoided.

Keywords: *applications, biochar, intercropping, cassava, maize, soil quality, efficiency, use, land.*

INTRODUCTION

Cassava is a substitute for rice crops, in addition to maize and other plants. The cassava plant yield is relatively low, with the potential yield of around 30 tons/ha and the production from the intercropping of cassava and maize is around 15 tons/ha. It is caused by the low quality of the soil, especially if the planting is done continuously in monoculture. This can deplete

nutrients in the soil and reduce organic matter in the topsoil. [1] [2]

This seems to be a common problem (1), and to increase the fertility and productivity of plants is by adding organic material to the soil. One of the sources of organic material is manure- compost and fermentation of plant biomass (green manure). Recently, the land has undergone soil degradation, so the addition of organic material often experiences rapid decomposition, which makes soil fertility decreases rapidly. Therefore, the addition of organic material to the soil needs to be done annually (2). Rapid decomposition of organic material is one of the contributors to global warming (3) beside soil management on highly weathered soil in the humid tropical area [3][4]

Another useful source of organic material is biochar, which can improve soil properties, including organic C, CEC, and other physical properties. The application of biochar has been successful in increasing crop production, such as beans, upland rice, and cassava. The application of biochar to monoculture cropping system on maize has been investigated and is quite effective in increasing crop production and yield. Similarly, it increases cassava and maize yields and mutualism in the intercropping system. Nutrient availability from the biochar application increases nutrient uptake, accelerates photosynthesis, and increases crop yield. [5][6][7]

The purpose of this study was to determine the effect of the application of 2 types of biochar (manure biochar and corn cob biochar) on intercropping cassava and maize and improving soil quality for efficient land use. It is expected that by intercropping cassava and maize, a mutualism occurs in the absorption of nutrients, so there is no decrease in soil quality. With the application of 2 types of biochar (manure biochar and corn cob biochar), there will be more improvement in the soil quality compared to the use of organic fertilizer from conventional manure.[8][9]

METHOD

This research was carried out on land in the village of Junrejo, Batu. The land was Andisols type land with an effective depth of 25 cm. Some soil properties are presented in table 1. The experiments began in January 2018 until the harvesting time of cassava in October

2018. It involved two cropping systems, control treatment, and two biochar applications. Two cropping systems were carried out: (1) intercropping, (2) monoculture. The treatments given were (1) without treatment, (2) biochar from chicken manure and (3) biochar from corn cobs. The three treatments were arranged in a randomized block design with three replications in plots measuring 6.25 x 6.0 m.

Chicken manure and corn cobs were obtained from farmers around the trial area and dried to 15% water content. Every 10 kg of chicken manure was dry air, put into a burner drum consisting of stainless steel measuring 50 cm high and 40 cm in diameter, burnt using wood sawdust. With this combustion, the temperature in the drum reached 300°C, (between 240°C - 300°C) and the biochar was taken after 8-10 hours. As for corn cob biochar, it was obtained from the waste maize on the farmer's land, then put in a burner drum and burnt using wood sawdust. The characteristics of biochar chicken manure and corn cob biochar are presented in Table 1.

Table 1. Characteristics of chicken manure biochar, corn cob biochar and soil used in the experiment

Soil / organic amendment	pH	C (%)	N (%)	P (%)	K (%)	CEC (cmol)
Chicken manure biochar	6.6	19.25	1.44	0.38	0.45	17.5
Corn cob biochar	7.9	22.50	0.79	0.85	0.78	12.6
Soil	6.3	0.95	0.08	2.0	1.55	12.5

Maize seedlings planted in this experiment, "pioneer" hybrid maize seeds and cassava seeds "Malang 4" varieties, with high production. Cassava was planted with a spacing of 1.25 x 1.0 m without mound and maize was planted with intercropping with cassava spacing of 1.25 x 0.30 m. with maize population of 30 plants per plot, whereas maize monoculture was planted with a spacing of 0.75 x 0.30 m

For this experiment, the dose of biochar used was 15 mg/ha containing c organic (table 2) and manure applied at a dose of 20 mg/ha. For all treatments 400 kg of urea (45% N) per ha was given, 100 kg SP36 (36% P2O5) per ha, and 100 kg KCL (50% K2O) per ha. P and K fertilizers were applied three times, at planting time, 30 days after the planting, and after the harvesting of the maize.

