Please list the reviewers' comments and author’s response into a Table.

Reviewer A

Page number	Line number	Reviewer’s Comment	Author’s Revision
	Abstract		
3	15	What type of manure Is this rice straw	Cattle manure; chopped rice straw
3	22	This is very poorly written. Please rewrite for clarity. Also use correct English .	I have rewritten it . The revision of the writing has been proof read by ASN
	Introduction		
3	33-38	Please rewrite the statement and include the source.	I did rewrite and include source (Suwardji et al., 2012 and Sukartono, et al., 2013)
4	55	What type of manure	Cattle manure
	Material and Methods		
4	86	Is it available P or total P	Available-P (Bray 1)
5	90	Font not italic	I have revised
5	91	Sentence not clear	I revised sentence through proof reading
5	101	Format not italic	2.2. Experimental design and treatments
5	105-112	Not clear. Which height? English problem. Not clear.	40 cm is the high of bed (from surface plot to the farrow). revised the sentence
5	112	state the water content also.	Soil was kept moist at 80% of water field capacity
5	114	Not clear. Please re-write.	I had rewritten sentence
5	126	Is it by the macro or micro Kjeldahl method	Total N was determined using Kjeldahl method (Rayment and Lyons, 2011). Kjeldahl glass used was 250 ml volume
5	124-133	Sentence not clear	I revised sentence
	Results section		
6	150-177	These results are not well reported. Please report your results properly and also eliminate the references since you are not discussing the results.	I made correction (rewrite) according to the reviewer suggestion
6	155	MWD is usually measured in mm. please present your result in mm, so that one can actually know the MWD of water stable aggregates	MWD is the mean weight diameter of aggregate (mm). I used the obtained MWD value (equation 1) to calculate aggregate stability (%) (equation 2).
6	162	What is TDB	TDB: top dry biomass already stated clearly in methods section (Agronomy measurements)
6	150-177	This presentation of the results is very poor. You can improve on it	I did correction for improving the results presentation
	Discussion section		
7	180	What is proposed treatment?	The organic amendment treatments
7	180-190	Are you presenting the results again or you should be discussing your results??	I already revised the sentence
7	191-225	Repetition of results instead of Discussion	I already revised the sentence
	Conclusion		
9	266	Conclusion: mention the soil properties	I already revised conclusion

Reviewer B

Page number	Line number	Reviewer's Comment	Author's Revision
	ABSTRACT		
3	11	Change word: A field trial to field exp.	Yes - A field experiment
3	14	Add the volume	Yes I added the amount of amendment material applied for treatments
	INTRODUCTION		
3	36	Can you add any reference about low nutrient and depletion of SOC in dryland?	Sukartono, et al (2013)
3	44	Every single statement here, I think you can add any reference.	This is general condition in the northern Lombok dry land until now. (no reference for this information)
	MATERIAL AND METHODS		
4	85	Please change all comma to dot = 1,14 g cm^{-3} to 1.14 g cm^{-3}. And please change in all text	Yes I already changed
5	91	Preparation of biochar, cattle manure and rice straw. Please add more information about it	Yes I already add more detail information dealing with biochar preparation
5	110-111	Did you any treatment for rice straw before incorporate to the soil wit biochar, like cutting in some centimeter.	Dry rice straw was chopped into size of approximately 3 cm
	RESULTS		
6	152	So the cattle manure and rice straw is fresh?	Dry cattle manure used had C/N of 25. Rice straw was dry. I revised the sentence to make it more clear
	DISCUSSION		
7	180-190	Discussion: Why and How the treatment can increase SOC; Why and How the treatment can improve Total N, available P, Ca, CEC and aggregate stability	I already explain briefly in the discussion section how the treatment can improve the soil characteristics of sandy loams soil in particular N, P, CEC and soil aggregate stability
8	251	How soc can improve the soil aggregate stability?	I already explained in the discussion section
8	226-dst	Evident about effect of biochar and other organic matter on soil quality actually already published in many journal. But more important is how biochar and other organic material can improve the soil quality its more important to explain especially in sandy soil	In the discussion section, I also have provided confirmation from several publications as evidence of the effect of the application of biochar and organic matter on improving soil quality, especially sandy soil
7	208	How you can state this statement without data? Did you measure the soil microorganism? If not how you can know?	Actually, I did not measure the microorganisms. However, theoretically, I would expect that rice straw as mulch mineralizes more slowly than when it is incorporated thoroughly with soil and/or manure.

Influence of biochar amendments on the soil quality indicators of sandy loam soils under cassava–peanut cropping sequence in the semi-arid tropics of Northern Lombok, Indonesia

ABSTRACT

Low nutrient retention and soil organic matter depletion are the major challenges of the cropping system in the sandy loam soils of Northern Lombok, Indonesia. A field experiment was conducted to evaluate the influence of biochar-based organic amendments on the soil quality of sandy loam soils under cassava (*Manihot Esculenta, Crants*)–peanut (*Arachis Hypogeae L.*) cropping sequence. The treatments were as follows: biochar (10 ton ha^{-1}) and rice straw (3 ton ha^{-1}) (B1); biochar (10 ton ha^{-1}), cattle manure (10 ton ha^{-1}), and rice straw (3 ton ha^{-1}) (B2); biochar (10 ton ha^{-1}) and cattle manure (10 ton ha^{-1}) (B3); biochar (10 ton ha^{-1}) and cattle manure (10 ton ha^{-1}) plus rice straw mulch (3 ton ha^{-1}) applied on surface soils (B4), and without organic amendments (B0) as control. Results showed that the biochar-based organic amendments significantly improved several soil quality indicators such as SOC, total N, available P, Ca, cation-exchange capacity (CEC), and aggregate stability but had no significant effect on pH, K, and Mg. Improvement in soil quality was strongly indicated by an increase in the growth and yield of cassava and peanuts.

Treatments B1, B2, B3, and B4 generally had a comparable effect on soil parameters and tended to improve the growth and yield of cassava and peanuts. Cassava was responsive to treatments B2 (biochar, cattle manure, and rice straw) and B3 (biochar and cattle manure) with its actual yield of 27 ton ha^{-1}, which is a 40% increase compared with that in the control. As a secondary crop growing after cassava, peanuts also exhibited higher yields in all amended plots compared with that in the control. The highest yield was obtained in B2 (1.38 ton ha^{-1}), followed by B4 (1.36 ton ha^{-1}), B1 (1.33 ton ha^{-1}), and B3 (1.25 ton ha^{-1}). In conclusion, the incorporation of biochar, cattle manure, and crop residues (rice straw) into soils is a promising option to maintain soil quality and sustainably produce cassava and peanuts in the sandy loam soils of the semi-arid tropics of Lombok, Indonesia.

Keywords: biochar, cattle manure, crop residues, soil quality

1. Introduction

Indonesia has a great opportunity to increase its production of cassava and peanuts by optimizing and developing sustainable agriculture practices in the dryland area. However, sustainable agriculture in dry land, particularly on sandy soils, generally faces large constraints due to low nutrient retention capacity and soil organic matter depletion (Sukartono, et al. 2011a). West Nusa Tenggara, located in the eastern part of Indonesia, has potential dry lands of about 1,807,463 ha; of which, 335, 136 ha is relatively suitable for agriculture and about 38,000 ha is located in North Lombok (Suwardji et al, 2012). This area is favorable for food crops such as cassava, peanuts, and maize. Soils in this area are dominated by entisols, which are predominately formed from volcanic ash materials derived from Mount Rinjani eruption. The characteristics of the soils are as follows: light texture with a sand fraction of more than 50%, poor soil structure, low soil organic C (SOC) content, infertility, and low water retention (Sukartono et al., 2013).

