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Pandu Yudha Adi Putra Wirabuana <pandu.yudha.a.p@ugm.ac.id>

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Syamsu Alam, Sahta Ginting, Muhammad Tufaila Hemon, Sitti Leomo, Pandu Yudha Adi Putra Wirabuana

Address

(Fill in your institution's name and address, your personal cellular phone and email)

Department of Forest Management, Faculty of Forestry, Universitas Gadjah Mada
Jln. Agro No. 1 Bulaksumur, Yogyakarta 55281, Indonesia
Phone. +6281226887738
E-mail. pandu.yudha.a.p@ugm.ac.id

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This study found the soil quality among land covers differed significantly in exchangeable potassium and cation exchange capacity. A similar trend was also observed in total carbon storage wherein the highest mean carbon storage was recorded in Forests (150.50±27.79 t ha^{-1}), followed by Shrubs (52.50±15.02 t ha^{-1}) and Savanna (45.97±4.42 t ha^{-1}). Our study noted there were three important soil attributes that significantly correlated to carbon storage, namely soil acidity, available phosphorus, and cation exchange capacity. Total carbon storage gradually declined with the increasing soil acidity while higher available phosphorus and cation exchange capacity increased total carbon stock. Our study also realized that the existence of vegetation aboveground played important contribution in improving total carbon storage at the study site.

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Soil quality and carbon storage at different land covers in Moramo Education Estate, Southeast Sulawesi

SYAMSU ALAM[1], SAHTA GINTING[1], MUHAMMAD TUFAILA HEMON[1], SITTI LEOMO[1], PANDU YUDHA ADI PUTRA WIRABUANA[2,♥]
[1]Department of Soil Science, Faculty of Agriculture, Universitas Halu Oleo, Jln. HEA Mokodompit, Kendari 93231, Southeast Sulawesi, Indonesia
[2]Department of Forest Management, Faculty of Forestry, Universitas Gadjah Mada, Jln. Agro No.1 Bulaksumur, Yogyakarta 55281, Indonesia
Tel./Fax.: +62-274-548815, ♥email: pandu.yudha.a.p@ugm.ac.id

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Abstract. This study investigated the influence of different land covers on soil quality and carbon storage in Moramo Education Estate. The information is required as fundamental consideration to determine the best landscape management strategies for supporting soil conservation and climate change mitigation. Data were collected from three types of land cover that are generally found in this area, including forests, shrubs, and Savanna. Three permanent sampling plots were randomly placed in every land cover as replicates with a size of 20 m x 20 m. Six parameters were used to describe soil quality, i.e., soil acidity, soil organic carbon, total nitrogen, available phosphorus, exchangeable potassium, and cation exchange capacity. Meanwhile, the carbon storage from every plot was quantified at below and aboveground conditions. Comparison mean of soil quality and carbon storage among land covers were examined using analysis of variance and followed by honestly significant Tukey's. Pearson correlation analysis was also applied to evaluate the relationship between soil quality and carbon storage. The results found soil quality differed significantly in exchangeable potassium and cation exchange capacity. A similar trend was also demonstrated in carbon storage at aboveground conditions. The highest average carbon storage was recorded in Forests (150.50±27.79 t ha^{-1}), followed by Shrubs (52.50±15.02 t ha^{-1}) and Savanna (45.97±4.42 t ha^{-1}). Total carbon storage at different land covers significantly correlated to soil acidity, available phosphorus, and cation exchange capacity. Carbon storage improved along with the increasing available phosphorus and cation exchange capacity. In contrast, a negative correlation was noted in the relationship between carbon storage and soil acidity. Overall, this study concluded that the different land covers significantly influenced soil quality and carbon storage in Moramo Education Estate.

Keywords: climate change mitigation, land cover, landscape management, permanent sampling plot, soil conservation

Running title: Soil quality and carbon storage

INTRODUCTION

Soil conservation and climate change mitigation have become strategic issues in agriculture development (Amelung et al. 2020), particularly in tropical countries. The management of the agriculture sector is currently targeted to stabilize the food supply and provide an essential contribution to maintaining soil quality and reducing carbon emissions in the atmosphere (Castellini et al. 2021). To anticipate these challenges, the optimum scenario of agriculture development is necessary to accommodate the objective of environmental preservation and farm cultivation. This scheme is only possible to implement when land managers know the influence of land cover on soil quality and carbon storage. The statement is also supported by previous studies that record the soil quality and carbon storage principally vary in every land cover due to the interaction between soil and vegetation above it (Sugihara et al. 2014; Chandra et al. 2016; Sadono et al. 2021). For example, higher plant biomass is commonly found in good soil than in poor soil because the availability of nutrients in good soil is more sufficient to support plant growth (Bhandari and Zhang 2019). Meanwhile, higher biomass accumulation will generate more litterfall that becomes the input of organic matter into the soil (Giweta 2020). When the organic matter decomposes, the amount of nutrients will be released into the soil and improve fertility (Purwanto and Alam 2020). Therefore, the availability of information about soil quality and carbon storage is highly required by land managers as consideration materials to determine the land conversion strategies in agriculture development.

As one of the priority locations for integrated agriculture development in Southeast Sulawesi, Moramo Education Estate (MEE) is a special-purpose area with a natural ecosystem with three different land covers, including forests, shrubs, and Savanna. This area is planned to be managed as a research center and site experiment to support the innovation of good agriculture practices (GAP), such as nutrients management, pest and disease control, crop yield estimation, etc. However, this plan can decline the essential roles of MEE in ecological functions, especially related to the nutrients cycle and carbon absorption. Therefore, conducting a preliminary study about the soil quality variation and carbon storage distribution at different land covers in MEE is necessary. This information will help the farm managers determine the type of land cover that can convert into agricultural land. This effort is expected to minimize the negative impacts of land-use change on the functionality ecosystems of MEE.

Based on those explanations, this study aims to evaluate the influence of land cover on soil quality and carbon storage in the MEE area. The primary focus of research is to compare the soil fertility and carbon storage among land cover types and examine the connectivity between soil characteristics and carbon stock accumulation from three different land covers.

MATERIALS AND METHODS

Study area

This study was conducted in the MEE area located in South Konawe District, Southeast Sulawesi. The geographic position of this site is situated in E4°6'30"−4°7'30" and S122°35'0"−122°35'30" (Figure 1). Altitude ranges from 25 to 137 m above sea level. Topography is predominantly by hilly area with an 8−15% slope level. The average daily temperature is 27.6°C with a minimum of 23.1°C and a maximum of 32.2°C. Annual rainfall reaches 3,179.70 mm year^{-1} with an average air humidity of 81%. The dry period is relatively longer than two months and commonly occurs from September to October. The land cover of MEE is dominated by forests (70%), followed by Savanna (20%) and shrubs (10%).

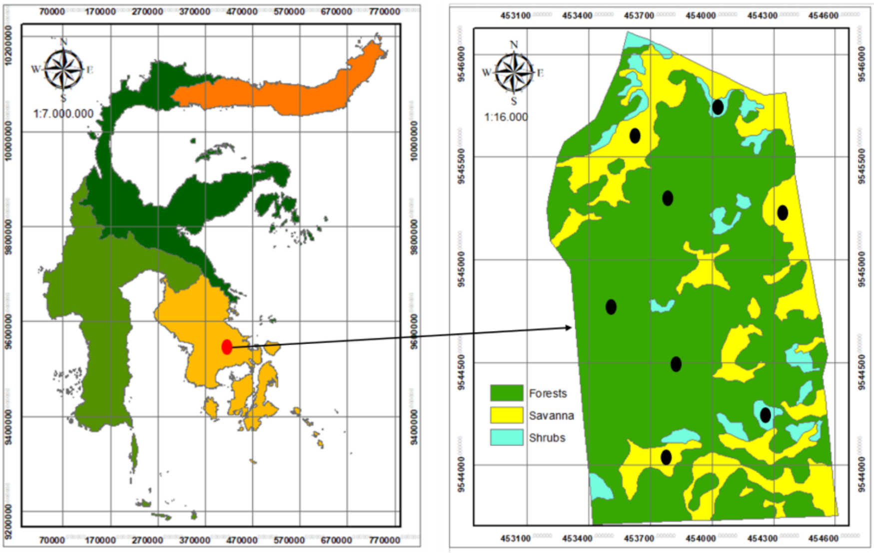

Figure 1. The study site of Moramo Education Estate in South Konawe. Black circles indicated sampling plots for data collection

Data Collection

The field survey was conducted by a stratified sampling method. The different land cover was assumed as the primary factor that caused the variation of soil quality and carbon storage. To facilitate the measurement activity, three permanent sampling plots were placed randomly in every land cover with a size of 20 m x 20 m (Grussu et al. 2016). The coordinate of each plot was also recorded using a global positioning system (GPS). It aimed to support long-term monitoring of soil quality and carbon storage dynamics at the study site. Then, the data collection process in every plot was divided into two steps, i.e., soil sampling and vegetation measurement.

Soil sampling was conducted from three different positions in every plot using ring samples with 8 cm in diameter and 10 cm in height. The soil sample was collected at a depth of 0−10 cm, 11−20 cm, 21−30 cm (Sadono et al. 2021a). Afterward, those samples were brought to the laboratory to determine their specific gravity, soil acidity, organic carbon, total nitrogen, available phosphorus, exchangeable potassium, and cation exchange capacity. The specific gravity was analyzed using the ASTM-D854 method, while soil acidity was determined by a pH meter. The determination of soil organic carbon was conducted using the Walkey and Black method, while total nitrogen was quantified using the Kjeldahl method. The HCl 25% extraction method was applied to quantify the available phosphorus and exchangeable potassium. Finally, cation exchange capacity was determined using the ammonium acetate method. The protocol of soil analysis was undertaken following the guidance of soil analysis published by (Estefan et al. 2013).

The measurement of vegetation was done using a nested method wherein every sampling plot was divided into several sub-plots to support the plant inventory based on their life stages, namely 1 m × 1 m (understorey), 2 m × 2 m (seedlings), 5 m × 5 m (saplings), 10 m × 10 m (poles), and 20 m × 20 m (trees) (Rambey et al. 2021). Several parameters were measured from the vegetation survey, including species, plant density, and diameter at breast height. However, the measurement of diameter was only implemented for pole and tree.

Carbon storage of vegetation in below and aboveground conditions was quantified using a conversion factor from biomass since approximately 50% biomass was composed of carbon elements (Latifah and Sulistiyono 2013; Taillardat et al. 2018; Wirabuana et al. 2020a). First, aboveground biomass in pole and tree was quantified using an allometric equation developed by Chave et al. (2005). Meanwhile, the root biomass of pole and tree was calculated using a conversion factor wherein a study recorded the ratio between root biomass and total aboveground biomass of 1:5 (Wirabuana et al. 2020b). Next, the biomass accumulation in understorey, seedlings, and saplings was measured using a destructive method. The harvesting process was carried out in every subplot. First, the fresh weight of each sample was measured using a hanging balance. Then approximately 500 g sub-sample was brought to the laboratory for drying using an oven at 70°C for 48 hours (Sadono et al. 2021b). Then, biomass was computed by multiplying the ratio of dry-fresh weight from the sub-sample with the total fresh weight. A similar method was also applied to quantify biomass in litter and necromass. In parallel, soil biomass was counted based on ring samples' relationship between its specific gravity and soil volumes estimated. Then, the result was multiplied by the soil organic carbon content to obtain the carbon stock in the soil. The measurement of soil carbon stock was done following the guidance published by Hairiah and Rahayu (2007). Total carbon storage in every land over was counted by summing carbon accumulation in soil, litter, necromass, and vegetation.

