International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 10, No. 4, p. 1-8, 2017

RESEARCH PAPER OPEN ACCESS

# Utilization of corn stover and pruned *Gliricidia sepium* biochars as soil conditioner to improve carbon sequestration, soil nutrients and maize production at dry land farming in Timor, Indonesia

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**Article published on April 16, 2017**

**Key words:** Biochars, Soil organic carbon, Soil nutrient, Maize production

## Abstract

The decreasing of land productivity for dryland farming system is mainly due to lack of soil organic carbon (SOC). Carbon sequestration ($C_{-seq}$) became a main issue for reducing carbon emission that affect to environment. Application of compost and biochar have proven to become a good solution for increasing soil quality and carbon storage. This research had been conducted in Timor-East Nusa Tenggara Indonesia, aims to understand the effectiveness of biochar as soil amelioration on C-sequestration, soil nutrients and maize production. Split plot factorial design (type and dosage of biochars) with three replications was used to test the hypotheses. The type of biochars were cow dung (CD), rice husks (RH), pruned *G. sepium* (GS) and corn stover (CS) and three levels of dosage (D1: 3 $t.ha^{-1}$; D2: 6 $ton.ha^{-1}$; and D3: 9 $t.ha^{-1}$ ). The results showed that the GS provided the best effect on the increasing of SOC (2.09%), soil nutrient ($N_{tot}$ 0.22%; P-available 11.34 ppm; K 0.62 me/100g soil), and other soil properties (CEC 28.10 me/10 g soil and reducing bulk density to 1.10 $cm^{-3}$). It means GS could provide about 68.64 $ton.ha^{-1}$ $C_{seq}$ that still remained in the soil for the next cro GS or long time utilizations. Not only long term, this study also suggested that GS benefited for maize production (maize gain 5.88 t $ha^{-1}$) at short term application. Although statically GS gave similar performance to MS but they are better than other tested biochars. As other previous studies, increasing the dosage of organic matter might affect to the increasing of soil quality and crop production.

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## Introduction

The development of dry land area as one of the potential assets in agricultural growth should be led to meet the growing food needs. In fact, the potential existence of dry land is not only high but also competitive and comparative in advantage while the productivity in dry land is relatively lower than in the wet lands. It is due to the high degradation in dry land as the result of no rules of soil conservation met in the conventional farming practices.

Optimizing use of degraded dry landfor providing food requirements needs to be preceded by rehabilitation of land to increase soil quality. The soil quality meant here is the function of land in natural or managed ecosystems to support crops productivity besides water and air quality, and to maintain environment and human life (Karlen *et al.*, 1997). The use of natural materials, such as latex, soil conditioner, manure/compost, *Flemingia congesta* biomass, and crop remaining is temporal in effect. Furthermore, the use of organic materials, such as manure and crop remaining, requires quite high doses of 15 to 30 t $ha^{-1}$ manure (Kurnia, 1996) and 20 to 25 t $ha^{-1}$ biomass *Flemingia congesta* (Nurida, 2006). By implication, it not only takes a sizeable number but also is often difficult to procure. Therefore, soil conditioner materials that are difficult to decompose and survive in the soil are required.

One of the materials meeting the quality is biochar. Biochars is a rich-carbon solid material converting from biomass through pyrolysis. Biochar is more resistant to weathering than the decomposed organic materials so it is able to restore the degradation of agricultural dry land. Moreover, the use of organic materials as biochar may support the conservation of soil carbon (Glaser *et al.*, 2002).

The materials that are difficult to decompose, such as agricultural wastes, are easily obtainable and potential as soil conditioners. However, in practice, an intermediary process is required such as incomplete combustion (phyrolysis) to provide charcoal (biochar) which is applicable to the soil.

In East Nusa Tenggara, the use of biochar is quiet potential due to the availability of agricultural wastes, such as rice husks, pruned plants, livestock manure, and crop yield wastes. During this time, the agricultural wastes have not been used optimally. As the materials are convertible in to biochars, it may not only increase the productivity of land but also survive in the soil besides reduce emissions because those materials do not quickly disappear through decomposition.

The provision of biochars to the agricultural soil will provide considerable benefits, for example, improving soil structure, holding water and soil from erosion because of the greater surface area, enriching organic carbon in the soil, and improving soil pH that the production of plants are able to increase indirectly (Ismail *et al.*, 2011). Chan *et al.*, (2007) stated that application of biochar might improve C-organic, pH, structure, and CEC of soil as well as soil-water-storage capacity. Consequently, the degraded agricultural land requires innovation through conditioner soil materials to increase the productivity and quality of dry land. The study aimed to determine the effect of biochar made of various agricultural wastes as natural soil conditioners to improve the productivity of dry land.