Traditional farmers in the dry land of North Lombok commonly grow cassava as the first crop in early wet season, followed by peanuts as a secondary crop soon after the harvesting of cassava. Hence, the common cropping pattern in the area is cassava–peanut–fallow. Peanuts are selected as a secondary crop after cassava due to several considerations: (i) peanut is a legume crop that generates biomass for good-quality green manure; (ii) peanut as a part of rotational crops contributes significantly to improve soil fertility, especially nitrogen and SOC; and (iii) this crop has promising economic value. Soil and cropping management based on organic amendments seems to be an appropriate strategy to achieve sustainable production for cassava and peanuts.

For the sustainable production of these two crops in North Lombok, the limiting factors of soil fertility (i.e., low SOC content and poor nutrient retention and soil structure) must be overcome by implementing conservation-based soil management including the addition of organic matter such as biochar and other fresh organic materials (i.e., cattle manure and crop residues). Soil management through the addition of fresh organic matter, such as cattle manure, has been widely reported to improve soil fertility (Bhatt et al., 2019; Rayne and Aula, 2020) and crop yield in dry land (Sukartono et al., 2011); however, the effect mostly lasts for only one growing season. The use of these organic sources combined with biochar for cropping rotation of cassava–peanuts has not been carried out.

Biochar is a recalcitrant and stable carbon material in soils. It is a good option as soil amendment for managing sandy soils. In the long run, biochar can maintain SOC stability (Kavitha et al. 2018). The incorporation of biochar and fresh organic matter into the sandy soils of tropics (Hussain et al. 2017) may have multiple benefits, including enriching SOC, improving soil aggregate stability and nutrient availability from the mineralization of fresh organic matter, and increasing the ability of the soil to retain nutrients and water. For this reason, the modification of plant rhizosphere using biochar and other fresh organic matter (cattle manure, compost, and crop residues) can also be a practical option to increase C sequestration in soils.

Previous studies showed that under tropical conditions, the addition of biochar into the soil significantly improved the soil chemical properties (Sukartono et al., 2013; Kartika et al., 2018), water retention, and soil aggregates (Zhang et al., 2017; Blanco-Canqui, 2017). Increased SOC content and soil water retention under maize cropping system was also reported in North Lombok by Sukartono et al., (2013). Unfortunately, the incorporation of biochar combined with local fresh organic matter such as cattle manure and rice straw in the root zone of the cassava–peanut cropping sequence in North Lombok has not been explored. Cassava and peanuts have a typical root system that requires crumb soil structure and good aggregates, both of which can be induced by supplementing biochar and fresh organic matter. These organic amendments may have a positive impact on the growth and yield of both crops. The present study aimed to evaluate the influence of biochar-based organic amendments (biochar, cattle manure, and rice straw) on the soil quality of sandy loam soils under cassava–peanut cropping sequence in Northern Lombok.

2. Material and Methods

A field experiment was carried out at an agricultural dry land in North Lombok, East Indonesia. The experimental site was located at Akar-Akar Village, Sub district of Bayan (08^{o} 25'S, 116^{o} 23' E) at 21 m above sea level. The soil developed from volcanic ash and pumice from Mount Rinjani eruption. The topsoil (0–15 cm) has a sandy loam texture (57% sand, 33% silt, and 10% clay), 1.14 g cm^{-3} bulk density (BD), pH of 5.98, and low contents of SOC (0.95%), total N (0.12%), available P (14.24 mgkg^{-1}), exchangeable K (0.57 cmol kg^{-1}), and cation-exchange capacity (CEC) (11.65 cmol kg^{-1}). The experiment was conducted under cassava– peanut cropping sequence with cassava as the first crop and peanut as the secondary crop.

2.1. Preparation of biochar

Biochar was produced using a traditional method by combusting coconut shells in an earth pit with dimensions of 1.0 m depth and 0.80 m diameter (Sukartono, et al. 2011a). Coconut husk was used as the fuel source (Sukartono, Utomo, Kusuma, et al. 2011). Combustion was performed from 195 °C to 340 °C with an average of 310 °C for 5–6 hours until the feedstock had completely changed into black charcoal. The char was then cooled by water spraying and dried for 1 day. Biochar yield from charring of coconut shell with this procedure was 74.80 %. Subsequently, the yield of biochar was collected, dried and crushed to pass through a 1.00 mm sieve to create suitable application. The final product of biochar contained 8.5% water, 70.20% C, 0.15% P, 0.76% K, and 8.12% ash with pH 8.9 and potential CEC of 12.08 cmol kg^{-1}. Cattle manure had pH 6.8 and contained 11% water, 10.18% C, 0.95% total N, 0, 70% available P, and 0.65% K.

2.2. Experimental design and treatments

Field experiment was set up using a randomized complete block design (RCBD) with five treatments replicated four times. The experiment was carried out in one cycle of the cassava–peanut cropping sequence from February 2015 to April 2016.

The organic amendments were as follows: incorporated biochar and rice straw (B1); incorporated biochar, cattle manure, and rice straw (B2); incorporated biochar and cattle manure (B3); incorporated biochar, cattle manure, and rice straw on surface soil (B4); and a control treatment without organic amendments (B0). The size of each plot was 4 m long, 3.5 m wide, and 40 cm high with a space of 0.5 m between plots. Biochar (10 ton ha^{-1}) combined with manure (10 ton ha^{-1}) and rice straw (3 ton ha^{-1}) was incorporated into each plot at a depth of 10 cm during tillage operation. Dry rice straw was chopped into size of approximately 3 cm before applied to the treatment. All treated plots were incubated for 7 days by watering the soil at approximately 80% field capacity.

2.3. Agronomic activities for cassava–peanuts

Seedlings from 12-month-old cassava stems (20 cm length and diameter of 2.5 cm) were planted at a depth of 5 cm and a spacing of 100 cm x 50 cm at 7 days post treatment (February 2015), and the soil was kept moist at 80% field capacity. Cassava was fertilized by urea at 300 kg ha^{-1}, SP 36 at 200 kg ha^{-1}, and KCL at 150 kg ha^{-1}. Urea at 100 kg ha^{-1} was applied three times at 10, 90, and 150 days after planting (DAP). SP-36 (200 kg ha^{-1}) and KCl (150 kg ha^{-1}) were basally applied at 5 cm from the stems and 10 cm deep in the soil.

Cassava was harvested at 330 DAP by pulling the tubers out from the soils. At 7 days post cassava harvesting in January 2016, a local variety of peanut seeds were sown using wooden steaks with a row spacing of 20 cm x 20 cm and a depth of 5 cm.

2.4. Soil sample collection and analysis

Soil samples were collected from each plot at 15 cm top soil before the harvesting of cassava at 330 DAP. SOC was measured by Walkley and Black method, pH was detected using a pH meter in 1:2.5 soil: water solution, total N was determined by the Kjeldahl method, extractable P was analyzed using Bray-1, and exchangeable cations of K, Ca, and Mg and CEC were studied by the NH_4OAc method (Rayment and Lyons, 2011). Soil aggregate stability was measured using a dry and wet sieving method and a modified Yoder sieving machine (Sun and Lu, 2014) with sieves in diameters of 8.00, 4.76, 2.83, 2.0, 1.0, 0.5, and 0.30 mm. The subsamples for aggregate stability analysis were sieved using a 10 mm diameter sieve. Approximately 400 g of the sieved samples were used to determine the mean size of the aggregates retained in each sieve. The mean weight diameter (MWD) of soil samples was computed using equation 1 (Sun and Lu, 2014):

$$MWD = \sum_{i}^{j} Xi.\ Wi, \quad (1)$$

where MWD is the mean weight diameter of aggregate (mm), *Xi* is the mean diameter of ith size fraction, and *Wi* is the proportion of the total sample weight in the corresponding size fraction. The obtained MWD value was used to calculate aggregate stability as follows:

$$\text{Aggregate stability} = \{1: (MWD_{dry} - MWD_{wet})\} \times 100\%. \quad (2)$$

2.5. Agronomic measurements

The agronomic parameters for cassava were top dry biomass (TDB) and weight of fresh tubers harvested at 330 DAP, and those for peanuts were TDB, weight of dry pods (WDP) and grains (WDG), and N uptake. N uptake was determined by multiplying the TDB with N concentration in plant tissue at 60 DAP. The effects of treatments on soil and agronomic parameters were analyzed using ANOVA, and significance was tested by Fischer's least significant difference (p = 0.05) using Minitab program version 18.