Table 1. Summary statistics of soil quality and carbon storage at different land covers

Land Use	Unit	pH	C-org (%)	TN (%)	Av-P (ppm)	Exc-K (meq 100g^{-1})	CEC (meq 100g^{-1})	AGC (t ha^{-1})	BGC (t ha^{-1})	TCS (t ha^{-1})
Savanna	Mean	4.54	1.44	0.14	4.38	0.16	10.3	6.07	39.90	45.97
	SD	0.29	0.52	0.03	1.05	0.06	1.22	1.45	2.97	4.42
	SE	0.12	0.21	0.01	0.43	0.03	0.50	0.84	1.71	2.55
	Min	4.16	0.88	0.10	3.39	0.09	8.62	4.40	36.70	41.10
	Max	4.92	2.06	0.19	6.03	0.27	11.7	7.00	42.50	49.50
Forests	Mean	4.25	1.64	0.15	5.11	0.30	13.2	114.00	36.50	150.50
	SD	0.47	0.75	0.05	2.62	0.06	2.01	18.00	9.79	27.79
	SE	0.19	0.31	0.02	1.07	0.02	0.82	10.39	5.65	16.04
	Min	3.30	0.98	0.12	2.37	0.24	10.8	96.60	29.60	126.20
	Max	4.50	3.06	0.24	9.07	0.37	16.4	132.00	47.70	179.70
Schrubs	Mean	4.65	1.59	0.13	3.28	0.26	11.3	14.10	38.40	52.50
	SD	0.19	0.53	0.03	1.79	0.09	1.64	9.33	5.69	15.02
	SE	0.08	0.22	0.01	0.73	0.04	0.67	5.39	3.29	8.67
	Min	4.28	0.93	0.10	1.26	0.14	9.94	7.50	32.10	39.60
	Max	4.81	2.29	0.17	6.40	0.39	14.2	24.80	43.10	67.90

Note: pH (soil acidity), C-org (soil organic carbon), TN (total nitrogen), Av-P (available phosphorus), Exc-K (Exchangeable potassium), CEC (cation exchange capacity), AGC (aboveground carbon storage), BGC (belowground carbon storage), TCS (total carbon storage), SD (standard deviation), SE (standard error), Min (minimum), Max (maximum).

Data analysis

Statistical analysis was processed using R software version 4.1.1 with a significant level of 5%. The agricolae package was selected to support the data analysis. A descriptive test was applied to quantify the data attributes, including minimum, maximum, mean, standard deviation, and standard error. The normality of data was examined using the Shapiro-Wilk test, while the homogeneity of variance was evaluated using Bartlet's test. Comparison means soil quality and carbon storage among three land covers were tested using one-way analysis of variance and followed by honestly significant Tukey's test. The study of Pearson correlation was also used to determine the critical soil parameters that correlated to carbon storage.

RESULTS AND DISCUSSION

Soil quality distribution

Soil quality among land covers was not significantly different in most parameters, except Exc-K (Figure 2). The highest average Exc-K was discovered in Forests (0.30±0.06 meq 100g^{-1}), followed by Shrubs (0.26±0.09 meq 100g^{-1}) and Savanna (0.16±0.06 meq 100g^{-1}). Interestingly, this study documented soil quality in Forests was slightly higher than other land covers for all parameters. It can be caused by dense vegetation that supplies more organic matter into soil through litterfall. In this context, more litterfall accumulation at aboveground can maintain land humidity that supports microorganism living (Sales et al. 2020).

Furthermore, many pieces of literature confirm the abundance of soil bacteria plays a significant contribution to accelerating the decomposition process (Jacoby et al. 2017; Grzyb et al. 2020; Miljaković et al. 2020). As a result, many nutrients will be released from litterfall to soil layers (Tang et al. 2013). This explanation indicates vegetation has a strategic position to improve soil quality since it correlated to the nutrients cycle. The concept of soil pedogenesis supports it, wherein organism, including vegetation, becomes one of the fundamental factors affecting on weathering process (Catoni et al. 2016). The results also implied the declining vegetation density from Forests to Savanna gradually decreased soil quality.

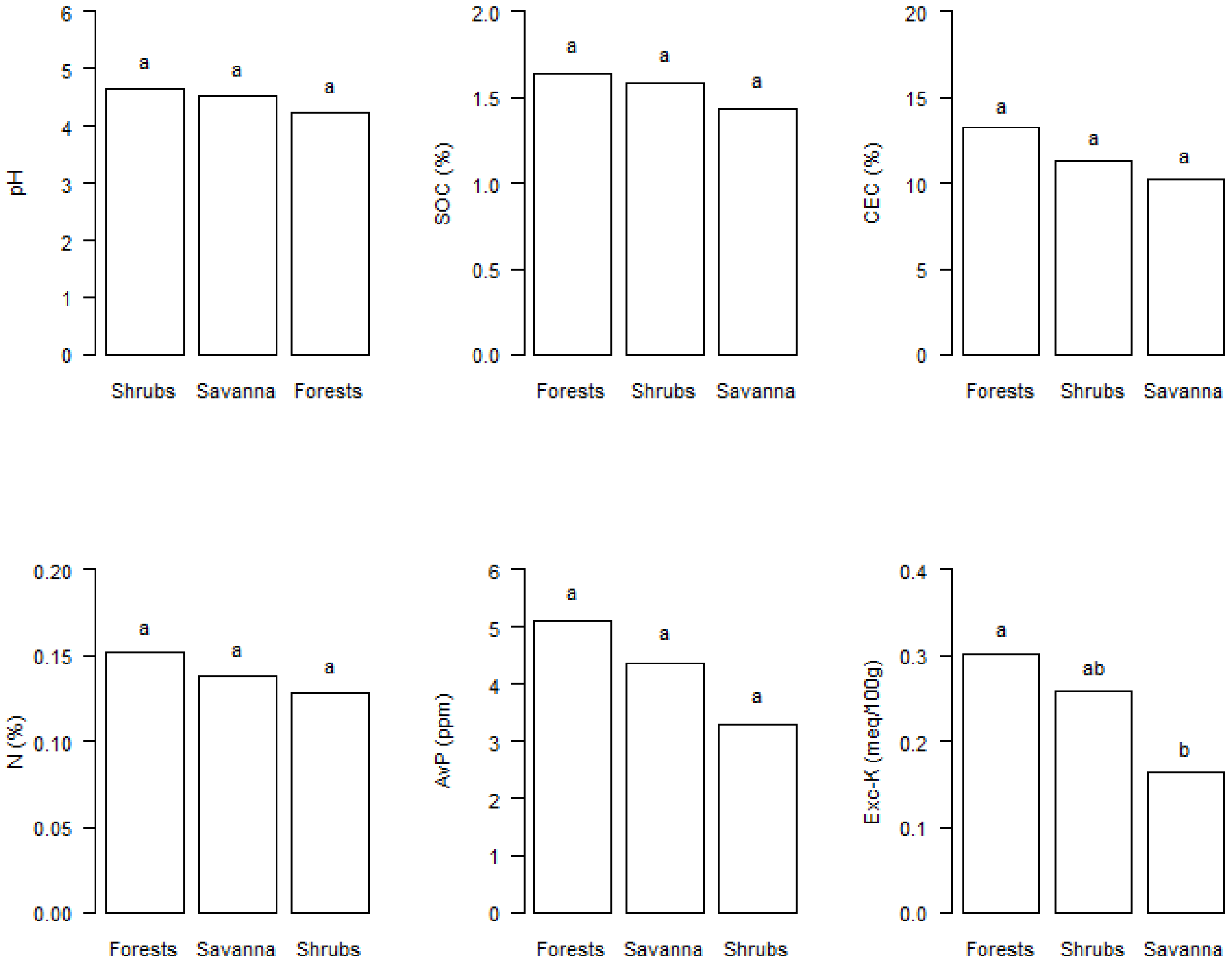

Figure 2. Comparison means soil quality among land covers. A similar letter above the bar graph indicated not a significantly different

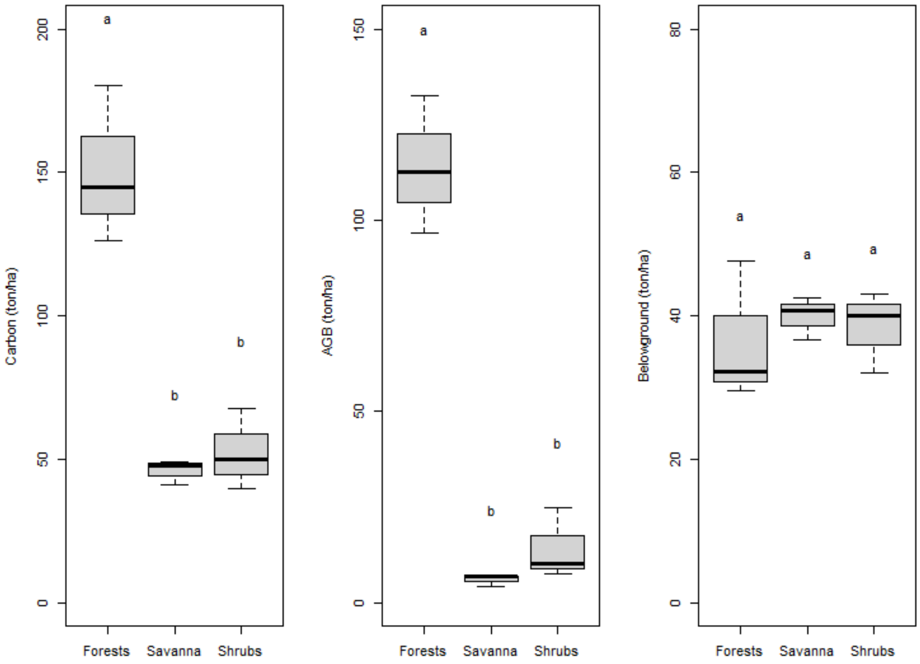

Figure 3. Comparison means carbon storage among land covers. A similar letter above the boxplot indicated not a significantly different

Carbon storage variation

Total carbon storage from three land covers was substantially different, wherein Forests had the highest carbon storage than other land covers by approximately 150.50±27.79 t ha^{-1} (Figure 3). It was almost four times higher than carbon stock in Shrubs and Savanna. Our study noted the most extensive accumulation of carbon stock in Forests occurred due to the vast contribution of vegetation aboveground. It was seen that the relative contribution of aboveground to total carbon storage in Forests is around 70% (Table 1). Meanwhile, there was no significant difference in belowground carbon among land covers. This outcome is not surprising since several publications have explained the essential role of vegetation in climate change mitigation (Setiahadi 2017; Matatula et al. 2021; Wirabuana et al. 2021). Furthermore, the higher dense canopy can absorb greenhouse gas emissions, particularly carbon dioxide (CO_2), which is more effective in photosynthesis than shrubs and grass (Xie et al. 2021).

Table 2. Pearson correlation analysis between soil parameters and carbon storage

Soil parameter	AGC		BGC		TCS	
	r	p-value	r	p-value	r	p-value
pH	-0.562	0.051^{ns}	-0.282	0.461^{ns}	-0.694	0.037*
C-org	0.398	0.287^{ns}	0.595	0.057^{ns}	0.477	0.193^{ns}
TN	0.488	0.181^{ns}	0.394	0.293^{ns}	0.533	0.138^{ns}
Av-P	0.525	0.071^{ns}	0.392	0.295^{ns}	0.670	0.048*
Exc-K	0.546	0.059^{ns}	-0.238	0.536^{ns}	0.619	0.075^{ns}
CEC	0.537	0.053^{ns}	0.218	0.571^{ns}	0.762	0.016*

Note: pH (soil acidity), C-org (soil organic carbon), TN (total nitrogen), Av-P (available phosphorus), Exc-K (Exchangeable potassium), CEC (cation exchange capacity), AGC (aboveground carbon storage), BGC (belowground carbon storage), TCS (total carbon storage), ^{ns} (non significant different), * (significant different).

Moreover, this study also recorded a significant correlation between soil characteristics and total carbon storage (Table 2). Three soil parameters significantly correlated to whole carbon storage, i.e., pH, Av-P, and CEC. However, the relationship among those parameters was relatively different. Total carbon storage improved along with the increasing Av-P and CEC. In contrast, a negative correlation was demonstrated in the relationship between carbon storage and pH. In general, the interaction between soil characteristics and total carbon storage in the landscape occurs because soil generally supplies nutrients for vegetation above it (Schjoerring et al., 2019). On another side, the life cycle of vegetation will provide the amount of litterfall and become organic matter inputs to soil (Sales et al. 2020). pH showed a negative correlation to total carbon storage since higher pH would reduce some kinds of nutrient availability. At the same time, a similar condition will also be found at the lower pH level (Feng et al., 2022). Therefore, most plants prefer to grow in soil with a pH-neutral of 6.5. Higher CEC increased total carbon storage because the increasing CEC would facilitate the mineralization process to make nutrients available (Costa et al. 2020). Meanwhile, higher Av-P significantly correlated to total carbon stock since the natural soil characteristics in the study site were classified into ultramafic soils having low Av-P (Alam et al. 2020). As one of the macronutrients, plants were substantially required to support their growth, mainly for supporting photosynthesis (Carstensen et al., 2018).