## Materials and methods

*Site description*

The study was conducted in the Oesao Garden Field Station of Kupang State Agricultural Polytechnic, East Kupang District, Kupang Regency, East Nusa Tenggara Province, Indonesia. The preliminary qualities of soil in the site of study are performed in Table 1.

*Chemical composition of biochars*

For the biochar-making, the raw materials were dried cow dungs that is not mixed with soil; rice husks obtained from rice milling wastes, pruned *G. sepium* derived from the fresh leaves and twigs, and corn stover obtained from corn yield wastes after harvesting. The fourth type of agricultural waste biochars is produced using a modified phyrolysis apparatus, that is a simple drum tube with a combustion temperature of 300-350°C, based on the instructions of Lehman *et al.* (2006). The preliminary chemical quality of biochar using in this study are presented in Table 2.

*Research design*

The study was conducted using factorial split plot design, in three replications. The main plots were four types of biochars i.e. cattle dungs, rice husks, pruned *G. sepium*, and corn stover biochars. As the subplots, there were three doses of biocharsi.e.3 tha$^{-1}$, 6 t ha$^{-1}$, and 9 tha$^{-1}$ of biochars.

As an indicator plant, there corn was used. The parameters were soil quality changes and yields of corn. The quality of soil were measured by bulk density, total pore spaces, pH ($H_2O$ 1:1) (potentiometer method), C-organic (Walkey & Black), N-total (Kjeldahl method), P-available (Bray I/II), K-exchangeable (HCl extracted and read by Flame photometer), and CEC ($NH_4OAc$ 1 N pH 7) of soil. While, yields of corn were by measuring dried seed-weight (ton ha$^{-1}$) and dried stover-weight (ton ha$^{-1}$). Those parameters were measured on the set tile-plots. Soil organic carbon storage (SOCS) was calculated using the equation of Shofiyati *et al.,* 2010; Komatsuzaki and Syuaib, 2010): SOCS (Mg ha$^{-1}$) = BD × SOC ×DP × A,

where BD is soil bulk density (Mg cm$^{-3}$); SOC is soil organic carbon content (%); DP is soil depth (m); A is area (ha).

*Statistical analyses*

This study used one way randomized block design for statistical analysis. Data were transformed using log 10 when necessary using COSTAT and MSTATC computer softwares. The means of each trait were compared according to Least significant difference at 5% (Gomez and Gomez, 1984). Figures were drawn using Excel software.

## Results and discussion

*Soil organic carbon (SOC)*

Soil organic Carbon is a main indicator for soil quality. This study suggested that biochars from waste agriculture have presented significant contribution to the increasing of SOC level. As Table 3 showed that biochars GS and CS gave similar effect on SOC but significantly higher than the other biochars tested in this study. They could increase about 30.77-33.97% SOC level in the soil (from 1.56% became 2.04 – 2.09%) that are remaining in the soil. On the other hand, CD increased only 16.03% and RH 1.92% of SOC. For dosage of bichars, the increasing of dosage had significantly improved the level of SOC to 2.51% of B3.

**Table 1.** The preliminary quality of soil in the site of study.

| Quality of soil | Value | Description |
|---|---|---|
| Soil texture | 72.74% clay, 18.35%dust,and 8.91% sand | Clay |
| pH ($H_2O$) | 7.35 | Neutral |
| C-organic | 1.56% | Low |
| N-total | 0.16% | Low |
| P-available(Bray 1) | 6.55 ppm | Low |
| K-Cations | 0.4 me/100 g | Moderate |
| CEC | 19.84 me/100 g | Moderate |

Source: Results of laboratory analysis (Rupa *et al.*, 2015).

In this study biochar GS and CS were the better type of biochars because of they have high compound of organic carbon (Table 2) and have highly resistance of decomposition and slowly release of nutrients to the soil.

As previous studies suggested that biochar has aromatic compound and recalcitrant, which presented stable C in the soil for log time period (Glaser *et al.*, (2003) and Hammond *et al.*, (2007).