3. Results

3.1. Soil chemical characteristics.

Table 1 shows that the addition of biochar + fresh organic matter based soil amendments had no significant effect on pH, K, and Mg but affected the concentration of SOC, total N, P, Ca, and CEC. These parameters were higher in the amended group than those in the control. Meanwhile, total N in B2 plot was higher than that in the control and was similar to those in B1, B3, and B4 plots.

3.2. Soil aggregate stability.

Soil aggregate stability in unit percent (%) was evaluated using MWD values (Sun and Lu 2014). As shown in Fig. 1, the soil aggregate stability was 59.24, 59.33, 58.21, and 58.95 (%) for B1, B2, B3, and B4 plots, respectively. These values were significantly higher than the 56.59% of no-amendment plot (B0). No significant difference in soil aggregate stability was observed among the plots under the four amendments.

3.3. Growth and yields of cassava and peanuts.

The biochar-based organic amendments had a significant effect on the growth and yield of cassava as the first crop and peanuts as the secondary crop (Table 2). The top dry biomass (TDB) of cassava increased significantly by 16% in B1 plot and 20% in B2, B3, and B4 plots relative to that in the control. No significant difference in harvested biomass was observed among the plots under the four amendments. However, tuber yield under all treatments significantly differed from that in the control (18.53 ton ha^{-1}). In particular, the yields under B2 and B3 were 26.57 and 26.80 tons ha^{-1}, respectively, which were nominally greater than those under B1 (24.37 ton ha^{-1}) and B4 (24.73 tons ha^{-1}).

The growth and component yields of peanuts were quantified using TDB, WDP, WDG, and weight of 1000 grains. Overall, the vegetative growth and yield of peanuts under the four treatments increased relatively to those in the control (B0). The grain yield under treatments B1, B2, B3, and B4 increased by 20%, 24%, 13%, and 23%, respectively. The grain yields of peanuts under B1 (1.33 ton ha^{-1}), B2 (1.38

ton ha^{-1}), and B4 (1.36 ton ha^{-1}) were comparable with each other but higher than that under B3. The highest yield was observed under B2 with the highest grain quality represented by the weight of 1000 grains (387.60 g) and N uptake. The N uptake by peanuts growing in the plots amended with a combination of biochar, cattle manure, and rice straw (B1, B2, B3, and B4) was significantly higher than that of the peanuts growing in the control plot (B0). The highest N uptake was observed for the plants growing under B2. N uptake was similar in plots under B1, B3, and B4.

4. Discussion

The results confirmed that the addition of biochar-based organic amendments for one cycle of cassava–peanut cropping sequence improved soil characteristics such as contents of SOC, total N, available P, and exchangeable Ca, CEC, and soil aggregate stability. However, soil pH, exchangeable K, and Mg were not affected. Biochar, cattle manure, and straw are potential sources of SOC (Kavitha et al. 2018). Proper preparation through pyrolysis produces high-quality biochar (Sukartono et al., 2013) and provides a large surface area that is beneficial to improve the nutrient holding capacity of sandy soils (Song et al., 2018). Decomposed cattle manure and rice straw can enrich negative charges, which directly contribute to the CEC of amended soil (Rayne and Aula, 2020). This study proved that biochar + organic amendments increased the CEC of sandy soil by 13%–15%. The results were mostly in line with previous findings on the potential of biochar combined with fresh organic amendment to increase soil fertility status (Agegnehu et al. 2015) including soil nutrient, SOC, and CEC (Islami et al., 2011).

The great percentage of soil aggregate stability in the biochar-based organic amended soils was a strong evidence of the potential role of biochar combined with manure and/or rice straw in soil physical properties. The role of SOC was essentially related to aggregate formation and stability (Zhang et al. 2017)(Zhang et al. 2017)(Zhang et al. 2017)(Zhang et al. 2017)(Zhang et al. 2017)[9](Zhang et al., 2017; Blanco-Canqui, 2017).

This study found that the biochar-based organic amendments improved the soil fertility of sandy loam and had a positive impact on the growth and yield of cassava as the first crop and peanuts as the secondary crop. Fertile soils provide essential plant nutrients in balance and thus enable plants to produce high biomass and yield (Karimi et al. 2019).

For the peanuts, the high N uptake on all amended plots was attributed to the availability of N derived from decomposed cattle manure and rice straw (Agegnehu et al. 2015). Although peanut is a legume crop that can directly fix N from the atmosphere, nitrogen in soils is still required to promote vegetative and generative growth in infertile soils (Zheng et al. 2013). In the study site, cattle manure and rice straw are locally available as main resource of nutrients. Therefore, biochar incorporated with cattle manure and rice straw (B2) seems to be promising for the sandy soils of entisols, which lack of CEC and have low holding water capacity (Sukartono et al, 2013; Bhatt et al., 2019). In theory, biochar can persist in soils for long term and therefore could be a sustainable component of soil amendments in the semi-arid tropics of North Lombok.

The application of biochar incorporated with fresh organic such as manure and crop residues was beneficial for improving the growth and yield of cassava. However, the lack of response of plant growth and yield under B1 and B4 might be attributed to two aspects, namely, (i) the slow mineralization of the straw applied as mulch and (ii) the limited access for soil microorganisms to decompose straw as mulch on the soil surface. In B2 and B3, straw was thoroughly incorporated in the root zone where it can have a direct contact with soil microorganisms and cattle manure naturally contains plant nutrients that are promptly available for crops. A field experiment in the dry land in Java (Islami et al., 2011; Yuniwati, 2018) confirmed the significant effect of biochar to improve the growth and yield of cassava.

B2, in which biochar, manure, and rice straw were thoroughly incorporated in the surface soil at 15 cm depth, can be a potential source of organic nutrients (fertilizers) that are commonly recommended for soil management in the tropical semi-arid environment. These raw materials are locally available and become nutrient reservoir for plants. The continuous addition of organic matter to sandy soils also has a positive contribution to soil quality, plant growth, and sustainable crop production. Hossain, et al. (2020) explained that biochar could influence soil nutrients as a nutrient sink for plant and microorganisms and as a soil conditioner that improves soil properties, conserves soil nutrients, and strengthens soil structure. Thus, the integration of biochar, fresh organic matter, and manure as soil amendments seems to have more benefits than their individual applications.

As a carbon-based soil amendment either applied individually or with fresh organic matter, biochar is beneficial for the enhancement of crop yield and soil quality (Kavitha et al., 2018; Song et al., 2018), such as by increasing the SOC, total N, available P, and CEC (Karimi et al. 2019). The increasing value of CEC in the soils receiving biochar-based organic amendment was associated with the high potential CEC of the biochar used in the experiment. The CEC of biochar is attributed to the generation of various functional groups, such as carboxyl and hydroxyl groups, during the pyrolysis of biomass; this process is governed by surface oxidation and the adsorption of highly oxidized organic matter onto the biochar surface (Tomczyk, Sokołowska, and Boguta 2020). Sukartono et al. (2011) also reported that the addition of biochar and manure increased the fertility of soil and yield of maize growing on sandy soil under maize cropping system in North Lombok. Hence, the addition of soil organic amendments such as the combination of biochar, cattle manure and rice straw can contribute to the improvement of the nutrient status and crop production in arid and semi-arid sandy soils with extremely low soil organic content.