Implications

Overall, this study confirmed a significant influence of land covers on soil quality and carbon storage in Moramo Education Estate, wherein the highest soil quality and carbon storage was found in Forests. Even though this location was allocated to develop integrated farming systems, a wise scheme should be formulated to minimize the impact of environmental degradation due to the activity of land conversion. Referring to these results, we suggest conducting land transition step by step from the land cover with the lowest fertility and carbon storage, first starting from Savanna and followed by Shrubs. It is thoroughly recommended to convert Forests at the last priority since the potential function of Forests in this site is more suitable as a carbon pool.

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SUBMISSION CHECKLIST

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Pandu Yudha Adi Putra Wirabuana <pandu.yudha.a.p@ugm.ac.id>

[biodiv] Editor Decision

1 message

Nor Liza <smujo.id@gmail.com> Sat, Aug 6, 2022 at 7:59 PM
To: Pandu Wirabuana <pandu.yudha.a.p@ugm.ac.id>

Pandu Wirabuana:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Soil quality and carbon storage at different land covers in Moramo Education Estate, Southeast Sulawesi".

Our decision is: Revisions Required

Reviewer A:

Notes

Title: I changed the term “covers” to “cover types.”

ABSTRACT

I edited the abstract to improve the sentence effectiveness.

INTRODUCTION

I edited the citation style, following the guide of the journal. E.g., (Purwanto and Alam, 2020) should be (Purwanto and Alam 2020), without a comma.

The land cover type should be written as singular if it refers to a category, but it can be written in plural if it refers to several sites, e.g., forests meaning several forests located at different sites. There is inconsistency in writing savanna: some in plural and some in singular.

MATERIALS AND METHODS

Minor editing was done in this section.

RESULTS AND DISCUSSION

I edited this section to improve the sentence effectiveness.

Line 176: As one of the macronutrients, plants are substantially required to support their growth, mainly for supporting photosynthesis (Carstensen et al., 2018).

Which nutrient? I guess it is P.

As one of the macronutrients, P is substantially required by plants to support their growth, mainly for supporting photosynthesis (Carstensen et al. 2018).

Recommendation: Revisions Required

Biodiversitas Journal of Biological Diversity

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Influence of land ~~covers~~ cover types on soil quality and carbon storage in Moramo Education Estate, South Sulawesi, Indonesia

Abstract. This study investigated the influence of different land cover types~~s~~ on soil quality and carbon storage in Moramo Education Estate (MEE). Information is required as fundamental consideration to determine the best landscape management strategies for supporting soil conservation and climate change mitigation. Data were collected from three types of land cover ~~that are~~ generally found in this area~~,~~ and savannas. Three permanent sampling plots were randomly placed in every land cover as replicates with a size of 20 m × 20 m. Six parameters were used to describe the soil quality, i.e., soil acidity, soil organic carbon, total nitrogen, available phosphorus, exchangeable potassium, and cation exchange capacity. ~~Meanwhile, the~~The above and below--ground carbon storage from every plot was quantified~~ at below and aboveground conditions~~. The ~~comparison means of the~~ soil quality and carbon storage among land cover types were ~~examined~~ compared using analysis of variance and Tukey's honestly significant difference. Pearson's correlation analysis was also applied to evaluate the relationship between soil quality and carbon storage. The results show that soil quality significantly differed in ~~terms of~~ the exchangeable potassium and cation exchange capacity. A similar trend was also demonstrated in above-ground carbon storage~~ at aboveground conditions~~. The highest average carbon storage was recorded in forests (150.50 ± 27.79 t ha^{-1}), followed by shrubs (52.50 ± 15.02 t ha^{-1}) and savannas (45.97 ± 4.42 t ha^{-1}). The total carbon storage at different land covers ~~is~~ was significantly correlated to soil acidity, available phosphorus, and cation exchange capacity. Carbon storage improved with the increased ~~in the~~ available phosphorus and cation exchange capacity. ~~By~~ In contrast, ~~a negative correlation was noted in the relationship between~~ carbon storage ~~and~~ was negatively correlated with soil acidity. Overall, the ~~different~~ land cover~~s~~ types significantly influenced soil quality and carbon storage in MEE.

Keywords: climate change mitigation, land cover, landscape management, permanent sampling plot, soil conservation

Running title: Soil quality and carbon storage

INTRODUCTION

Soil conservation and climate change mitigation have become strategic issues in agriculture development (Amelung et al. 2020), particularly in tropical countries. The management of the agriculture sector is currently targeted to stabilize the food supply and ~~provide an essential contribution~~contribute to maintaining soil quality and reducing carbon emissions in the atmosphere (Castellini et al.~~,~~ 2021). To anticipate these challenges, the optimum scenario of agriculture development is necessary to accommodate the objective of environmental preservation and farm cultivation. This scheme is only possible to implement when land managers know the influence of land cover on the soil quality and carbon storage. The statement is also supported by previous studies that recorded the soil quality and carbon storage principally varying in every land cover due to the interaction between soil and the vegetation above it (Sugihara et al.~~,~~ 2014; Chandra et al.~~,~~ 2016; Sadono et al.~~,~~ 2021). For example, ~~a~~ higher plant biomass is commonly found in good soil than in poor soil because~~ the availability of~~ nutrients are more available in good soil ~~is more sufficient~~ to support plant growth (Bhandari and Zhang~~,~~ 2019). Meanwhile, higher biomass accumulation will generate more litterfall that becomes the input of organic matter into the soil (Giweta~~,~~ 2020). When the organic matter decomposes, ~~the amount of~~ nutrients will be released into the soil, ~~and improve~~improving fertility (Purwanto and Alam~~,~~ 2020). Therefore, ~~the availability of~~ information about soil quality and carbon storage is highly required by land managers as consideration materials to determine land conversion strategies in agriculture development.

Moramo Education Estate (MEE) is a special-purpose area managed by Universitas Halu Oleo in Southeast Sulawesi. It is a natural ecosystem with three land cover ~~variations~~types: ~~, namely,~~ forest~~s~~, shrub~~s~~, and savanna~~s~~. According to a government policy, MEE will become the priority location for integrated agriculture development. This area is designed as a research center and site experiment to facilitate the innovation of good agriculture practices, such as nutrient management, pest and disease control, and crop yield estimation. However, this scheme will ~~provide negative impacts on the contribution of~~ negatively impact MEE's contribution ~~in~~ to ecological functions because there will be an intensive land conversion from natural ecosystems to agricultural land. It will also reduce carbon absorption and cause an imbalanced nutrient cycle. Therefore, a preliminary study on the soil quality variation and carbon storage distribution at different land covers in MEE is required to determine an optimum scenario ~~of~~ for land transition. This information will help managers formulate priority land covers that can be converted into agricultural land. The effort is expected to minimize the negative impacts of land-use change on MEE ecosystems.

This study ~~aims~~ aimed to evaluate the effect of land covers on soil quality and carbon storage in MEE. The primary focus of this research ~~is~~ was to compare the soil fertility and carbon stock among land cover types and examine the connectivity between soil characteristics and carbon storage accumulation from different land covers. Results will provide adequate information as a ~~basis~~ basic consideration to select the priority land cover type for agriculture development without sacrificing the ecological function of MEE.

MATERIALS AND METHODS

Study area

This study was conducted in MEE located in South Konawe District, Southeast Sulawesi. The geographic position of this site is E4°6'30"–4°7'30" and S122°35'0"–122°35'30" (Figure 1). Its altitude ranges from 25 to 137 m above sea level. Topography is predominantly a hilly area with an 8%–15% slope level. The average daily temperature is 27.6 °C, with a minimum temperature of 23.1 °C and a maximum temperature of 32.2 °C. Annual rainfall reaches 3,179.70 mm year^{-1} with an average air humidity of 81%. The dry period is relatively longer than two months and commonly occurs from September to October. The land cover of MEE is dominated by forests (70%), followed by savannas (20%) and shrubs (10%).

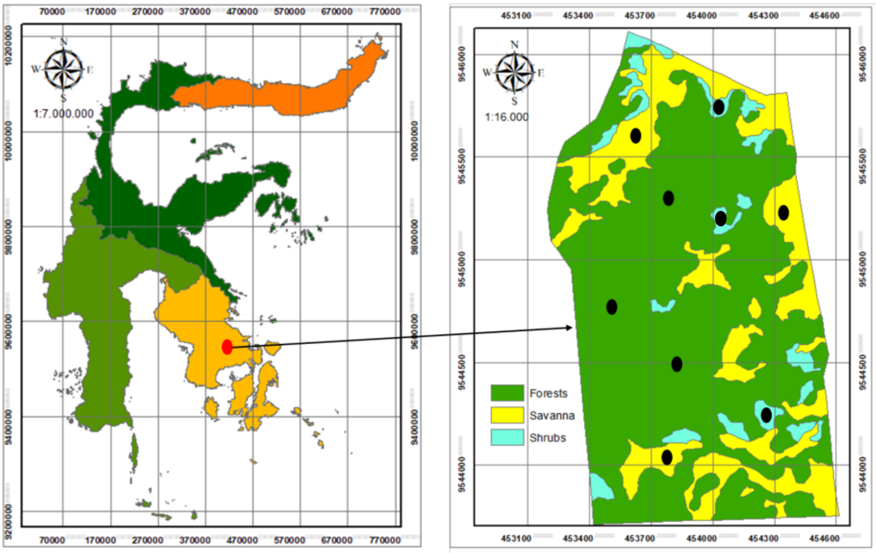

Figure 1. Study site of Moramo Education Estate in South Konawe. Black circles indicate sampling plots for data collection.

Data collection

The field survey was conducted using a stratified sampling method. The different land covers were assumed as the primary factor that caused the variations in soil quality and carbon storage. ~~To facilitate the measurement activity, t~~Three permanent sampling plots were randomly placed in every land cover with a size of 20 m × 20 m (Grussu et al.~~,~~ 2016). The coordinate of each plot was also recorded using a global positioning system. This method aimed to support the long-term monitoring of soil quality and carbon storage dynamics at the study site. Then, the data collection process in every plot was divided into two steps, i.e., soil sampling and vegetation measurement.

Soil sampling was conducted from three different positions in every plot using ring samples, ~~with~~ 8 cm in diameter and 10 cm in height. The soil sample was collected at a depth of 0–10, 11–20, and 21–30 cm (Sadono et al. 2021a). Afterward, the samples were brought to the laboratory to determine their specific gravity, soil acidity, organic carbon, total nitrogen, available phosphorus, exchangeable potassium, and cation exchange capacity. The specific gravity was analyzed using the ASTM-D854 method, and soil acidity was determined using a pH meter. The determination of soil organic carbon was conducted using the Walkley–Black method, and the total nitrogen was quantified using the Kjeldahl method. The 25% HCl extraction method was applied to quantify the available phosphorus and exchangeable potassium. Finally, cation exchange capacity was determined using the ammonium acetate method. The soil analysis protocol was undertaken following the guidance of soil analysis published by Estefan et al. (2013).

The vegetation measurement was performed using a nested method wherein every sampling plot was divided into several subplots to support the plant inventory based on their life stages: 1 m × 1 m (understorey), 2 m × 2 m (seedlings), 5 m × 5 m (saplings), 10 m × 10 m (poles), and 20 m × 20 m (trees) (Rambey et al.~~,~~ 2021). Several parameters were measured from the vegetation survey, including species, plant density, and diameter at breast height. However, the diameter measurement was only implemented for the poles and trees.

The carbon storage of vegetation in below and aboveground conditions was quantified using a conversion factor from biomass because approximately 50% of biomass was composed of carbon elements (Latifah and Sulistiyono, 2013; Taillardat et al.~~,~~ 2018; Wirabuana et al.~~,~~ 2020a). First, aboveground biomass in poles and trees was quantified using an allometric equation developed by Chave et al. (2005). Meanwhile, the root biomass of poles and trees was calculated using a conversion factor, wherein a ratio between the root biomass and total aboveground biomass of 1:5 was recorded (Wirabuana et al. 2020b). Next, the biomass accumulation in understorey, seedlings, and saplings was measured using a destructive method. The harvesting process was performed in every subplot. First, the fresh weight of each sample was measured using a hanging balance. Then, approximately 500 g subsample was brought to the laboratory for drying using an oven at 70 °C for 48 h (Sadono et al.~~,~~ 2021b). Then, biomass was computed by multiplying the ratio of dry-fresh weight from the subsample with the total fresh weight. A similar method was also applied to quantify biomass in litter and necromass. In parallel, the soil biomass was counted based on the ring samples' relationship between its specific gravity and estimated soil volumes. Then, the result was multiplied by the soil organic carbon content to obtain the carbon stock in the soil. The measurement of the soil carbon stock was performed in accordance with the guidance published by Hairiah and Rahayu (2007). The total carbon storage in every land cover type was counted by summing the carbon accumulation in soil, litter, necromass, and vegetation.