*Bulk density and porosity of the soil*

Utilization of biochar from waste agriculture had significantly reduced bulk density (BD) but increased porosity of soil at 0-20 cm soil depth. As previous study suggested that biochars were able to reduce BD of soil up to 0.9 $g.cc^{-1}$ (Aslam *et al*, 2014), this study showed that biochar GS had reduced BD 15.47% while CD and CS reduced 14.41% lower than RH only 6% decreasing (Table 3). The reducing of BD due to the increasing of organic matter returned to the soil from organic residues at 0-20 cm soil depth and varied for the types.

**Table 2.** The preliminary chemical quality of biochar.

| Parameters | Agricultural waste Biochars | | | |
|---|---|---|---|---|
| | CD: cow dung | RH: rice husks | GS: pruned *G. sepium* | CS: corn stover |
| Ph | 9.30 | 9.3 | 9.10 | 9.3 |
| C-Organic (%) | 9.90 | 6.68 | 12.68 | 13.65 |
| Humic acid (%) | 0.48 | - | 1.8 | 1.08 |
| Fulvic acid(%) | 0.47 | 0.05 | 2.55 | 1.86 |
| C/N | 15 | 13 | 7 | 14 |
| N (%) | 0.64 | 0.67 | 1.79 | 0.96 |
| P (%) | 0.6 | 0.33 | 21.0.50 | 0.24 |
| K (%) | 2.88 | 2.60 | 0.27 | 0.24 |
| CEC (Me/100 g) | 21.81 | 17.46 | 56.11 | 53.11 |

Source: Results of laboratory analysis (Rupa *et al.*, 2015).

The reducing of BD affected to total soil porosity (SP). The CD, GS, CS have high organic C that consist of humic and fulvic acids might affect to improve soil structure. Aromatic compound persist in SOC would able to build organic mineral and affect to construct soil aggregation. Stability of SOC was assumed to be affect to the composition of soil fractions and end up with the improvement of BD and SP. As suggested by Laird *et al* (2010) that organic carbon used as an amelioration material would able to improve physical properties of soil. As well Wolf (2008) found that organic acid may create organic mineral that could build better soil aggregation and enhance other functional compound to the soil.

**Table 3.** Soil organic carbon (SOC), bulk density, total porosity, total N, available- P, K-exchangeable and Conductivity Electric Capacity (CEC) at influence on the types and dosage of agricultural waste biochars after harvesting corn.

| Single Factor Treatment | SOC. (%) | Bulk Density (g $cm^{-3}$) | Total porosity (%) | Total N (%) | Available-P (ppm) | K-exchangeable (me/100g) | CEC (me/100 g soil |
|---|---|---|---|---|---|---|---|
| Types of biochar: | | | | | | | |
| CD: cow dung | $1.81^{ab}$ | $1.11^{a}$ | $58.03^{b}$ | $0.15^{b}$ | $9.18^{b}$ | $0.53^{b}$ | $23.34^{b}$ |
| RH: rice husks | $1.59^{b}$ | $1.21^{b}$ | $53.38^{a}$ | $0.13^{c}$ | $8.64^{b}$ | $0.45^{c}$ | $19.92^{c}$ |
| GS: *G. sepium* | $2.09^{a}$ | $1.10^{a}$ | $58.31^{b}$ | $0.22^{a}$ | $11.34^{a}$ | $0.62^{a}$ | $28.10^{a}$ |
| CS: corn stover | $2.04^{a}$ | $1.11^{a}$ | $58.05^{b}$ | $0.21^{a}$ | $11.19^{a}$ | $0.59^{a}$ | $27.91^{a}$ |
| Dose of biochar: | | | | | | | |
| B1: 3-t $ha^{-1}$ | $1.65^{b}$ | $1.18^{b}$ | $55.50^{b}$ | $0.15^{b}$ | $8.75^{b}$ | 0.43a | $22.42^{a}$ |
| B2: 6-t $ha^{-1}$ | $1.90^{a}$ | $1.14^{a}$ | $57.07^{a}$ | $0.18^{a}$ | $10.05^{a}$ | $0.55^{a}$ | $24.13^{a}$ |
| B3: 9-t $ha^{-1}$ | $2.10^{a}$ | $1.09^{a}$ | $59.02^{a}$ | $0.19^{a}$ | $11.46^{a}$ | $0.66^{a}$ | $27.90^{a}$ |

Notes: Values followed by the same letter in the same columns and factors are not significantly different at 5% Duncan Multiple Range Test.