The data observation included maize and cassava harvesting, physical properties of the soil before planting and after harvesting maize and cassava, and the wet weight of plant crops. Soil samples were taken at 20 cm depth, with a zigzag system and 0.5 kg composite sample for analysis of soil chemical properties.

Statistical analysis was performed for each treatment using the Land Use Efficiency (LUE). LUE was calculated using equations.

$$LUE = RY1: RY2 \dots\dots\dots (1)$$

RY1 = a crop yield on intercropping system treatment
 RY2 = the crop yields in on monoculture cropping system treatment.

RESULT

The results of table 2 show that the maize and cassava yield on intercropping systems showed an increase after the application of chicken manure and corn cob biochar. The increase in maize yields caused by improvements in crop production processes influenced the improvement of soil physical properties and the soil nutrient (see tables 4 and 5). The high yield of maize (3.89 Mg ha⁻¹) and cassava (18.33 Mh ha⁻¹) was caused by additional nutrients from corn cob biochar in intercropping systems and partly from the improvement of soil physical properties. Maize (4.56 Mg ha⁻¹) in monoculture treatment with biochar treatment of chicken manure showed the highest yield. Significant effects were found. Because of this treatment, the elements obtained from the application of biochar were very influential and durable in the soil (slow release), so that in subsequent cropping systems the availability of nutrients could be used and crop yields did not experience a significant decrease [10][11].

Table 2. Effect of biochar application on cassava products on the intercropping and monoculture systems

Treatment	Cropping system	maize (Mg ha ⁻¹)	Cassava (Mg ha ⁻¹)
No treatment	-	2.05 a	16.62 a
Chicken manure biochar	Intercropping (maize and cassava)	2.64 a	17.74 ab
Corn cob biochar	intercropping (maize and cassava)	3.89 c	18.33 b
No treatment	-	3.07 b	-
Chicken manure biochar	Monoculture maize	3.58 b	-
Corn cob biochar	Monokulture maize	4.07 c	-
No treatment	-	-	22.35 a
Chicken manure biochar	Monoculture cassava	-	25.62 a
Corn cob biochar	Monoculture cassava	-	32.81 b

A different result was observed for cassava treated with biochar. The treatment using chicken manure biochar showed higher production in cassava than the monoculture, but the highest increase in the cassava yield was resulted from corn cob biochar treatment. This indicates that the nutrients provided by biochar were much higher and greatly influenced the crop production. The high availability of C organic from Biochar corn cobs improved soil chemical properties, thus increasing nutrient availability and soil fertility (table 3). The biochar impurities application using chicken and corn cob biochar had a positive effect on improving soil chemical properties. The corn cob biochar contained high organic C (2.55%), nitrogen content 0.10%, P 12.20 ppm, CEC 18.64 cmol, and K 1.70%, which was higher than chicken manure biochar. A very significant difference compared to control.[5] [9][12].

Table 3. Effect of biochar application on some soil chemical properties after harvesting on various cropping system

Treatments	Cropping system	Chemical properties after the third maize (2010)				
		C(%)	N (%)	P (ppm)	CEC (cmol)	K (%)
No treatment	-	0.91 a	0.08	11.64	14.73 a	1.44
Chicken manure biochar	Intercropping (maize and cassava)	1.40 a	0.09	12.12	16.92 abc	1.62
Corn cob biochar	Intercropping (maize and cassava)	2.55 b	0.10	12.20	18.64	1.70
No treatment	-	0.99 a	0.09	10.47	14.35 a	1.47
Chicken manure biochar	Monoculture maize	0.92 a	0.09	10.42	14.25 a	1.48
Corn cob biochar	Monoculture maize	2.55 b	0.10	12.22	17.59 b	1.66
No treatment	-	0.90 a	0.09	10.47	14.35 a	1.47
Chicken manure biochar	Monoculture cassava	1.12 a	0.09	11.12	14.02 a	1.58
Corn cob biochar	Monoculture cassava	2.50 b	0.10	12.22	18.08 c	1.64

The results in Table 4. show that the application of chicken manure biochar and corn cob biochar decreased soil density and increased aggregate soil mass after harvesting maize. The positive effect of biochar chicken manure on soil density dropped. It was because the increase in soil aggregation with organic amendments was a logical consequence of the rise in C-organic soil (as seen in Table 2). The effect of increasing soil microorganisms was previously reported by Chan et al. [13], [9], [5].