Table 1. Summary statistics of the soil quality and carbon storage at different land cover~~s~~ types

Land Use	Unit	pH	C-org (%)	TN (%)	Av-P (ppm)	Exec-K (meq 100 g^{-1})	CEC (meq 100 g^{-1})	AGE (t ha^{-1})	BGC (t ha^{-1})	TCS (t ha^{-1})
Savanna	Mean	4.54	1.44	0.14	4.38	0.16	10.3	6.07	39.90	45.97
	SD	0.29	0.52	0.03	1.05	0.06	1.22	1.45	2.97	4.42
	SE	0.12	0.21	0.01	0.43	0.03	0.50	0.84	1.71	2.55
	Min	4.16	0.88	0.10	3.39	0.09	8.62	4.40	36.70	41.10
	Max	4.92	2.06	0.19	6.03	0.27	11.7	7.00	42.50	49.50
Forest~~s~~	Mean	4.25	1.64	0.15	5.11	0.30	13.2	114.00	36.50	150.50
	SD	0.47	0.75	0.05	2.62	0.06	2.01	18.00	9.79	27.79
	SE	0.19	0.31	0.02	1.07	0.02	0.82	10.39	5.65	16.04
	Min	3.30	0.98	0.12	2.37	0.24	10.8	96.60	29.60	126.20
	Max	4.50	3.06	0.24	9.07	0.37	16.4	132.00	47.70	179.70
Shrub~~s~~	Mean	4.65	1.59	0.13	3.28	0.26	11.3	14.10	38.40	52.50
	SD	0.19	0.53	0.03	1.79	0.09	1.64	9.33	5.69	15.02
	SE	0.08	0.22	0.01	0.73	0.04	0.67	5.39	3.29	8.67
	Min	4.28	0.93	0.10	1.26	0.14	9.94	7.50	32.10	39.60
	Max	4.81	2.29	0.17	6.40	0.39	14.2	24.80	43.10	67.90

Note: pH (soil acidity), C-org (soil organic carbon), TN (total nitrogen), Av-P (available phosphorus), Exc-K (Exchangeable potassium), CEC (cation exchange capacity), AGC (aboveground carbon storage), BGC (belowground carbon storage), TCS (total carbon storage), SD (standard deviation), SE (standard error), Min (minimum), Max (maximum).

Data analysis

Statistical analysis was ~~processed~~ conducted using R software version 4.1.1 with a significant level of 5%. The ~~agricolae~~ Agricolae package was selected to support the data analysis. A descriptive test was applied to quantify the data attributes, including minimum, maximum, mean, standard deviation, and standard error. The normality of data was examined using the Shapiro–Wilk test, and the homogeneity of variance was evaluated using Bartlet's test. Comparison means of the soil quality and carbon storage among the three land covers were tested using the one-way analysis of variance and Tukey's honestly significant difference. Pearson's correlation analysis was also used to determine the critical soil parameters ~~that are~~ correlated to carbon storage.

RESULTS AND DISCUSSION

Soil quality distribution

Soil quality among land cover~~s~~ types was not significantly different in most parameters, except Exc-K (Figure 2). The highest average Exc-K was discovered in forests (0.30 ± 0.06 meq 100 g^{-1}), followed by shrubs (0.26 ± 0.09 meq 100 g^{-1}) and savannas (0.16 ± 0.06 meq 100 g^{-1}). As one of the soil macronutrients, the ~~availability of~~available potassium in the study location is ~~highly~~ extremely low because the soil type is categorized into ultramafic soils. It is a mature soil with low nutrient availability due to the ~~impact of~~ intensive weathering processes for long periods. Therefore, the potassium supply in this soil commonly comes from litterfall decomposition. This fact is ~~also~~ confirmed by ~~why~~the higher exchangeable K in forests ~~had higher Exc-K~~ than in other land cover types.

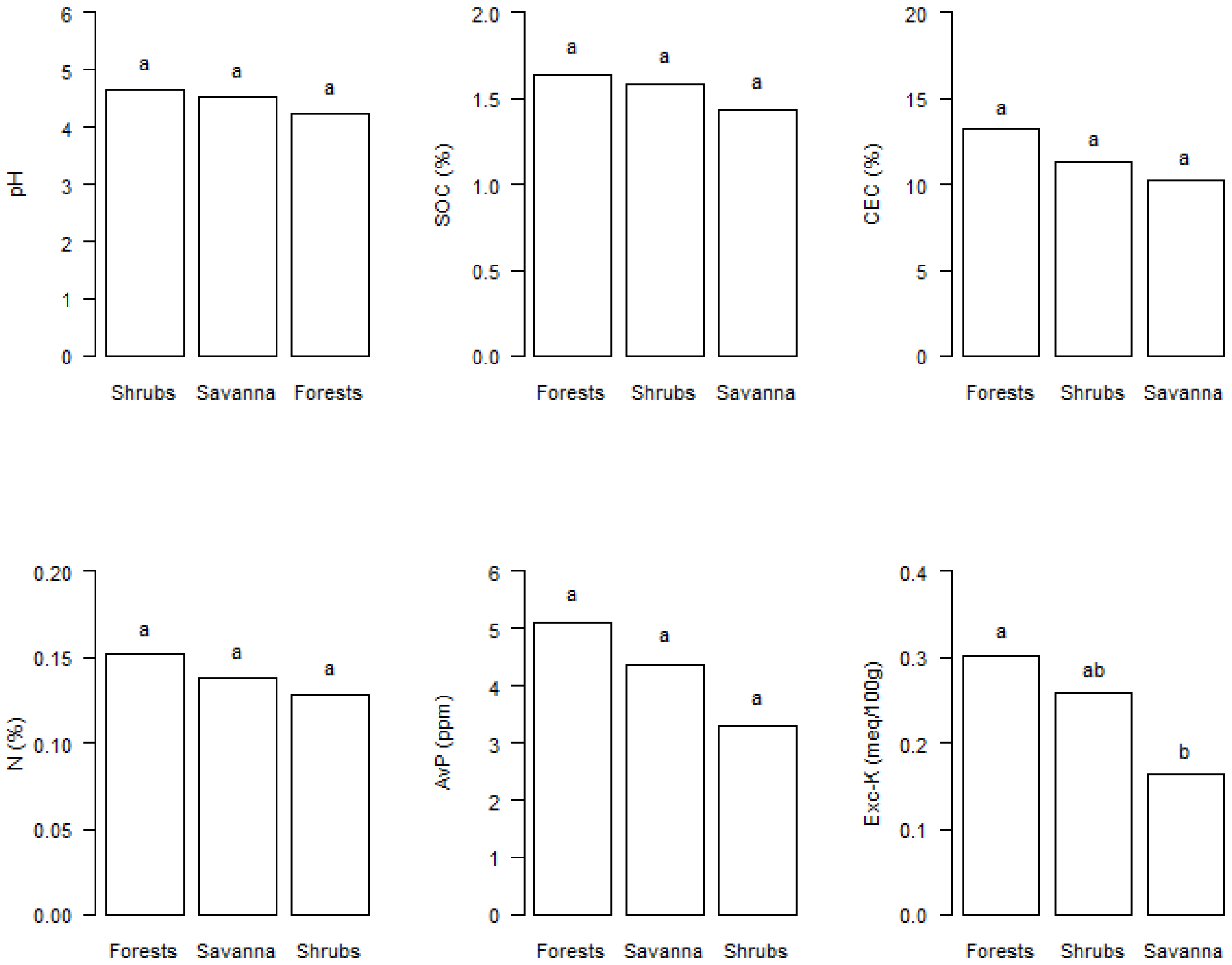

Figure 2. Comparison means of the soil quality among land cover types. A similar letter above the bar graph indicates a non-significant difference.

The high availability of nutrients in forests can be caused by the dense vegetation that supplies many organic matters into the soil through litterfall. ~~In this context, m~~More litterfall accumulation ~~at the~~ aboveground can maintain land humidity, which supports microorganism life (Sales et al.~~,~~ 2020). Furthermore, many pieces of literature confirm that the abundance of soil bacteria significantly accelerates the decomposition process (Jacoby et al.~~,~~ 2017; Grzyb et al.~~,~~ 2020; Miljaković et al.~~,~~ 2020). As a result, many nutrients will be released from litterfall into the soil layers (Tang et al., 2013). ~~This explanation indicates that~~ Therefore, vegetation ~~has a strategic position~~plays an important role in ~~to~~ ~~improve~~improving soil quality ~~because it is correlated to~~through the nutrient cycle. ~~The concept of soil pedogenesis supports this phenomenon, wherein organisms, including v~~Vegetation~~,~~ becomes one of the fundamental factors affecting the weathering process during soil genesis (Catoni et al.~~,~~ 2016). The results also imply that the declining vegetation density from forests to savanna gradually decreases soil quality.

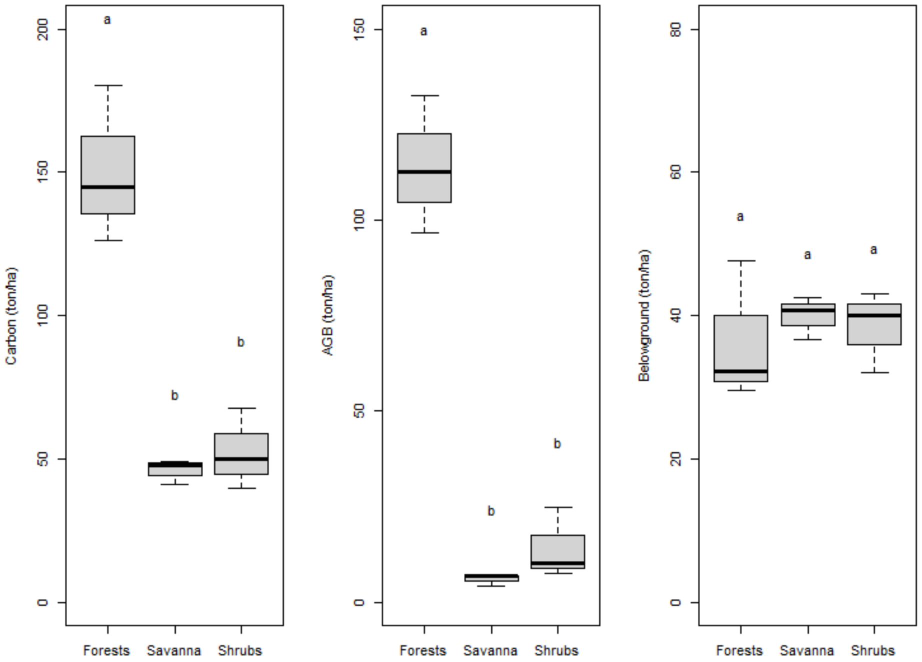

Figure 3. Comparison means of the carbon storage among land cover~~s~~ types. A similar letter above the boxplot indicates a non-significant difference.

Carbon storage variation

The total carbon storage from the three land cover~~s~~ types was ~~substantially~~ significantly different, wherein forests had the highest carbon storage than other land covers by approximately 150.50 ± 27.79 t ha^{-1} (Figure 3). It was almost four times higher than the carbon stock in shrubs and savannas. The most extensive accumulation of carbon stock in forests occurred due to the vast contribution of vegetation aboveground. The relative contribution of the aboveground to the total carbon storage in forests ~~is~~ was approximately 70% (Table 1). Meanwhile, there was no significant difference in the belowground carbon among land covers. This outcome is not surprising because several publications have explained the essential role of vegetation in climate change mitigation (Setiahadi~~,~~ 2017; Matatula et al.~~,~~ 2021; Wirabuana et al.~~,~~ 2021). Furthermore, the highly dense forest canopy can absorb greenhouse gas emissions, particularly carbon dioxide (CO_2), ~~which~~ because it is more effective in photosynthesis than shrubs and grasses (Xie et al.~~,~~ 2021).

Table 2. Pearson's correlation analysis between soil parameters and carbon storage

Soil parameter	AGE		BGC		TCS	
	r	p-value	r	p-value	r	p-value
pH	−0.562	0.051^{ns}	−0.282	0.461^{ns}	−0.694	0.037*
C-org	0.398	0.287^{ns}	0.595	0.057^{ns}	0.477	0.193^{ns}
TN	0.488	0.181^{ns}	0.394	0.293^{ns}	0.533	0.138^{ns}
Av-P	0.525	0.071^{ns}	0.392	0.295^{ns}	0.670	0.048*
Exc-K	0.546	0.059^{ns}	−0.238	0.536^{ns}	0.619	0.075^{ns}
CEC	0.537	0.053^{ns}	0.218	0.571^{ns}	0.762	0.016*

Note: pH (soil acidity), C-org (soil organic carbon), TN (total nitrogen), Av-P (available phosphorus), Exc-K (Exchangeable potassium), CEC (cation exchange capacity), AGC (aboveground carbon storage), BGC (belowground carbon storage), TCS (total carbon storage), ^{ns} (not significantly different), * (significantly different).