Biochar with dosage 3-9 $t.ha^{-1}$ had provided significant effect to inherent physical soil improvement. Dosage 9 $t.ha^{-1}$ of biochar would able to reduce BD up to 8.47% and SP 6.34%. Changes of physical soil indicated that there was increasing of organic compound (organic acids) in the soil from those biochars. This indicated that the dray land soils that used in this study still need organic matter amendment from biochar to change inherent soil in-situ that dominated by clay fraction (Table 1).

*Total N, Available P, K-exchangeable and Conductivity Electric Capacity (CEC)*

Biochar GS had significantly increased $N_{tot}$ (37.5%) similar to CS (31.25%) while other biochars CD and RH were not significant different (Table 3). As well as inorganic phosphorus ($P_{inorg}$), $K_{exc}$ and CEC showed significantly high.

Overall, GS and CS have higher nutrients left in the soil after harvesting than CD and RH. Dosage 9 t.ha$^{-1}$ significantly increased also soil N 26.67%. It can be assumed that GS and CS became good source and sink for soil nutrient due to high compound of organic minerals, humic and fulvic acids, and also stable for long time.

**Table 4.** The Effect of a single factor of types and doses of agricultural waste biochars to the maize yields.

| Single factor treatment | Weight of dry maize grain (t ha$^{-1}$) | Plant dry weight (t ha$^{-1}$) |
|---|---|---|
| Types of biochar | | |
| CD: biochar cow dung | 5.56$^{b}$ | 8.04$^{b}$ |
| RH: biochar rice husks | 4.45$^{c}$ | 5.96$^{c}$ |
| GS: pruned G. sepium biochar | 5.79$^{a}$ | 9.70$^{a}$ |
| CS: corn stover | 5.88$^{a}$ | 9.89$^{a}$ |
| Dose of biochar | | |
| B1: 3 t ha$^{-1}$ | 4.88$^{c}$ | 7.80$^{b}$ |
| B2: 6 t ha$^{-1}$ | 5.46$^{b}$ | 8.40$^{a}$ |
| B3: 9 t ha$^{-1}$ | 5.93$^{a}$ | 8.89$^{a}$ |

Notes: Values followed by the same letter in the same and the same factor are not significantly different at 5%Duncan Multiple Range Test.

The positive impact of biochar as soil amelioration were soil buffering for leaching effect on soil nutrients and CEC system. Wolf (2008) recommended that biochar not only consists of stable organic C, also has numbers of organic compounds (organic acids) that could release soil nutrients. $P_{inorg}$ could be released from amorf fraction (alofan) due to the increasing of organic acids in biochar, so that available P will be increase. As suggested by Hastuti (2003), mineralization of organic matter produced humic and fulvic acids which could release P bounded at mineral soils to become available for plant uptake.

*Soil Organic Carbon Sequestration*

Soil organic carbon (SOC) storage has been widely considered as a measure for mitigating global climate change through C sequestration in soils (Huang *et al.*, 2010). In this study, the highest C storage in the soil was performed by biochar of GS about 68.64 t.ha$^{-1}$ at 30 cm soil depth. It was similar to biochar CS (67.93 t.ha$^{-1}$) however, they were higher than biochar of CD (60. t.ha$^{-1}$) and RH (57.21 t.ha$^{-1}$) (Figure 1).

Meanwhile, the dosage of biochars affected also to C storage in which it increased 21.06% (up to 68.04 t.ha$^{-1}$) compare to initial C storage (56.08 t.ha$^{-1}$).

Soil properties like BD, CEC, soil texture, and aggregation of soil (Brokers and Perry, 1992) determined the increasing of soil C storage. The lower the BD and the depth the soil, affected to the increasing of C storage in the soil although varied among type of organic matter. As this study showed the maximum C storage about 68.64 t.ha$^{-1}$ but other study Diare *et al* (2015) found it could be obtained up to 81.35 t.ha$^{-1}$. This was due to repeat application of organic matter.

*Maize yields*

The effect of agricultural waste biochars as soil conditioners on maize yields in the vertisol soil is presented in Table 4. The maize yields in various types and doses of biochar were significant. The CS and GS biochars were significantly increased maize yields higher than the CD and RH (the lowest).CS and GS biochars significantly increased dried seed-weight by 31.46%, higher than that in RH biochar (from 4.45 t $ha^{-1}$ to 5.58 t $ha^{-1}$) and dried straw-weight by 64.34% (from 5.96 t $ha^{-1}$ to 9.79 t $ha^{-1}$).