The high nutrient availability in the amended soils (Table 1) implied the contribution of fine biochar interacting with fresh organic matter (manure and chopped rice straw) to produce a rich negative surface charge from the various functional groups of the aromatic carbon structure (Hussain et al. 2017). As a result, the soils exhibit an increased capacity to retain nutrients from external input (fertilizers) and internal input (mineralization of organic matter) (Yuan et al., 2016). In addition, Yuan et al. (2016) explained that the negative surface charge of the soil containing high carbon aromaticity can provide a high nutrient-retaining capacity for the soil, thereby reducing nutrient loss through leaching. However, the number of functional groups of aromatic carbon was related to the typical characteristics of coconut shell-biochar obtained from auto thermal combusting at a low temperature of 310^{o}C (Sukartono et al., 2013). Biochar produced under low temperature (200 °C–400 °C) had a large amount of oxygen-containing functional groups, such as –COOH, –OH, C=O, phenolic–OH, and –CHO groups, which stimulated nutrient exchange and thereby increased soil fertility (Mandal et al., 2020).

In terms of soil aggregate stability, the biochar-based organic amended soils exhibited significant improvement. These results confirmed that biochar incorporated with fresh organic manure improved soil aggregate and structure by forming a particulate organic matter (POM)–biochar–clay complex (Hossain, et al., 2020). Biochar is a recalcitrant C compound; when mixed with POM, biochar acts as a binding agent in the formation of soil micro and macro aggregates (Zhang et al., 2020). The high MWD in all amended soils (Fig1) was in line with the findings of Blanco-Canqui (2017), who reported that biochar increased the coarse aggregate stability of sandy textured soils.

On the basis of the crop yields under one cycle of field experiment, the incorporation of biochar, cattle manure, and rice straw into the root zone had a positive effect on the physical and chemical characteristics of the soils, thus improving the yield of cassava and peanuts. Over time, the addition of biochar combined with cattle manure and crop residues could improve nutrient use efficiency and thus provide favorable conditions for plant growth and yield. Earlier research reported that the biochar-induced increase in CEC was associated with nutrient retention and affected crop yield (Sukartono et al., 2011; Hussain et al., 2017).

5. Conclusion

The addition of biochar-based organic amendments in one cycle of cassava–peanuts cropping sequence improved the soil characteristics of sandy loam entisols by increasing SOC, total N, available P, Ca, CEC, and aggregate stability. The yield significantly increased for cassava and peanuts in the cropping sequence. The combination of biochar, cattle manure, and rice straw potentially contributed to nutrient enhancement as part of soil quality indicators and crop production of cassava and peanuts growing in the sandy loam of tropical semi-arid region in Northern Lombok, Eastern Indonesia. Further field study on the coupling of biochar and other locally fresh organic matter with various rates for multiple years of cropping season is recommended to ascertain the proper combination and rates of the carbon-based amendment that could generate the most significant crop responses.

Figure

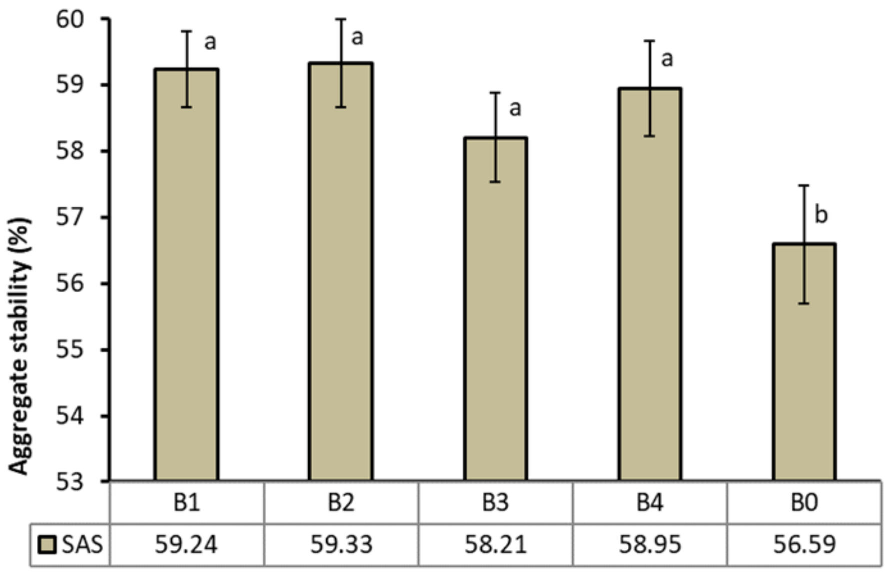

Fig. 1. Effect of biochar-based organic amendment on soil aggregate stability (%) under cassava–peanut cropping sequence. Bars with the same letters do not differ significantly.

Table 1. Effect of biochar-based organic amendments on the chemical properties of the soil under cassava–peanut cropping sequence.

Treatments	Soil Chemical properties							
	pH	SOC %	N %	P mg kg^{-1}	K cmol kg^{-1}	Ca cmol kg^{-1}	Mg cmol kg^{-1}	CEC cmol kg^{-1}
B1	6.2a	1.12a	0.13ab	16.10a	1.26a	3.34a	1.49a	14.02a
B2	6.4a	1.14a	0.15a	16.77a	1.40a	3.68a	1.53a	14.18a
B3	6.3a	1.02ab	0.13ab	15.40a	1.21a	3.29a	1.42a	14.11a
B4	6.4a	1.11a	0.14ab	15.51a	1.15a	3.55a	1.41a	13.95a
B0	6.1a	0.90b	0.11b	12.70b	1.03a	2.32b	1.24a	12.37b

Means with the same letters within column do not differ significantly (p = 0.05)

Table 2. Effect of biochar-based organic amendment on the growth and yield of cassava and peanuts.

Treatments	***Cassava (First Crop)***			***Peanuts (second crops)***				
	TFB ton ha^{-1}	TDB ton ha^{-1}	TY ton ha^{-1}	TDB ton ha^{-1}	WDP ton ha^{-1}	WDG ton ha^{-1}	W-1000 g	N Uptake g plant^{-1}
B1	20.65a	6.20a	24.37a	3.78a	2.33a	1.33a	362.87ab	0.19a
B2	21.30a	6.39a	26.57a	4.11a	2.28a	1.38a	387.60a	0.24c
B3	21.20a	6.36a	26.80a	3.34ab	2.08ab	1.25ab	332.80ab	0.18a
B4	21.13a	6.34a	24.73a	3.79a	2.31a	1.36a	356.23ab	0.19a
B0	17.80b	5.34b	18.53b	2.77b	1.69b	1.11b	303.73b	0.15b

TFB = top fresh biomass; TDB: top dry biomass; TY; tuber yields (cassava); WDP: weight dry pods; WDG: weight of dry grains; W-1000: weight of 1000 grains. Means with the same letters within a single column do not differ significantly (p = 0.05).