Moreover, this study recorded a significant correlation between soil characteristics and total carbon storage (Table 2)—three soil parameters are significantly correlated to the whole carbon storage, i.e., pH, Av-P, and CEC. However, the relationship among these parameters was relatively different. The total carbon storage improved along with the increasing Av-P and CEC. In~~By~~ contrast, a negative correlation was demonstrated in the relationship between carbon storage and pH. ~~In general, the interaction~~The correlation between soil characteristics and total carbon storage in the landscape ~~occurred~~

occurs because soil generally supplies nutrients for the vegetation above it (Schjoerring et al., 2019). Furthermore, the life cycle of vegetation will provide the amount of litterfall ~~and~~ that becomes organic matter inputs to soil (Sales et al., 2020). pH has a negative correlation to the total carbon storage because a high pH would reduce nutrient availability. At the same time, a similar condition is found at the low pH level (Feng et al.~~,~~ 2022). Therefore, most plants prefer to grow in soil with a pH of 6.5. A high CEC increases the total carbon storage because it would facilitate the mineralization process to make nutrients available (Costa et al.~~,~~ 2020). Meanwhile, a high Av-P is significantly correlated to the total carbon stock because the natural soil characteristics in the study site are classified into ultramafic soils having low Av-P (Alam et al. 2020). As one of the macronutrients, P is ~~plants are~~ substantially required by plants to support their growth, mainly for supporting photosynthesis (Carstensen et al.~~,~~ 2018).

Implications

Overall, this study confirmed a significant influence of land cover~~s~~ types on the soil quality and carbon storage in MEE, wherein the highest soil quality and carbon storage were found in forests. Although this location was allocated to develop integrated farming systems, a wise scheme should be formulated to minimize the impact of environmental degradation due to the land conversion activity. Based on the results, we suggest conducting a step-by-step land transition from the land cover types with the lowest fertility and carbon storage: ~~, first~~ starting from savannas and then ~~to~~ from ~~Shrubs~~shrubs. We strongly recommended converting forests lastly because of their potential function in this site ~~is highly suitable~~ as a high carbon pool.

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The authors deliver our gratitude to the manager of Moramo Education Estate ~~that~~ who ~~allows~~ allowed us to conduct this study in their area. We are also very grateful to reviewers for suggestions to improve this article's quality.

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Influence of land cover types on soil quality and carbon storage in Moramo Education Estate, South Sulawesi, Indonesia

Abstract. This study investigated the influence of different land cover types on soil quality and carbon storage in Moramo Education Estate (MEE). Information is required as fundamental consideration to determine the best landscape management strategies for supporting soil conservation and climate change mitigation. Data were collected from three types of land cover generally found in this area and savannas. Three permanent sampling plots were randomly placed in every land cover as replicates with a size of 20 m × 20 m. Six parameters were used to describe the soil quality, i.e., soil acidity, soil organic carbon, total nitrogen, available phosphorus, exchangeable potassium, and cation exchange capacity. The above and below-ground carbon storage from every plot was quantified. The soil quality and carbon storage among land cover types were compared using analysis of variance and Tukey's honestly significant difference. Pearson's correlation analysis was also applied to evaluate the relationship between soil quality and carbon storage. The results show that soil quality significantly differed in the exchangeable potassium and cation exchange capacity. A similar trend was also demonstrated in above-ground carbon storage. The highest average carbon storage was recorded in forests (150.50 ± 27.79 t ha^{-1}), followed by shrubs (52.50 ± 15.02 t ha^{-1}) and savannas (45.97 ± 4.42 t ha^{-1}). The total carbon storage at different land covers was significantly correlated to soil acidity, available phosphorus, and cation exchange capacity. Carbon storage improved with the increased available phosphorus and cation exchange capacity. In contrast, carbon storage was negatively correlated with soil acidity. Overall, the land cover types significantly influenced soil quality and carbon storage in MEE.

Keywords: climate change mitigation, land cover, landscape management, permanent sampling plot, soil conservation

Running title: Soil quality and carbon storage

INTRODUCTION

Soil conservation and climate change mitigation have become strategic issues in agriculture development (Amelung et al. 2020), particularly in tropical countries. The management of the agriculture sector is currently targeted to stabilize the food supply and contribute to maintaining soil quality and reducing carbon emissions in the atmosphere (Castellini et al. 2021). To anticipate these challenges, the optimum scenario of agriculture development is necessary to accommodate the objective of environmental preservation and farm cultivation. This scheme is only possible to implement when land managers know the influence of land cover on the soil quality and carbon storage. The statement is also supported by previous studies that recorded the soil quality and carbon storage principally varying in every land cover due to the interaction between soil and the vegetation above it (Sugihara et al. 2014; Chandra et al. 2016; Sadono et al. 2021). For example, higher plant biomass is commonly found in good soil than in poor soil because nutrients are more available in good soil to support plant growth (Bhandari and Zhang 2019). Meanwhile, higher biomass accumulation will generate more litterfall that becomes the input of organic matter into the soil (Giweta 2020). When the organic matter decomposes, nutrients will be released into the soil, improving fertility (Purwanto and Alam 2020). Therefore, information about soil quality and carbon storage is highly required by land managers as consideration materials to determine land conversion strategies in agriculture development.

Moramo Education Estate (MEE) is a special-purpose area managed by Universitas Halu Oleo in Southeast Sulawesi. It is a natural ecosystem with three land cover types: forest, shrub, and savanna. According to a government policy, MEE will become the priority location for integrated agriculture development. This area is designed as a research center and site experiment to facilitate the innovation of good agriculture practices, such as nutrient management, pest and disease control, and crop yield estimation. However, this scheme will negatively impact MEE’s contribution to ecological functions because there will be an intensive land conversion from natural ecosystems to agricultural land. It will also reduce carbon absorption and cause an imbalanced nutrient cycle. Therefore, a preliminary study on the soil quality variation and carbon storage distribution at different land covers in MEE is required to determine an optimum scenario for land transition. This information will help managers formulate priority land covers that can be converted into agricultural land. The effort is expected to minimize the negative impacts of land-use change on MEE ecosystems.

This study aimed to evaluate the effect of land covers on soil quality and carbon storage in MEE. The primary focus of this research was to compare the soil fertility and carbon stock among land cover types and examine the connectivity between soil characteristics and carbon storage accumulation from different land covers. Results will provide adequate information as a basic consideration to select the priority land cover type for agriculture development without sacrificing the ecological function of MEE.

MATERIALS AND METHODS

Study area

This study was conducted in MEE located in South Konawe District, Southeast Sulawesi. The geographic position of this site is E4°6'30"–4°7'30" and S122°35'0"–122°35'30" (Figure 1). Its altitude ranges from 25 to 137 m above sea level. Topography is predominantly a hilly area with an 8%–15% slope level. The average daily temperature is 27.6 ℃, with a minimum temperature of 23.1 ℃ and a maximum temperature of 32.2 ℃. Annual rainfall reaches 3,179.70 mm year^{-1} with an average air humidity of 81%. The dry period is relatively longer than two months and commonly occurs from September to October. The land cover of MEE is dominated by forests (70%), followed by savannas (20%) and shrubs (10%).

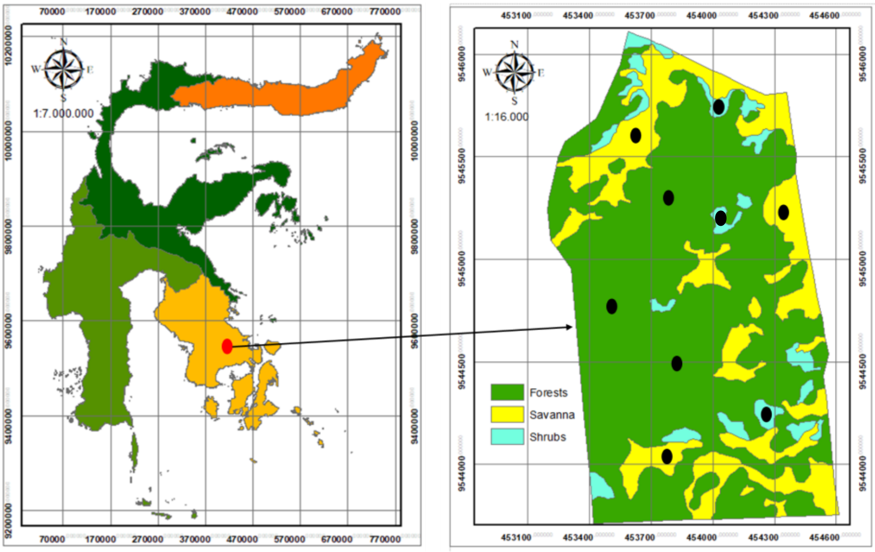

Figure 1. Study site of Moramo Education Estate in South Konawe. Black circles indicate sampling plots for data collection.

Data collection

The field survey was conducted using a stratified sampling method. The different land covers were assumed as the primary factor that caused the variations in soil quality and carbon storage. Three permanent sampling plots were randomly placed in every land cover with a size of 20 m × 20 m (Grussu et al. 2016). The coordinate of each plot was also recorded using a global positioning system. This method aimed to support the long-term monitoring of soil quality and carbon storage dynamics at the study site. Then, the data collection process in every plot was divided into two steps, i.e., soil sampling and vegetation measurement.

Soil sampling was conducted from three different positions in every plot using ring samples, 8 cm in diameter and 10 cm in height. The soil sample was collected at a depth of 0–10, 11–20, and 21–30 cm (Sadono et al. 2021a). Afterward, the samples were brought to the laboratory to determine their specific gravity, soil acidity, organic carbon, total nitrogen, available phosphorus, exchangeable potassium, and cation exchange capacity. The specific gravity was analyzed using the ASTM-D854 method, and soil acidity was determined using a pH meter. The determination of soil organic carbon was conducted using the Walkley–Black method, and the total nitrogen was quantified using the Kjeldahl method. The 25% HCl extraction method was applied to quantify the available phosphorus and exchangeable potassium. Finally, cation exchange capacity was determined using the ammonium acetate method. The soil analysis protocol was undertaken following the guidance of soil analysis published by Estefan et al. (2013).

The vegetation measurement was performed using a nested method wherein every sampling plot was divided into several subplots to support the plant inventory based on their life stages: 1 m × 1 m (understorey), 2 m × 2 m (seedlings), 5 m × 5 m (saplings), 10 m × 10 m (poles), and 20 m × 20 m (trees) (Rambey et al. 2021). Several parameters were measured from the vegetation survey, including species, plant density, and diameter at breast height. However, the diameter measurement was only implemented for the poles and trees.

The carbon storage of vegetation in below and aboveground conditions was quantified using a conversion factor from biomass because approximately 50% of biomass was composed of carbon elements (Latifah and Sulistiyono, 2013; Taillardat et al. 2018; Wirabuana et al. 2020a). First, aboveground biomass in poles and trees was quantified using an allometric equation developed by Chave et al. (2005). Meanwhile, the root biomass of poles and trees was calculated using a conversion factor, wherein a ratio between the root biomass and total aboveground biomass of 1:5 was recorded (Wirabuana et al. 2020b). Next, the biomass accumulation in understorey, seedlings, and saplings was measured using a destructive method. The harvesting process was performed in every subplot. First, the fresh weight of each sample was measured using a hanging balance. Then, approximately 500 g subsample was brought to the laboratory for drying using an oven at 70 °C for 48 h (Sadono et al. 2021b). Then, biomass was computed by multiplying the ratio of dry-fresh weight from the subsample with the total fresh weight. A similar method was also applied to quantify biomass in litter and necromass. In parallel, the soil biomass was counted based on the ring samples' relationship between its specific gravity and estimated soil volumes. Then, the result was multiplied by the soil organic carbon content to obtain the carbon stock in the soil. The measurement of the soil carbon stock was performed in accordance with the guidance published by Hairiah and Rahayu (2007). The total carbon storage in every land cover type was counted by summing the carbon accumulation in soil, litter, necromass, and vegetation.