Table 4. Effect of biochar application on some physical properties after harvesting on various cropping systems

Treatments	Cropping systems	Soil physical properties		
		Bulk density (Mgm-3)	Porosity (%)	Mean weight diameter (mm)
No treatment	-	1.20 b	54.72	1.75 a
Chicken manure biochar	intercropping (maize and cassava)	1.16 ab	56.33	2.30 b
Corn cob biochar	Intercropping (maize and cassava)	1.12 a	57.74	2.62 b
No treatment	-	1.22 a	53.97	1.68 a
Chicken manure biochar	Monoculture maize	1.21 bc	54.34	2.75 b
Corn cob biochar	Monoculture maize	1.14 a	56.99	2.69 b
No treatment	-	1.22 c	53.97	1.75 a
Chicken manure biochar	Monoculture cassava	1.22 c	53.97	2.78 b
Corn cob biochar	Monoculture cassava	1.16 a	56.33	2.45 b

It is interesting to study the relationship of biochar application with the sustainability of land use efficiency (LUE). LUE is calculated by comparing the crop yields after the application of biochar on the intercropping system and the crop yields after biochar application on monoculture cropping system. The results of the calculations are presented in Table 5 below, which shows higher LUE in intercropping systems compared to that in monoculture cropping systems.

The application of chicken manure biochar shows higher land use efficiency, both in maize yield (0.75) and in cassava yield (0.69). The highest yield was obtained from the application of corn cob biochar (1.03 for maize yield and 0.69 for cassava yield). This happened because the addition of organic C and some nutritional maize biomass of plants to the intercropping system influenced

the nutrient requirements of the cassava plants. Based on these results, obtaining sustainable production through intercropping of maize and cassava using biochar application, especially those made from chicken manure and corn cobs was highly recommended [14] - [16].

Table 5. Land Use Efficiency (LUE) of cassava and maize in the intercropping system, influenced by organic amendments application

Treatments	Cropping system	Yield (Mg ha-1)		Land Use Efficiency	
		Maize	Cassava	Maize	Cassava
No treatment	-	2.73 a	14.40 a	0.69	0.61
Chicken manure biochar	Intercropping (maize and cassava)	2.69 a	13.73 a	0.75	0.64
Corn cob biochar	Intercropping (maize and cassava)	4.13 c	23.20 b	1.03	0.72

CONCLUSION

The application of chicken manure and corn cob biochar can improve soil quality and increase the efficiency of land use. It can also multiply the maize and cassava yield. After the application of chicken manure biochar in the intercropping cropping systems, the maize and cassava yields increased significantly at 2.69 Mg ha⁻¹ and 13.73 Mg ha⁻¹, respectively. Similarly, the chicken manure biochar improves the physical and chemical properties of the soil. However, the application of corn cob biochar on intercropping system of maize and cassava showed a significant difference in improving soil physical properties (Bulk density 1.12 Mg m⁻³, porosity 57.74% and mean weight diameter 2.62 mm) and improving soil chemical properties (C = 2.55 %, N = 0.10%, P = 12.20 ppm, CEC = 18.64 cmol, K = 1.70%). The improvement of soil quality was strengthened by the results of the calculation of land use efficiency (LUE) of 1.03 for maize plants, and 0.72 for cassava plants. The intercropping of cassava and maize has better results and is more efficient than the monoculture after the application of chicken manure and corn cob biochar. With the increase in soil quality, damage from land degradation can be avoided.

ACKNOWLEDGEMENT

This research was funded by Directorate of Research and Community Service, Unemployment Research Scheme of Higher Education, Indonesian Ministry of Research, Technology and Higher Education, with Contract No. SP DIPA- Nomor 229/SP2H/LT/DRPM/2019.