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Influence of biochar amendments on the soil quality indicators of sandy loam soils under cassava - peanut cropping sequence in the semi-arid tropics of Northern Lombok, Indonesia

ABSTRACT

Low nutrient retention and soil organic matter depletion are the major challenges of the cropping system in the sandy loam soils of Northern Lombok, Indonesia. A field trial was conducted to evaluate the influence of biochar-based organic amendments on the soil quality of sandy loam soils under cassava (*Manihot Esculenta, Crants*)-peanut (*Arachis Hypogeae L.*) cropping sequence. The treatments were as follows: biochar and rice straw (B1), biochar, cattle manure and rice straw (B2), biochar and cattle manure (B3), biochar and cattle manure, plus rice straw mulch applied on surface soils (B4), and without organic amendments (B0) as control. Results showed that biochar-based organic amendments significantly improved several soil quality indicators such as SOC, total-N, available P, Ca, cation exchange capacity (CEC) and aggregate stability, but had no significant effect on pH, K and Mg. Improvement in soil quality was strongly indicated by an increase in the growth, and yields of cassava and peanuts. Treatments B1, B2, B3 and B4, generally had a comparable effect on soil parameters and tended to improve the growth and yield of cassava and peanuts. Cassava was responsive to treatments B2 (biochar, cattle manure and rice straw) and B3 (biochar and cattle manure) with its actual yield of 27 ton ha^{-1}, which is a 40% increase compared with that in the control. As a secondary crop growing after cassava, peanuts also exhibit higher yields in all amended plots compared with that in the control. The highest yield was obtained in B2 (1.38 ton ha^{-1}), followed by B4 (1.36 ton ha^{-1}), B1 (1.33 ton ha^{-1}), and B3 (1.25 ton ha^{-1}). In conclusion, the incorporation of biochar, cattle manure and crop residues (rice straw) into soils is a promising option to maintain soil quality and sustainably produce cassava and peanuts in the sandy loam soils of the semi-arid tropics of Lombok, Indonesia.

Keywords: biochar, cattle manure, crop residues, soil quality

1. INTRODUCTION

Indonesia has a great opportunity to increase production of cassava and peanuts by optimizing and developing sustainable agriculture practices in the dryland area. However, sustainable agriculture in the dry land in particular on sandy soils, generally faces large constraints due to low nutrient retention capacity and soil organic matter depletion.

West Nusa Tenggara, located in the eastern part of Indonesia, has potential dry lands of about 1,807,463 ha; of which, 335, 136 ha is relatively suitable for ~~productive~~ agriculture and about 38,000 ha is located in North Lombok (Suwardji, et al., 2012). This area is favorable for food crops such as cassava, peanuts and maize. Soils in this area are dominated by entisols, which are predominately formed from volcanic ash materials derived from the Mount Rinjani eruption. The ~~C~~characteristics of the ~~The~~ soils ~~,~~are as follows: ~~has a~~ light texture with a sand fraction of more than 50%, poor soil structure, low soil organic-C (SOC) content, infertility and low water retention (Sukartono et al., 2013)

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Traditional farmers in the dry land of North Lombok commonly grow cassava as the first crop in early wet season, followed by peanuts as a secondary crop soon after harvesting of cassava. Hence, the common cropping pattern in the area is cassava-peanut-fallow. Peanuts are selected as a secondary crop after cassava due to several considerations: (i) peanut is a legume crop that generates biomass for good quality green manure; (ii) peanut as a part of rotational crops contributes significantly to improve soil fertility, especially nitrogen and SOC (iii) this crop has promising economic value. Soil and cropping management based on organic amendments seems to be an appropriate strategy to achieve sustainable production for both cassava and peanuts.

For sustainable production of these two crops in North Lombok, the limiting factors of soil fertility (i.e. low SOC content and poor nutrient retention and soil structure) must be overcome by implementing conservation-based soil management including addition of organic amendments materials such as biochar and other fresh organic materials (i.e., cattle manure and crop residues). Soil management through the addition of fresh organic matter such as cattle manure has been widely reported to improve soil fertility (Bhatt et al., 2019; Rayne and Aula, 2020) and crop yield in dry land (Sukartono et al. 2011), however, the effect mostly lasts for only one growing season. The use of these organic sources combined with biochar for a cropping rotation of cassava-peanuts has not been carried out.

Biochar is a recalcitrant and stable carbon material in soils. It is a good option as soil amendment for

Previous studies showed that under tropical conditions, the addition of biochar into the soil significantly improved soil chemical properties (Sukartono et al., 2013; Kartika et al., 2018), water retention, and soil aggregates (Zhang et al., 2017; Blanco-Canqui, 2017). Increased SOC content and soil water retention under maize cropping system was also reported in North Lombok by Sukartono et al., (2013). Unfortunately, the incorporation of biochar combined with local fresh organic matter such as cattle manure and rice straw in the root zone of the cassava-peanut cropping sequence in North Lombok has not been explored. Cassava and peanut have a typical root system that requires crumb soil structure and good aggregate, both of which can be induced by supplementing biochar and fresh organic matter. These organic amendments may have a positive impact on the growth and yields of both crops. The present study aimed to evaluate the influence of biochar-based organic amendments (biochar, cattle manure and rice-straw) in improving soil quality of sandy loam soils under cassava-peanut cropping sequence in Northern Lombok.

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2. MATERIAL AND METHODS

A field experiment was carried out at an agricultural dry land in North Lombok, East Indonesia. The experimental site was located at Akar-Akar Village, Subdistrict of Bayan (08° 25'S, 116° 23' E) at 21 m above sea level. The soil developed from volcanic ash and pumice from Mount Rinjani eruption. The topsoil (0-15 cm) has a sandy loam texture (57% sand, 33% silt and 10% clay), 1.14 g cm^{-3}bulk density (BD), pH of 5.98, and low contents of SOC (0.95%), total N (0.12%); available P (14.24 $mgkg^{-1}$), exchangeable K (0.57 cmol kg^{-1}) and cation exchange capacity (CEC) (11.65 cmol kg^{-1}). The trial was conducted under cassava- peanut cropping sequence with casava as the first crop and peanut as the secondary crop.

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2.1. Preparation of biochar.

Biochar was produced using a traditional method by combusting coconut shells in an earth pit with dimensions of 1.0 m depth 0.80 m diameter. Coconut husk was used as the fuel source (Sukartono et al., 2011). Combustion was performed from 195°C to 340°C with an average of 310°C for 5 to 6 hours until the feedstock had completely changed into black charcoal. The chars was then cooled by water spraying and dried for one day. The chars was ground and sieved using a 1.0 mm mesh sieve. The final product of biochar contained 8.5% water, 70.20% C, 0.15% P, 0.76% K, 8.12% ash with pH 8.9 and potential CEC of 12.08 cmol kg^{-1}. Cattle manure had pH 6.8, and contained 11% water, 10.18% C, 0.95% total N, 0, 70% available P, and and 0.65% K.

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2.2. Experimental design and treatments.

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Field experiment was set up using a randomized complete block design with five treatments replicated four times. The experiment was carried out in one cycle of the cassava-peanut cropping sequence from February 2015 to April 2016.

The organic amendments were as follows: incorporated biochar and rice straw (B1), incorporated biochar, cattle manure and rice straw (B2); incorporated biochar and cattle manure (B3); incorporated biochar, cattle manure, and rice straw on surface soil (B4); and a control treatment without organic amendments (B0). The size of each plot was 4 m long, 3.5 m wide, and 40 cm high with a space of 0.5 m between plots. Biochar (10 tons ha^{-1}) combined with manure (10 ton ha^{-1}) and rice-straw (3 ton ha^{-1}) was incorporated into each plot at a depth of 10 cm during tillage operation. All treated plots were incubated for 7 days by watering the soil at approximately 80% field capacity.

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2.3. Agronomic activities for cassava – peanuts.