Table 1. Summary statistics of the soil quality and carbon storage at different land cover types

Land Use	Unit	pH	C-org (%)	TN (%)	Av-P (ppm)	Exec-K (meq 100 g^{-1})	CEC (meq 100 g^{-1})	AGE (t ha^{-1})	BGC (t ha^{-1})	TCS (t ha^{-1})
Savanna	Mean	4.54	1.44	0.14	4.38	0.16	10.3	6.07	39.90	45.97
	SD	0.29	0.52	0.03	1.05	0.06	1.22	1.45	2.97	4.42
	SE	0.12	0.21	0.01	0.43	0.03	0.50	0.84	1.71	2.55
	Min	4.16	0.88	0.10	3.39	0.09	8.62	4.40	36.70	41.10
	Max	4.92	2.06	0.19	6.03	0.27	11.7	7.00	42.50	49.50
Forest	Mean	4.25	1.64	0.15	5.11	0.30	13.2	114.00	36.50	150.50
	SD	0.47	0.75	0.05	2.62	0.06	2.01	18.00	9.79	27.79
	SE	0.19	0.31	0.02	1.07	0.02	0.82	10.39	5.65	16.04
	Min	3.30	0.98	0.12	2.37	0.24	10.8	96.60	29.60	126.20
	Max	4.50	3.06	0.24	9.07	0.37	16.4	132.00	47.70	179.70
Shrub	Mean	4.65	1.59	0.13	3.28	0.26	11.3	14.10	38.40	52.50
	SD	0.19	0.53	0.03	1.79	0.09	1.64	9.33	5.69	15.02
	SE	0.08	0.22	0.01	0.73	0.04	0.67	5.39	3.29	8.67
	Min	4.28	0.93	0.10	1.26	0.14	9.94	7.50	32.10	39.60
	Max	4.81	2.29	0.17	6.40	0.39	14.2	24.80	43.10	67.90

Note: pH (soil acidity), C-org (soil organic carbon), TN (total nitrogen), Av-P (available phosphorus), Exc-K (Exchangeable potassium), CEC (cation exchange capacity), AGC (aboveground carbon storage), BGC (belowground carbon storage), TCS (total carbon storage), SD (standard deviation), SE (standard error), Min (minimum), Max (maximum).

Data analysis

Statistical analysis was conducted using R software version 4.1.1 with a significant level of 5%. The Agricolae package was selected to support the data analysis. A descriptive test was applied to quantify the data attributes, including minimum, maximum, mean, standard deviation, and standard error. The normality of data was examined using the Shapiro–Wilk test, and the homogeneity of variance was evaluated using Bartlet's test. Comparison means of the soil quality and carbon storage among the three land covers were tested using the one-way analysis of variance and Tukey's honestly significant difference. Pearson's correlation analysis was also used to determine the critical soil parameters correlated to carbon storage.

RESULTS AND DISCUSSION

Soil quality distribution

Soil quality among land cover types was not significantly different in most parameters, except Exc-K (Figure 2). The highest average Exc-K was discovered in forests (0.30 ± 0.06 meq 100 g^{-1}), followed by shrubs (0.26 ± 0.09 meq 100 g^{-1}) and savannas (0.16 ± 0.06 meq 100 g^{-1}). As one of the soil macronutrients, the available potassium in the study location is extremely low because the soil type is categorized into ultramafic soils. It is a mature soil with low nutrient availability due to the intensive weathering processes for long periods. Therefore, the potassium supply in this soil commonly comes from litterfall decomposition. This fact is confirmed by the higher exchangeable K in forests than in other land cover types.

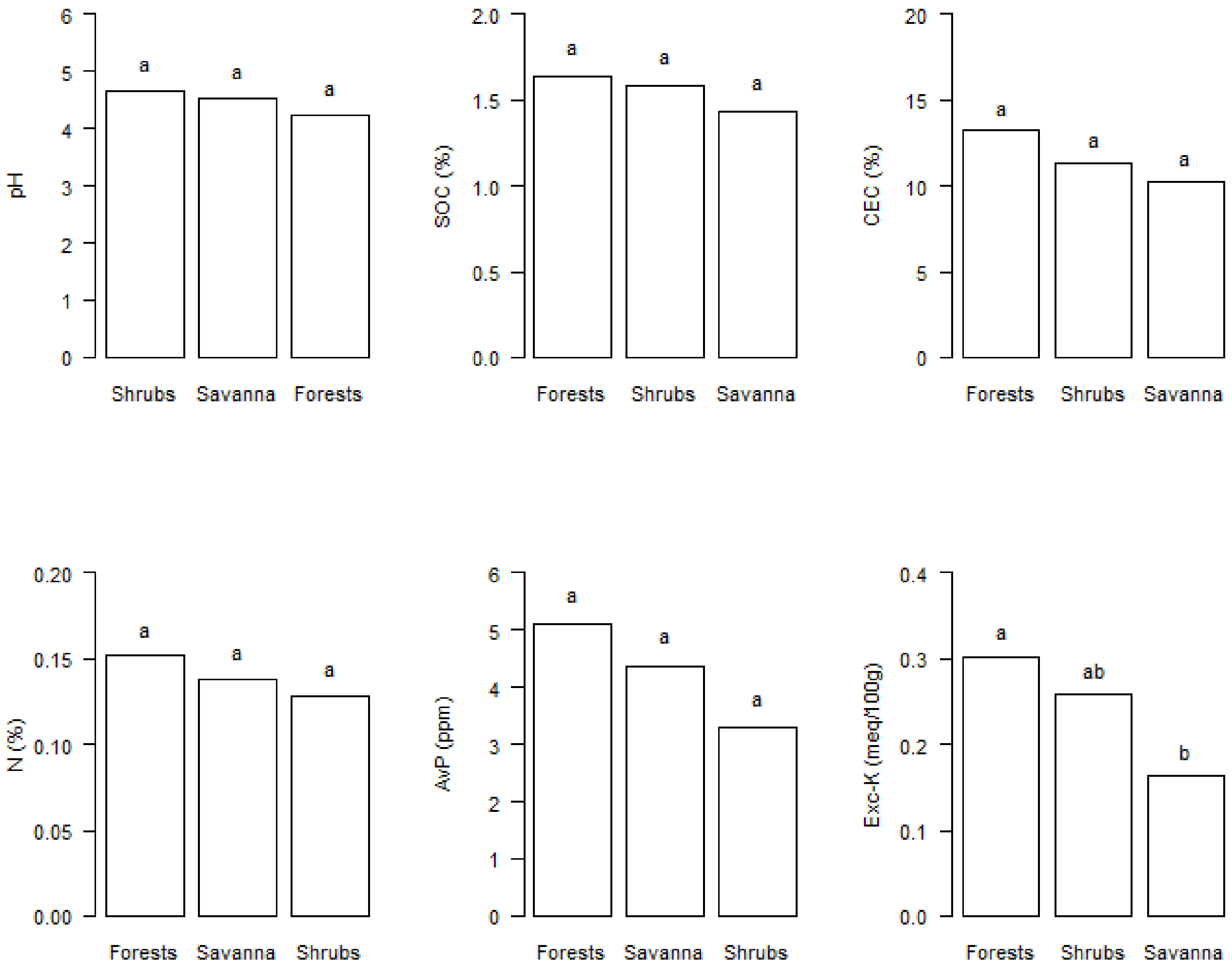

Figure 2. Comparison means of the soil quality among land cover types. A similar letter above the bar graph indicates a non-significant difference.

The high availability of nutrients in forests can be caused by the dense vegetation that supplies many organic matters into the soil through litterfall. More litterfall accumulation aboveground can maintain land humidity, which supports microorganism life (Sales et al. 2020). Furthermore, many pieces of literature confirm that the abundance of soil bacteria significantly accelerates the decomposition process (Jacoby et al. 2017; Grzyb et al. 2020; Miljaković et al. 2020). As a result, many nutrients will be released from litterfall into the soil layers (Tang et al., 2013). Therefore, vegetation plays an important role in improving soil quality through the nutrient cycle. Vegetation becomes one of the fundamental factors affecting the weathering process during soil genesis (Catoni et al. 2016). The results also imply that the declining vegetation density from forests to savanna gradually decreases soil quality.

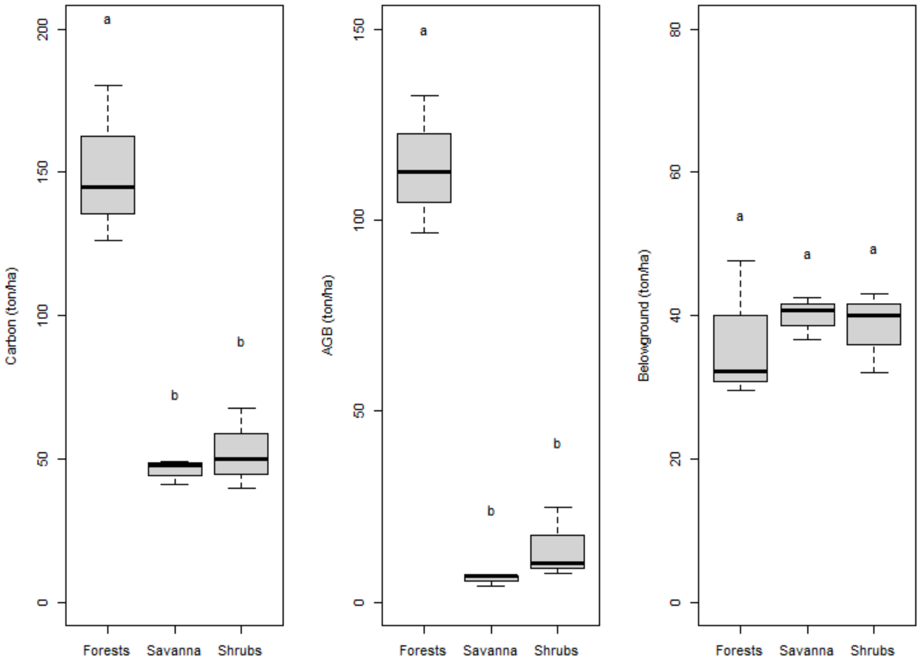

Figure 3. Comparison means of the carbon storage among land cover types. A similar letter above the boxplot indicates a non-significant difference.

Carbon storage variation

The total carbon storage from the three land cover types was significantly different, wherein forests had the highest carbon storage than other land covers by approximately 150.50 ± 27.79 t ha^{-1} (Figure 3). It was almost four times higher than the carbon stock in shrubs and savannas. The most extensive accumulation of carbon stock in forests occurred due to the vast contribution of vegetation aboveground. The relative contribution of the aboveground to the total carbon storage in forests was approximately 70% (Table 1). Meanwhile, there was no significant difference in the belowground carbon among land covers. This outcome is not surprising because several publications have explained the essential role of vegetation in climate change mitigation (Setiahadi 2017; Matatula et al. 2021; Wirabuana et al. 2021). Furthermore, the highly dense forest canopy can absorb greenhouse gas emissions, particularly carbon dioxide (CO_2), because it is more effective in photosynthesis than shrubs and grasses (Xie et al. 2021).

Table 2. Pearson's correlation analysis between soil parameters and carbon storage

Soil parameter	AGE		BGC		TCS	
	r	p-value	r	p-value	r	p-value
pH	−0.562	0.051^{ns}	−0.282	0.461^{ns}	−0.694	0.037^{*}
C-org	0.398	0.287^{ns}	0.595	0.057^{ns}	0.477	0.193^{ns}
TN	0.488	0.181^{ns}	0.394	0.293^{ns}	0.533	0.138^{ns}
Av-P	0.525	0.071^{ns}	0.392	0.295^{ns}	0.670	0.048^{*}
Exc-K	0.546	0.059^{ns}	−0.238	0.536^{ns}	0.619	0.075^{ns}
CEC	0.537	0.053^{ns}	0.218	0.571^{ns}	0.762	0.016^{*}

Note: pH (soil acidity), C-org (soil organic carbon), TN (total nitrogen), Av-P (available phosphorus), Exc-K (Exchangeable potassium), CEC (cation exchange capacity), AGC (aboveground carbon storage), BGC (belowground carbon storage), TCS (total carbon storage), ^{ns} (not significantly different), * (significantly different).