REFERENCES

- [1] T. Islami and E. I. Wisnubroto, "Effect of Chemical and Mechanical Weed Control on Cassava Yield, Soil Quality and Erosion under Cassava Cropping System," *J. Adv. Agric. Technol.*, vol. 4, no. 1, pp. 57–61, 2017.
- [2] E. D. Yuniwati, W. H. Utomo, and R. H. Howeler, "Farmers' Based Technology Development for Sustainable Cassava Production System," *Int. J. Agric. Res.*, vol. 10, no. 2, pp. 54–64, 2015.
- [3] J. Lehmann and M. Rondon, *Bio-Char Soil*

Management on Highly Weathered Soils in the Humid Tropics. Boca Raton: CRC Press, 2002.

- [4] T. Islami, B. Guritno, N. Basuki, and A. Suryanto, "Biochar for sustaining the productivity of cassava-based cropping systems in the degraded lands of East Java, Indonesia," *J. Trop. Agric.*, vol. 49, pp. 40–46, 2011.
- [5] E. D. Yuniwati, "LAND HUSBANDRY: THE ROLE OF BIOCHAR AS A SOIL ENHANCER IN CASSAVA CROPPING SYSTEM," *Int. J. Agric. Environ. Res.*, vol. 03, no. 05, pp. 3727–3735, 2017.
- [6] B. Šlapáková, J. Jeřábková, K. Voříšek, V. Tejnecký, and O. Drábek, "The biochar effect on soil respiration and nitrification," *Plant Soil Env.*, vol. 64, no. 3, pp. 114–119, 2018.
- [7] E. D. Yuniwati, E. I. Wisnubroto, and W. H. Utomo, "Effect of nitrate-enriched biochar on Cassava (*Manihotesculentacrants.*) growth and fertilization efficiency," in *Proceedings of 141 st IASTEM International Conference*, 2018, pp. 1–5.
- [8] H. Yuananto and W. H. Utomo, "Effects of Application of Maize Cob Biochar Enriched with Nitric Acid on Organic C, Nitrogen, and Growth of Maize on Various Soil Acidity Levels," *J. Tanah dan Sumber. Lahan*, vol. 5, no. 1, pp. 655–662, 2018.
- [9] E. D. Yuniwati, "Land husbandry: The effect of chicken manure and corn cob biochar on soil fertility and crop yield on," *Eur. J. Adv. Res. to Biol. Life Sci.*, vol. 6, no. 4, pp. 11–19, 2018.
- [10] T. Islami, S. Kurniawan, W. H. Utomo, T. Islami, and S. Kurniawan, "Yield Stability of Cassava (*Manihot esculenta Crantz*) Planted in Intercropping System After 3 Years of Biochar Application," *Am. J. Sustain. Agric.*, vol. 7, no. 4, pp. 306–312, 2013.
- [11] N. Jafri, W. Y. Wong, V. Doshi, L. W. Yoon, and K. H. Cheah, "A review on production and characterization of biochars for application in direct carbon fuel cells," *Process Safety and Environmental Protection*, vol. 118, 2018.
- [12] P. Yuan, J. Wang, Y. Pan, B. Shen, and C. Wu, "Review of biochar for the management of contaminated soil: Preparation, application and prospect," *Science of the Total Environment*, vol. 659, 2019.
- [13] K. Y. A. Chan, L. V. Z. B, I. A. Meszaros, A. C. Downie, and S. D. Joseph, "Agronomic values of greenwaste biochar as a soil amendment," pp. 629–634, 2007.
- [14] T. Islami, B. Guritno, N. Basuki, and A. Suryanto, "Maize Yield and Associated Soil Quality Changes in Cassava + Maize intercropping System After 3 Years of Biochar Application," *J. Agric. Food. Tech.*, 2011.
- [15] "Agroforestry, the future of global land use," *Choice Rev. Online*, 2013.
- [16] S. T. Holden and K. Otsuka, "The roles of land tenure reforms and land markets in the context of population growth and land use intensification in Africa," *Food Policy*, 2014.