Seedling from 12-month-old cassava stems (20 cm length and diameter of 2.5 cm) were planted at depth of 5 cm and a spacing of 100 cm x 50 cm at 7 days post treatment (February 2015), and the soil was kept moist at 80% field capacity. Cassava was fertilized by Urea at rates of 300 kg Urea ha^{-1}, SP 36 at 200 kg ha^{-1} and KCl at 150 kg ha^{-1}. Urea at 100 kg ha^{-1} was applied three times at 10, 90 and 150 days after planting (DAP). SP-36 (200 kg ha^{-1}) and KCl (150 kg ha^{-1}) were basally applied at 5 cm from the stems and 10 cm deep in the soil.

Cassava was harvested at 330 DAP by pulling the tubers out from soils. At 7 days post cassava harvesting in January 2016, a local variety of peanut seeds were sown using wooden steaks with a row spacing of 20 cm x 20 cm and a depth of 5 cm.

2.4. Soil sample collection and analysis

Soil samples were collected from each plot at 15 cm top soil before harvest of cassava at 330 DAP. SOC was measured by Walkley and Black method, pH was detected using a pH meter in 1:2.5 soil : water solution, total N was determined by the Kjeldahl method, extractable P was analyzed using Bray-1, and exchangeable cations of K, Ca and Mg and CEC were studied by the NH_4OAc method (Rayment and Lyons, 2011). Soil aggregate stability was measured using a dry and wet sieving method and a modified Yoder sieving machine (Sun and Lu, 2014) with sieves in diameters of 8.00, 4.76, 2.83, 2.0, 1.0, 0.5, and 0.30 mm. The subsamples for aggregate stability analysis were sieved using a 10 mm diameter sieve. Approximately 400 g of the sieved samples were used to determine mean size of the aggregates retained at each sieve. The mean weight diameter (MWD) of soil samples was computed using equation 1 (Sun and Lu, 2014):

$$MWD = \sum_{i}^{j} Xi.Wi \quad (1)$$

Where MWD is the mean weight diameter of aggregate (mm), *Xi* is the mean diameter of ith size fraction, and *Wi* is the proportion of the total sample weight in the corresponding size fraction. The obtained MWD value was used to calculate aggregate stability as follows:

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$$\text{Aggregate stability} = \{1: (MWD_{dry} - MWD_{wet})\} \times 100\% \quad (2)$$

2.5. Agronomic measurements

The agronomic parameters for cassava were top dry biomass (TDB) and weight of fresh tubers harvested at 330 DAP, and those for peanuts were TDB , weight of dry pods (WDP) and grains (WDG) and N uptake. N-uptake was determined by multiplying the TDB with N concentration in plant tissue at 60 DAP. The effects of treatments on soil and agronomics parameters were analyzed using ANOVA, and significance was tested by Fischer's least significant difference (p=0,05) using Minitab program version 18.

3. RESULTS

3.1. Soil chemical characteristics.

Table 1 shows that the addition of biochar + fresh organic matter based soil amendments had no significant effect on pH, K, and Mg, but affected concentration of SOC, total N, P, Ca and CEC. These parameters were higher in the amended group than those in the control. Meanwhile, total N in B2 plot was higher than that in the control and was similar to those in B1, B3 and B4 plots.

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3.2. Soil aggregate stability.

Soil aggregates stability in unit percent (%) was evaluated using MWD values (Sun & Lu, 2014). As shown in Fig. 1, the soil aggregate stability was 59.24, 59.33, 58.21, and 58.95 (% MWD) for B1, B2, B3 and B4 plots respectively. These values were significantly higher than the 56.59% MWD of no-amendment plot (B0). No significant difference in soil aggregate stability was observed among the plots under the four amendments.

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3.3. Growth and yields of cassava and peanuts.

The biochar-based organic amendments had a significant effect on the growth and yield of cassava as the first crop and peanuts as the secondary crop (Table 2). The TDB of cassava increased significantly by 16% in B1 plot and 20% in B2, B3, and B4 plots relative to that in the control. No significant difference in harvested biomass was observed among the plots under the four amendments. However, tuber yield under all treatments significantly differed from that in the control (18.53 ton

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1. INTRODUCTION

Indonesia has a great opportunity to increase its production of cassava and peanuts by optimizing and developing sustainable agriculture practices in the dryland area. However, sustainable agriculture in dry land, particularly on sandy soils, generally faces large constraints due to low nutrient retention capacity and soil organic matter depletion (Sukartono, 2011). West Nusa Tenggara, located in the eastern part of Indonesia, has potential dry lands of about 1,807,463 ha; of which, 335, 136 ha is relatively suitable for agriculture and about 38,000 ha is located in North Lombok (Sukartono, 2011). This area is favorable for food crops such as cassava, peanuts, and maize. Soils in this area are dominated by entisols, which are predominately formed from volcanic ash materials derived from the Mount Rinjani eruption. The characteristics of the soils are as follows: light texture with a sand fraction of more than 50%, poor soil structure, low soil organic C (SOC) content, infertility, and low water retention (Sukartono et al., 2013).

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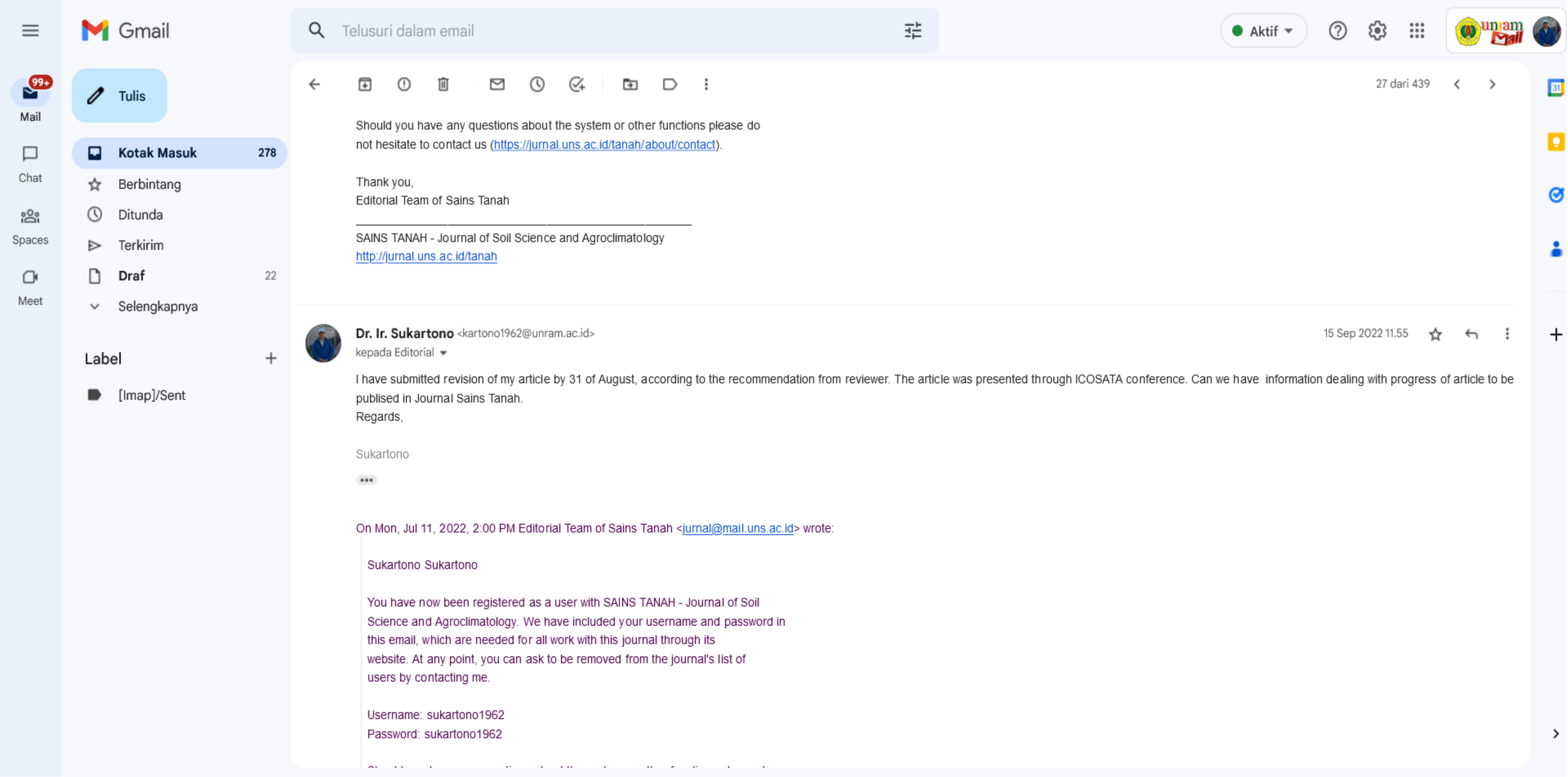