Moreover, this study recorded a significant correlation between soil characteristics and total carbon storage (Table 2)—three soil parameters are significantly correlated to the whole carbon storage, i.e., pH, Av-P, and CEC. However, the relationship among these parameters was relatively different. The total carbon storage improved along with the increasing Av-P and CEC. In contrast, a negative correlation was demonstrated in the relationship between carbon storage and pH. The correlation between soil characteristics and total carbon storage in the landscape occurs because soil generally supplies nutrients for the vegetation above it (Schjoerring et al., 2019). Furthermore, the life cycle of vegetation will provide the amount of litterfall that becomes organic matter inputs to soil (Sales et al., 2020). pH has a negative correlation to the total carbon storage because a high pH would reduce nutrient availability. At the same time, a similar condition is found at the low pH level (Feng et al. 2022). Therefore, most plants prefer to grow in soil with a pH of 6.5. A high CEC increases the total carbon storage because it would facilitate the mineralization process to make nutrients available (Costa et al. 2020). Meanwhile, a high Av-P is significantly correlated to the total carbon stock because the natural soil characteristics in the study site are classified into ultramafic soils having low Av-P (Alam et al. 2020). As one of the macronutrients, P is substantially required by plants to support their growth, mainly for supporting photosynthesis (Carstensen et al. 2018).

Implications

Overall, this study confirmed a significant influence of land cover types on the soil quality and carbon storage in MEE, wherein the highest soil quality and carbon storage were found in forests. Although this location was allocated to develop integrated farming systems, a wise scheme should be formulated to minimize the impact of environmental degradation due to the land conversion activity. Based on the results, we suggest conducting a step-by-step land transition from the land cover types with the lowest fertility and carbon storage: starting from savannas and then from shrubs. We strongly recommended converting forests lastly because of their potential function in this site as a high carbon pool.

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Pandu Yudha Adi Putra Wirabuana <pandu.yudha.a.p@ugm.ac.id>

[biodiv] Editor Decision

1 message

Managers <smujo.id@gmail.com> Mon, Aug 29, 2022 at 4:51 PM
To: SYAMSU ALAM <author@smujo.id>, PANDU YUDHA ADI PUTRA WIRABUANA <pandu.yudha.a.p@ugm.ac.id>

SYAMSU ALAM, SAHTA GINTING, M. TUFAILA HEMON, SITTI LEOMO, LAODE MUHAMMAD HARJONI KILOWASID, JUFRI KARIM KARIM, YUSANTO NUGROHO, JERIELS MATATULA, PANDU YUDHA ADI PUTRA WIRABUANA:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Influence of land cover types on soil quality and carbon storage in Moramo Education Estate, Southeast Sulawesi, Indonesia".

Our decision is to: Accept Submission

Biodiversitas Journal of Biological Diversity

Source details

Biodiversitas

Open Access

Scopus coverage years: from 2014 to Present

Publisher: Biology department, Sebelas Maret University Surakarta

ISSN: 1412-033X E-ISSN: 2085-4722

Subject area: Agricultural and Biological Sciences: Animal Science and Zoology | Agricultural and Biological Sciences: Plant Science | Biochemistry, Genetics and Molecular Biology: Molecular Biology

Source type: Journal

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CiteScore 2021
1.7

SJR 2021
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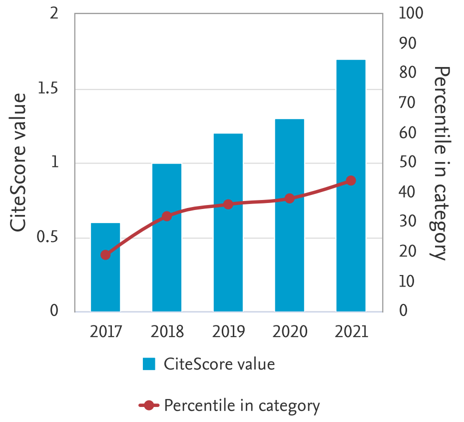
CiteScore rank 2021

In category: Plant Science

	Rank	Source title	CiteScore 2021	Percentile
☆	#266 482	Biodiversitas	1.7	44th percentile
☆	#1	Annual Review of Plant Biology	38.3	99th percentile
☆	#2	Trends in Plant Science	28.4	99th percentile
☆	#3	Annual Review of Phytopathology	23.7	99th percentile
☆	#4	Nature Plants	20.8	99th percentile
☆	#5	Molecular Plant	19.5	99th percentile
☆	#6	Plant Biotechnology Journal	16.6	98th percentile
☆	#7	Plant Cell	16.5	98th percentile
☆	#8	New Phytologist	15.7	98th percentile
☆	#9	Current Opinion in Plant Biology	14.7	98th percentile
☆	#10	Mycosphere	13.9	98th percentile
☆	#11	NJAS - Wageningen Journal of Life Sciences	13.4	97th percentile
☆	#12	Plant Physiology	12.7	97th percentile
☆	#13	Plant, Cell and Environment	12.5	97th percentile
☆	#14	Journal of Integrative Plant Biology	11.8	97th percentile