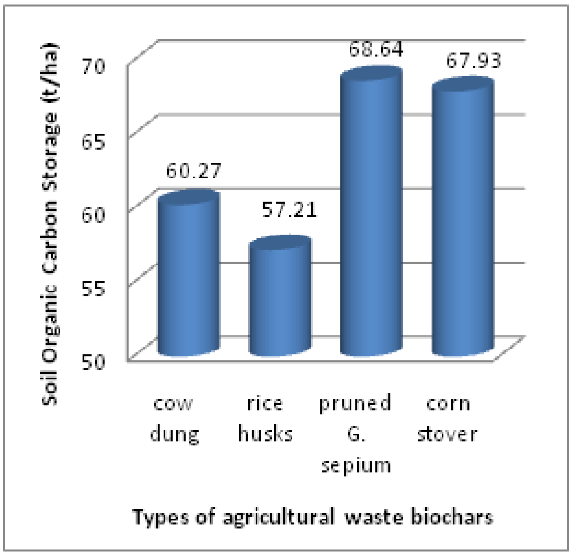


**Fig. 1.** The soil carbon organic storage (SOCS) at a depth of 0-30 cm from application of biochar types.

All three doses of biochars treated also significantly increased the yield of maize. Increasing doses of biochar from 3 to 9 t $ha^{-1}$ significantly increased maize yields of both dried seed-weight (21.52%) and dried straw-weight (23.97%). This is apparently due to the use of biochar dose of 9 t $ha^{-1}$ that can meet the physical and chemical soil fertility before meeting the nutrient needs of plants.

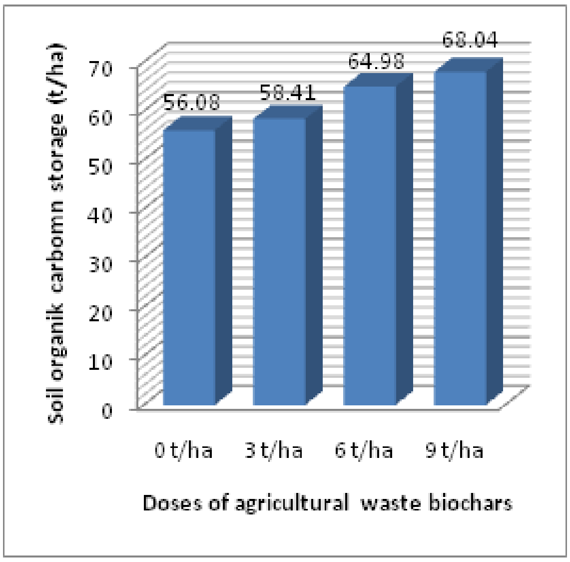


**Fig. 2.** The soil carbon organic storage (SOCS) at a depth of 0-30 cm due to dosing biochar.

The increased maize yields in the soil treated by CS and GS biochars may be caused by the existence of chemical characteristics in the both biochars. The results of laboratory analysis (Table 2) showed that the content of C-organic besides humic and fulvic acids on the both biochars is higher than those in cow dung and rice husk biochars.

The high organic acids contained in biochar can be boundless essential nutrients for plant needs. Biochars also works as an amendment (conditioner) soil materials that can improve the adoption of nutrients in soil so even without the addition of chemical inputs from the outside, such as inorganic fertilizers, biochars can increase dried weight of plant.

Topoliantz *et al*,. (2007) and Widowati *et al.*, (2012) stated that biochars produced through pyrolysis are potential as amendment material to maintain the continuity of soil fertility and productivity in the tropics. Furthermore, Bot and Benites (2005) suggested that humic and fulvic acids derived from pyrolysis of organic materials is more resistant to degradation than those from the decomposition of organic materials are.

## Conclusion

The chemical characteristics in GS and CS biochars were higher than those in CD and RH biochars that are eligible as a soil conditioner to recover the degraded soil. The improved physical and chemical quality of soil treated by GS and CS biochars were higher than treated by CD and RH biochars.

The GS and CS biochars were significantly higher to increase dried seed-weight (31.46%) and dried straw-weight of maize (64.34%) than the RH biochar. The doses of biochars from 3 $tha^{-1}$ to 9 $tha^{-1}$ significantly increased the dried seed-weight of maize by 21.52% and dried straw-weight of maize by 23.97%.

## Acknowledgement

We acknowledge to the Directorate General of Strengthening Research and Development through the Directorate of Research and Community Service, the Ministry of Research Technology and Higher Education, for providing funds of competitive grants research, during 2015 and 2016.

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