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Notify Editor	Editor/Author Email Record 2022-12-01		
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Author Version	65452-186906-1-ED.docx	2022-11-07	Delete
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Dear Sukartono:

We have reached a decision regarding your submission to SAINS TANAH - Journal of Soil Science and Agroclimatology, "The influence of biochar-based organic amendments on changes in soil quality of sandy loam soils under cropping sequence of cassava-peanut in the tropical-semi-arid of northern Lombok, Indonesia".

Our decision is: Revisions Required (due date is November 07, 2022)

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Reviewer A:

50 dari 372

Revision Sukartono Article

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Dr. Ir. Sukartono <kartono1962@unram.ac.id>
kepada Komariah

Rab, 26 Okt 2022, 20.19

Dear editor, Thanks very much for sending me the revision article from reviewer. I am going to make great revision as recommended by reviewer and I should resubmit before 7 of Nov. I would like to ask whether you have proof reading services. I am happy to spent compensation fee for the proof reading if possible. I am trying hard to revise very soon.
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J. Soil Sci. & Agric <sainstanah@mail.uns.ac.id>
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Dr. Ir. Sukartono <kartono1962@unram.ac.id>
kepada Soil

Jum, 28 Okt 2022, 07.48

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Salam

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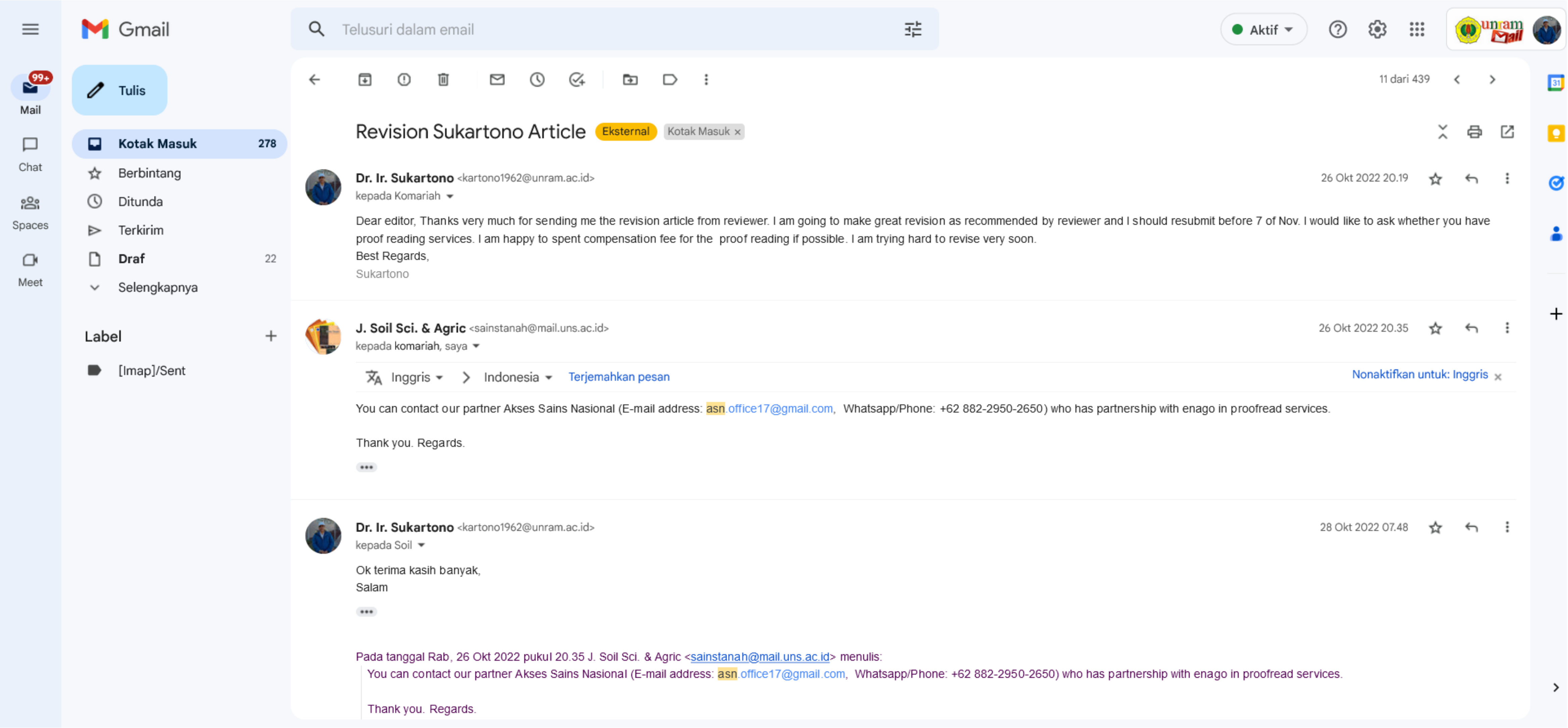

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Dear Editor,
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Sukartono

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17 Nov 2022 09.23

Dear Editor Jurnal Sains Tanah

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I also have submitted the article to the web of sains tanah journal.
Wassalam

Author
Sukartono

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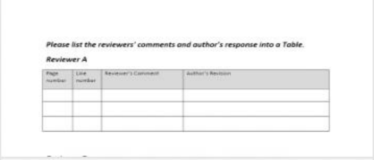