CiteScore trend



☆	Rank	Source title	CiteScore 2021	Percentile
☆	#15	Phytochemistry Reviews	11.6	96th percentile
☆	#16	Molecular Plant Pathology	11.0	96th percentile
☆	#17	Journal of Experimental Botany	10.9	96th percentile
☆	#18	Plant Journal	10.4	96th percentile
☆	#19	Journal of Pest Science	10.1	96th percentile
☆	#20	Journal of Ecology	9.9	95th percentile
☆	#21	Plant and Cell Physiology	9.2	95th percentile
☆	#22	European Journal of Agronomy	9.1	95th percentile
☆	#23	Environmental and Experimental Botany	9.1	95th percentile
☆	#24	Plant Methods	8.9	95th percentile
☆	#25	Annals of Botany	8.6	94th percentile
☆	#26	Horticulture Research	8.5	94th percentile
☆	#27	BMC Biology	8.4	94th percentile
☆	#28	Plant Reproduction	8.3	94th percentile
☆	#29	Critical Reviews in Plant Sciences	8.2	94th percentile
☆	#30	Harmful Algae	8.1	93rd percentile
☆	#31	Plant Science	8.0	93rd percentile
☆	#32	Frontiers in Plant Science	8.0	93rd percentile
☆	#33	Metabarcoding and Metagenomics	7.9	93rd percentile
☆	#34	Rice	7.9	93rd percentile
☆	#35	Plant Cell Reports	7.8	92nd percentile
☆	#36	Plant Communications	7.6	92nd percentile
☆	#37	Plant Molecular Biology	7.4	92nd percentile
☆	#38	Journal of Plant Interactions	7.4	92nd percentile
☆	#39	Annals of Agricultural Sciences	7.4	92nd percentile
☆	#40	Plant Physiology and Biochemistry	7.3	91st percentile
☆	#41	Plant and Soil	7.3	91st percentile
☆	#42	Tree Physiology	7.1	91st percentile
☆	#43	Physiologia Plantarum	7.1	91st percentile
☆	#44	Journal of Plant Growth Regulation	7.0	90th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#45	Journal of Plant Physiology	6.9	90th percentile
☆	#46	BMC Plant Biology	6.9	90th percentile
☆	#47	Crop Journal	6.9	90th percentile
☆	#48	Planta	6.9	90th percentile
☆	#49	Perspectives in Plant Ecology, Evolution and Systematics	6.7	89th percentile
☆	#50	Protoplasma	6.7	89th percentile
☆	#51	Fungal Ecology	6.6	89th percentile
☆	#52	Journal of Systematics and Evolution	6.6	89th percentile
☆	#53	Life Science Alliance	6.5	89th percentile
☆	#54	Photosynthesis Research	6.4	88th percentile
☆	#55	Photosynthetica	6.3	88th percentile
☆	#56	Phytochemistry	6.2	88th percentile
☆	#57	Phytobiomes Journal	6.2	88th percentile
☆	#58	Journal of Agronomy and Crop Science	6.1	88th percentile
☆	#59	Mycorrhiza	6.1	87th percentile
☆	#60	Phytopathology	6.0	87th percentile
☆	#61	Plant Growth Regulation	6.0	87th percentile
☆	#61	Rice Science	6.0	87th percentile
☆	#63	Preslia	6.0	87th percentile
☆	#64	NeoBiota	5.8	86th percentile
☆	#65	Horticultural Plant Journal	5.8	86th percentile
☆	#66	Plant Biology	5.8	86th percentile
☆	#67	EFSA Journal	5.7	86th percentile
☆	#68	Plant Genome	5.7	85th percentile
☆	#69	Environmental Technology and Innovation	5.7	85th percentile
☆	#70	Phytocoenologia	5.6	85th percentile
☆	#71	International Journal of Phytoremediation	5.6	85th percentile
☆	#71	Natural Products and Bioprospecting	5.6	85th percentile
☆	#73	Journal of Integrative Agriculture	5.6	84th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#74	Journal of Applied Phycology	5.5	84th percentile
☆	#75	American Journal of Botany	5.5	84th percentile
☆	#76	Phytochemical Analysis	5.5	84th percentile
☆	#77	Molecular Breeding	5.4	84th percentile
☆	#78	Functional Plant Biology	5.3	83rd percentile
☆	#79	Fermentation	5.3	83rd percentile
☆	#80	Current Plant Biology	5.2	83rd percentile
☆	#81	Journal of Applied Research on Medicinal and Aromatic Plants	5.1	83rd percentile
☆	#82	Plant Biosystems	5.1	83rd percentile
☆	#83	Botanical Journal of the Linnean Society	5.1	82nd percentile
☆	#84	AoB PLANTS	5.1	82nd percentile
☆	#85	Plants People Planet	5.1	82nd percentile
☆	#86	The Botanical Review	5.0	82nd percentile
☆	#87	Botanical Studies	5.0	82nd percentile
☆	#88	Dendrochronologia	5.0	81st percentile
☆	#89	Plant Phenome Journal	4.9	81st percentile
☆	#90	Plant Pathology	4.9	81st percentile
☆	#91	Weed Science	4.9	81st percentile
☆	#92	Journal of Plant Nutrition and Soil Science	4.9	80th percentile
☆	#92	Vegetation History and Archaeobotany	4.9	80th percentile
☆	#94	Microbes and Environments	4.9	80th percentile
☆	#95	Phycologia	4.8	80th percentile
☆	#96	Plant Direct	4.7	80th percentile
☆	#97	Journal of Integrated Pest Management	4.7	79th percentile
☆	#98	Annual Plant Reviews Online	4.7	79th percentile
☆	#99	Applications in Plant Sciences	4.6	79th percentile
☆	#100	Journal of Plant Research	4.6	79th percentile
☆	#101	European Journal of Phycology	4.6	79th percentile
☆	#102	Plant Diversity	4.6	78th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#103	Plant Ecology and Diversity	4.6	78th percentile
☆	#104	Fottea	4.6	78th percentile
☆	#105	Italian Botanist	4.6	78th percentile
☆	#106	European Journal of Forest Research	4.5	78th percentile
☆	#107	Journal of Vegetation Science	4.5	77th percentile
☆	#108	Trees - Structure and Function	4.5	77th percentile
☆	#109	Wood Science and Technology	4.5	77th percentile
☆	#110	Journal of Phycology	4.4	77th percentile
☆	#111	Weed Research	4.4	77th percentile
☆	#112	Advances in Botanical Research	4.3	76th percentile
☆	#113	Acta Physiologiae Plantarum	4.3	76th percentile
☆	#114	South African Journal of Botany	4.3	76th percentile
☆	#115	Foods	4.1	76th percentile
☆	#116	Journal of Fungi	4.1	76th percentile
☆	#117	Physiological and Molecular Plant Pathology	4.0	75th percentile
☆	#118	Crop and Pasture Science	4.0	75th percentile
☆	#118	Current protocols in plant biology	4.0	75th percentile
☆	#120	Plant Disease	4.0	75th percentile
☆	#121	Alpine Botany	4.0	75th percentile
☆	#122	Canadian Journal of Plant Pathology	4.0	74th percentile
☆	#123	Natural Product Research	4.0	74th percentile
☆	#124	In Vitro Cellular and Developmental Biology - Plant	3.9	74th percentile
☆	#125	Journal of Soil Science and Plant Nutrition	3.9	74th percentile
☆	#126	Economic Botany	3.9	73rd percentile
☆	#127	Algae	3.9	73rd percentile
☆	#128	Opuscula Philolichenum	3.9	73rd percentile
☆	#129	Journal of Plant Biology	3.8	73rd percentile
☆	#130	Breeding Science	3.8	73rd percentile
☆	#131	International Journal of Plant Sciences	3.8	72nd percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#132	Physiology and Molecular Biology of Plants	3.8	72nd percentile
☆	#133	Systematics and Biodiversity	3.7	72nd percentile
☆	#134	Journal of Forestry	3.7	72nd percentile
☆	#135	Soil Science and Plant Nutrition	3.7	72nd percentile
☆	#136	Aerobiologia	3.7	71st percentile
☆	#137	European Journal of Plant Pathology	3.7	71st percentile
☆	#138	Phytopathologia Mediterranea	3.7	71st percentile
☆	#139	Aquatic Botany	3.6	71st percentile
☆	#140	Plants	3.6	71st percentile
☆	#141	Flora: Morphology, Distribution, Functional Ecology of Plants	3.6	70th percentile
☆	#142	New Zealand Journal of Agricultural Research	3.6	70th percentile
☆	#143	Integrative Organismal Biology	3.6	70th percentile
☆	#144	Horticulture Environment and Biotechnology	3.6	70th percentile
☆	#145	Records of Natural Products	3.5	70th percentile
☆	#146	IAWA Journal	3.5	69th percentile
☆	#147	Plant Breeding	3.5	69th percentile
☆	#148	Rhizosphere	3.5	69th percentile
☆	#149	Forest and Society	3.5	69th percentile
☆	#150	Euphytica	3.4	68th percentile
☆	#151	Plant Biotechnology Reports	3.4	68th percentile
☆	#152	Biologia Plantarum	3.4	68th percentile
☆	#153	Botany Letters	3.4	68th percentile
☆	#154	International Journal of Plant Production	3.4	68th percentile
☆	#155	Plant Signaling and Behavior	3.4	67th percentile
☆	#156	Australian Systematic Botany	3.3	67th percentile
☆	#157	Journal of Berry Research	3.3	67th percentile
☆	#158	Seed Science Research	3.3	67th percentile
☆	#159	Taxon	3.3	67th percentile
☆	#160	Egyptian Journal of Biological Pest Control	3.3	66th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#161	Phycological Research	3.3	66th percentile
☆	#162	Cryptogamie, Algologie	3.2	66th percentile
☆	#163	Journal of Plant Ecology	3.2	66th percentile
☆	#164	Plant Gene	3.2	66th percentile
☆	#165	Theoretical and Experimental Plant Physiology	3.1	65th percentile
☆	#166	Annals of the Missouri Botanical Garden	3.1	65th percentile
☆	#167	Plant Ecology	3.1	65th percentile
☆	#168	Journal of Bryology	3.1	65th percentile
☆	#169	Agriculture (Switzerland)	3.1	65th percentile
☆	#170	Phytochemistry Letters	3.1	64th percentile
☆	#171	In Silico Plants	3.1	64th percentile
☆	#172	California Agriculture	3.0	64th percentile
☆	#173	Journal of Phytopathology	3.0	64th percentile
☆	#174	Botanica Marina	3.0	64th percentile
☆	#175	Acta Botanica Brasilica	3.0	63rd percentile
☆	#176	Plant Molecular Biology Reporter	3.0	63rd percentile
☆	#177	Hacquetia	2.9	63rd percentile
☆	#178	Sydowia	2.9	63rd percentile
☆	#179	Tropical Plant Pathology	2.9	62nd percentile
☆	#180	Weed Technology	2.9	62nd percentile
☆	#181	Plant Systematics and Evolution	2.9	62nd percentile
☆	#182	Asian Pacific Journal of Reproduction	2.9	62nd percentile
☆	#183	aBIOTECH	2.9	62nd percentile
☆	#184	Bryologist	2.8	61st percentile
☆	#185	Legume Science	2.8	61st percentile
☆	#186	Turkish Journal of Botany	2.8	61st percentile
☆	#187	Genetic Resources and Crop Evolution	2.8	61st percentile
☆	#188	Journal of Crop Improvement	2.8	61st percentile
☆	#189	Folia Cryptogamica Estonica	2.8	60th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#190	Plant Genetic Resources: Characterisation and Utilisation	2.7	60th percentile
☆	#191	Australasian Plant Pathology	2.7	60th percentile
☆	#192	Archives Animal Breeding	2.7	60th percentile
☆	#193	Folia Geobotanica	2.7	60th percentile
☆	#194	Journal of Plant Diseases and Protection	2.7	59th percentile
☆	#195	Plant Sociology	2.7	59th percentile
☆	#196	New Zealand Journal of Forestry Science	2.6	59th percentile
☆	#197	Grassland Science	2.6	59th percentile
☆	#198	Australian Journal of Botany	2.6	59th percentile
☆	#199	Journal of Applied Botany and Food Quality	2.6	58th percentile
☆	#200	Annals of Forest Research	2.5	58th percentile
☆	#201	Phytopathology Research	2.5	58th percentile
☆	#202	Edinburgh Journal of Botany	2.5	58th percentile
☆	#203	Journal of Ethnobiology	2.5	57th percentile
☆	#204	Acta Agrobotanica	2.5	57th percentile
☆	#205	Acta Botanica Hungarica	2.5	57th percentile
☆	#206	Genetica	2.5	57th percentile
☆	#207	Tropical Plant Biology	2.4	57th percentile
☆	#208	Acta Societatis Botanicorum Poloniae	2.4	56th percentile
☆	#209	Lindbergia	2.4	56th percentile
☆	#210	Phytoparasitica	2.4	56th percentile
☆	#211	Tuexenia	2.4	56th percentile
☆	#212	Gayana - Botanica	2.3	56th percentile
☆	#213	Comparative Cytogenetics	2.3	55th percentile
☆	#214	International Journal of Vegetable Science	2.3	55th percentile
☆	#215	Botany	2.3	55th percentile
☆	#216	Russian Journal of Plant Physiology	2.3	55th percentile
☆	#217	Acta Botanica Croatica	2.3	55th percentile
☆	#218	Willdenowia	2.2	54th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#219	Horticulture Journal	2.2	54th percentile
☆	#220	Bulletin of the Peabody Museum of Natural History	2.2	54th percentile
☆	#221	Dendrobiology	2.2	54th percentile
☆	#222	PhytoKeys	2.1	54th percentile
☆	#223	Journal of Plant Biochemistry and Biotechnology	2.1	53rd percentile
☆	#224	Biotechnology, Agronomy and Society and Environment	2.1	53rd percentile
☆	#224	Plant Ecology and Evolution	2.1	53rd percentile
☆	#226	Journal of General Plant Pathology	2.1	53rd percentile
☆	#227	Agricultural Research	2.1	53rd percentile
☆	#228	Journal of Crop Science and Biotechnology	2.1	52nd percentile
☆	#229	Grana	2.1	52nd percentile
☆	#230	Plant Physiology Reports	2.1	52nd percentile
☆	#231	Acta Biologica Cracoviensia Series Botanica	2.1	52nd percentile
☆	#232	Revista Brasileira de Botanica	2.1	51st percentile
☆	#233	Biologia (Poland)	2.1	51st percentile
☆	#234	Plant Breeding and Biotechnology	2.1	51st percentile
☆	#235	Blumea: Journal of Plant Taxonomy and Plant Geography	2.0	51st percentile
☆	#236	Pakistan Journal of Botany	2.0	51st percentile
☆	#237	Mediterranean Botany	2.0	50th percentile
☆	#237	Urban Agriculture and Regional Food Systems	2.0	50th percentile
☆	#239	Nova Hedwigia	2.0	50th percentile
☆	#240	Natural Product Communications	2.0	50th percentile
☆	#241	Plant Species Biology	2.0	50th percentile
☆	#242	Czech Journal of Genetics and Plant Breeding	2.0	49th percentile
☆	#243	Ethnobiology and Conservation	2.0	49th percentile
☆	#244	Tropical Ecology	2.0	49th percentile
☆	#245	Eurasian Journal of Soil Science	1.9	49th percentile
☆	#246	Plant Biotechnology	1.9	49th percentile
☆	#247	New Zealand Journal of Botany	1.9	48th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#248	Invasive Plant Science and Management	1.9	48th percentile
☆	#249	Annali di Botanica	1.9	48th percentile
☆	#250	Tropical Grasslands - Forrajes Tropicales	1.9	48th percentile
☆	#251	Notulae Botanicae Horti Agrobotanici Cluj-Napoca	1.9	48th percentile
☆	#252	Systematic Botany	1.9	47th percentile
☆	#253	EPPO Bulletin	1.9	47th percentile
☆	#254	USDA Forest Service - General Technical Report RMRS-GTR	1.9	47th percentile
☆	#255	Phytotaxa	1.8	47th percentile
☆	#256	Horticulturae	1.8	46th percentile
☆	#257	Plant Health Progress	1.8	46th percentile
☆	#258	Journal of Plant Pathology	1.8	46th percentile
☆	#259	Reference Series in Phytochemistry	1.8	46th percentile
☆	#260	Journal of Biologically Active Products from Nature	1.8	46th percentile
☆	#261	International Journal of Fruit Science	1.8	45th percentile
☆	#262	Biodiversity Data Journal	1.8	45th percentile
☆	#263	Revista Brasileira de Fruticultura	1.8	45th percentile
☆	#264	Allelopathy Journal	1.8	45th percentile
☆	#265	Journal of Plant Protection Research	1.7	45th percentile
☆	#266	Biodiversitas	1.7	44th percentile
☆	#267	Agrosystems, Geosciences and Environment	1.7	44th percentile
☆	#267	Rodriguesia	1.7	44th percentile
☆	#269	Karstenia	1.7	44th percentile
☆	#270	Kew Bulletin	1.7	44th percentile
☆	#271	Journal of Plant Nutrition and Fertilizers	1.7	43rd percentile
☆	#272	Journal of Asia-Pacific Biodiversity	1.7	43rd percentile
☆	#273	Bothalia	1.7	43rd percentile
☆	#274	Chinese Journal of Eco-Agriculture	1.7	43rd percentile
☆	#275	Planta Daninha	1.7	43rd percentile
☆	#276	Ecologica Montenegrina	1.7	42nd percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#277	Chinese Journal of Plant Ecology	1.7	42nd percentile
☆	#278	Journal of the Indian Academy of Wood Science	1.6	42nd percentile
☆	#279	Canadian Journal of Plant Science	1.6	42nd percentile
☆	#280	Webbia	1.6	42nd percentile
☆	#281	Revista de la Facultad de Ciencias Agrarias	1.6	41st percentile
☆	#282	Agriculture	1.6	41st percentile
☆	#283	Forest Products Journal	1.6	41st percentile
☆	#284	South African Journal of Plant and Soil	1.6	41st percentile
☆	#285	Plant and Fungal Systematics	1.6	40th percentile
☆	#286	Nordic Journal of Botany	1.6	40th percentile
☆	#287	Acta Mycologica	1.6	40th percentile
☆	#288	Israel Journal of Plant Sciences	1.6	40th percentile
☆	#289	Chinese Journal of Rice Science	1.6	40th percentile
☆	#290	Brittonia	1.5	39th percentile
☆	#291	Ethnobotany Research and Applications	1.5	39th percentile
☆	#292	Journal of Apicultural Science	1.5	39th percentile
☆	#293	Cryptogamie, Bryologie	1.5	39th percentile
☆	#294	Journal of the Professional Association for Cactus Development	1.5	39th percentile
☆	#295	Herba Polonica	1.5	38th percentile
☆	#296	Ornamental Horticulture	1.5	38th percentile
☆	#297	Boletin Latinoamericano y del Caribe de Plantas Medicinales y Aromaticas	1.5	38th percentile
☆	#298	New Disease Reports	1.5	38th percentile
☆	#299	Haseltonia	1.5	38th percentile
☆	#300	Plant OMICS	1.4	37th percentile
☆	#301	Current Research in Environmental and Applied Mycology	1.4	37th percentile
☆	#302	Horticultura Brasileira	1.4	37th percentile
☆	#303	Cytologia	1.4	37th percentile
☆	#304	Botanica Pacifica	1.4	37th percentile
☆	#305	Hellenic Plant Protection Journal	1.4	36th percentile

☆	Rank	Source title	CiteScore 2021	Percentile
☆	#306	Novosti Sistematiki Nizshikh Rastenii	1.4	36th percentile
☆	#307	Beitrage zur Tabakforschung International/ Contributions to Tobacco Research	1.4	36th percentile
☆	#308	Australasian Plant Disease Notes	1.4	36th percentile
☆	#309	Journal of Plant Biotechnology	1.4	35th percentile
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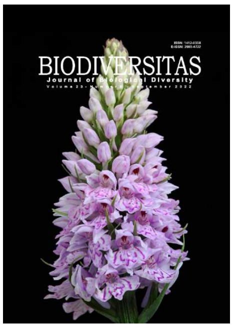

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ADDRESS:

Sebelas Maret University
Jl. Ir. Sutami 36A Surakarta 57126. Tel. +62-271-7994097, Tel. & Fax.: +62-271-663375, email: editors@smujo.id

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