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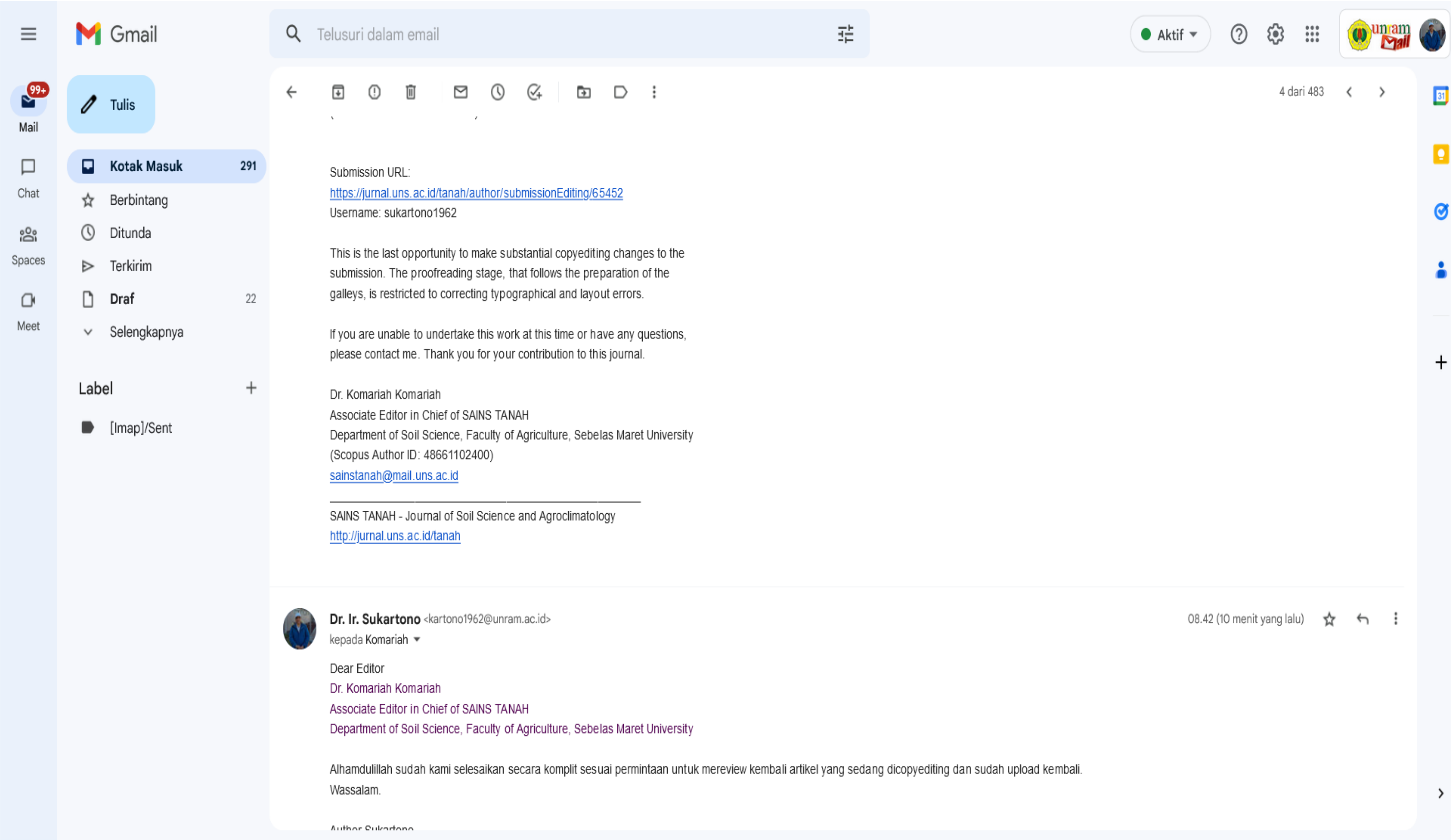
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If you are unable to undertake this work at this time or have any questions, please contact me. Thank you for your contribution to this journal.

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Dr. Ir. Sukartono <kartono1962@unram.ac.id> 08.42 (10 menit yang lalu)
kepada Komariah

Dear Editor
Dr. Komariah Komariah
Associate Editor in Chief of SAINS TANAH
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Alhamdulillah sudah kami selesaikan secara komplit sesuai permintaan untuk mereview kembali artikel yang sedang dicopyediting dan sudah upload kembali.
Wassalam.

Author Sukartono

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Dear Dr. Sukartono:

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Dr. Komariah
Associate Editor in Chief of SAINS TANAH
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Dr. Ir. Sukartono <kartono1962@unram.ac.id>
kepada Komariah
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Matur nuwun bu Dr. Komariah atas perhatian dan kerjasamanya
Salam hormat

Sukartono

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Influence of biochar amendments on the soil quality indicators of sandy loam soils under cassava–peanut cropping sequence in the semi-arid tropics of Northern Lombok, Indonesia

Sukartono*, Bambang Hari Kusumo, Suwardji, Arifin Aria Bakti, Mahrup, Lolita Endang Susilowati, Fahrudin

Department of Soil Science, Faculty of Agriculture, University of Mataram, Indonesia

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Email address:
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ABSTRACT

Low nutrient retention and soil organic matter depletion are the major challenges of the cropping system in the sandy loam soils of Northern Lombok, Indonesia. A field experiment was conducted to evaluate the influence of biochar-based organic amendments on the soil quality of sandy loam soils under cassava (*Manihot esculenta*, Crantz)–peanut (*Arachis hypogaea* L.) cropping sequence. The treatments were as follows: biochar (10 ton ha^{-1}) and rice straw (3 ton ha^{-1}) (B1); biochar (10 ton ha^{-1}), cattle manure (10 ton ha^{-1}), and rice straw (3 ton ha^{-1}) (B2); biochar (10 ton ha^{-1}) and cattle manure (10 ton ha^{-1}) (B3); biochar (10 ton ha^{-1}) and cattle manure (10 ton ha^{-1}) plus rice straw mulch (3 ton ha^{-1}) applied on surface soils (B4), and without organic amendments (B0) as control. Results showed that the biochar-based organic amendments significantly improved several soil quality indicators such as SOC, total N, available P, Ca, cation-exchange capacity (CEC), and aggregate stability but had no significant effect on pH, K, and Mg. Improvement in soil quality was strongly indicated by an increase in the growth and yield of cassava and peanuts. Treatments B1, B2, B3, and B4 generally had a comparable effect on soil parameters and tended to improve the growth and yield of cassava and peanuts. Cassava was responsive to treatments B2 (biochar, cattle manure, and rice straw) and B3 (biochar and cattle manure) with its actual yield of 27 tons ha^{-1}, which is a 40% increase compared with that in the control. As a secondary crop growing after cassava, peanuts also exhibited higher yields in all amended plots compared with that in the control. The highest yield was obtained in B2 (1.38 ton ha^{-1}), followed by B4 (1.36 ton ha^{-1}), B1 (1.33 ton ha^{-1}), and B3 (1.25 ton ha^{-1}). In conclusion, the incorporation of biochar, cattle manure, and crop residues (rice straw) into soils is a promising option to maintain soil quality and sustainably produce cassava and peanuts in the sandy loam soils of the semi-arid tropics of Lombok, Indonesia.

How to Cite: Sukartono., Kusumo, B H., Suwardji., Bakti, A A., Mahrup., Susilowati, L E., Fahrudin. (2022). Influence of biochar amendments on the soil quality indicators of sandy loam soils under cassava–peanut cropping sequence in the semi-arid tropics of Northern Lombok, Indonesia. Sains Tanah Journal of Soil Science and Agroclimatology, 19(2): 205-210. https://dx.doi.org/10.20961/stjssa.v19i2.65452

1. INTRODUCTION

Indonesia has a great opportunity to increase its production of cassava and peanuts by optimizing and developing sustainable agriculture practices in the dryland area. However, sustainable agriculture in dry land, particularly on sandy soils, generally faces large constraints due to low nutrient retention capacity and soil organic matter depletion (Sukartono, 2011). West Nusa Tenggara, located in the eastern part of Indonesia, has potential dry lands of about 1,807,463 ha; of which, 335, 136 ha is relatively suitable for agriculture and about 38,000 ha is located in North Lombok (Sukartono, 2011). This area is favorable for food crops such as cassava, peanuts, and maize. Soils in this area are dominated by entisols, which are predominately formed from volcanic ash materials derived from the Mount Rinjani eruption. The characteristics of the soils are as follows: light texture with a sand fraction of more than 50%, poor soil structure, low soil organic C (SOC) content, infertility, and low water retention (Sukartono et al., 2013).

Traditional farmers in the dry land of North Lombok commonly grow cassava as the first crop in early wet season,

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