The influence of land covers on soil quality and carbon storage in Moramo Education Estate, South Sulawesi

By Pandu Yudha Adi Putra Wirabuana

The influence of land covers on soil quality and carbon storage in Moramo Education Estate, South Sulawesi

SYAMSU ALAM[1], SAHTA GINTING[1], M. TUFAILA HEMON[1], SITTI LEOMO[1], LAODE MUHAMMAD HARJONI KILOWASID[2], JUFRI KARIM[3], YUSANTO NUGROHO[4], JERIELS MATATULA[5], PANDU YUDHA ADI PUTRA WIRABUANA[6,♥]
[1]Department of Soil Science, Faculty of Agriculture, Universitas Halu Oleo, Jl. HEA Mokodompit, Kendari 93231, Southeast Sulawesi, Indonesia
[2]Department of Agrotechnology, Faculty of Agriculture,Universitas Halu Oleo, Jl. H.E.A. Mokodompit, Kendari 93231, Indonesia
[3]Department of Geography, Faculty of Earth Science and Technology, Universitas Halu Oleo, Kendari 93231, Indonesia
[4]Faculty of Forestry, Universitas Lambung Mangkurat. Jl. A. Yani, Banjarbaru 70714, South Kalimantan, Indonesia
[5]Forestry Field Program, Politeknik Pertanian Negeri Kupang. Jl. Prof. Herman Johanes, Kupang 85011, East Nusa Tenggara, Indonesia
[6]Department of Forest Management, Faculty of Forestry, Universitas Gadjah Mada, Jl. Agro No.1 Bulaksumur, Yogyakarta 55281, Indonesia
Tel./Fax.: +62-274-548815, ♥email: pandu.yudha.a.p@ugm.ac.id

Manuscript received:………………. Revision accepted: 2021

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 (5[illegible]±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.

Moramo Education Estate (MEE) is a special-purpose area managed by Universitas Halu Oleo in Southeast Sulawesi. It is a natural ecosystems with three land covers variation, including Forests, Shrubs, and Savanna. According to the government policy, MEE will become the priority locations for integrated agriculture development. This area is designed as a research center and site experiment to facilitate the innovation of good agriculture practices (GAP), such as nutrients management, pest and disease control, crop yield estimation, etc. However, this scheme will provide negative impacts on the contribution of MEE in ecological functions since there will be intensive land conversion from natural ecosystems to agricultural land. It will reduce carbon absorption and cause inbalance nutrients cycle. Therefore, a preliminary study about the soil quality variation and carbon storage distribution at diffferent land covers in MEE is required to determine an optimum scenario of land transition. This information will help the managers to formulate the 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 to evaluate the effect of land covers on soil quality and carbon storage in the MEE. The primary focus of research is 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 basis consideration to select the priority land cover for agriculture development without sacrificing ecological function of MEE.

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%).

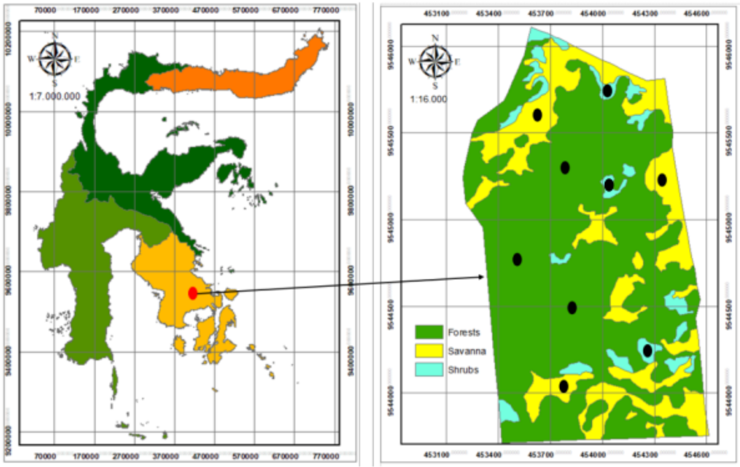

Figure 1. The study site of Moramo Education Estate in South Konawe. Black circles indicated sampling plots for data collection.

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-plot 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)	Exec-K (meq 100g^{-1})	CEC (meq 100g^{-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
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
Shrubs	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}). As one of the soil macronutrients, the availability of potassium in the study location is highly low because the soil type is categorized into ultramafic soils. It is a mature soil with low nutrient availability due to the impact of intesive weathering process for long periods. Therefore, the potassium supply in this soil commonly comes from litterfall decomposition. This also confirmed why Forests indicated higher Exc-K than other land covers.

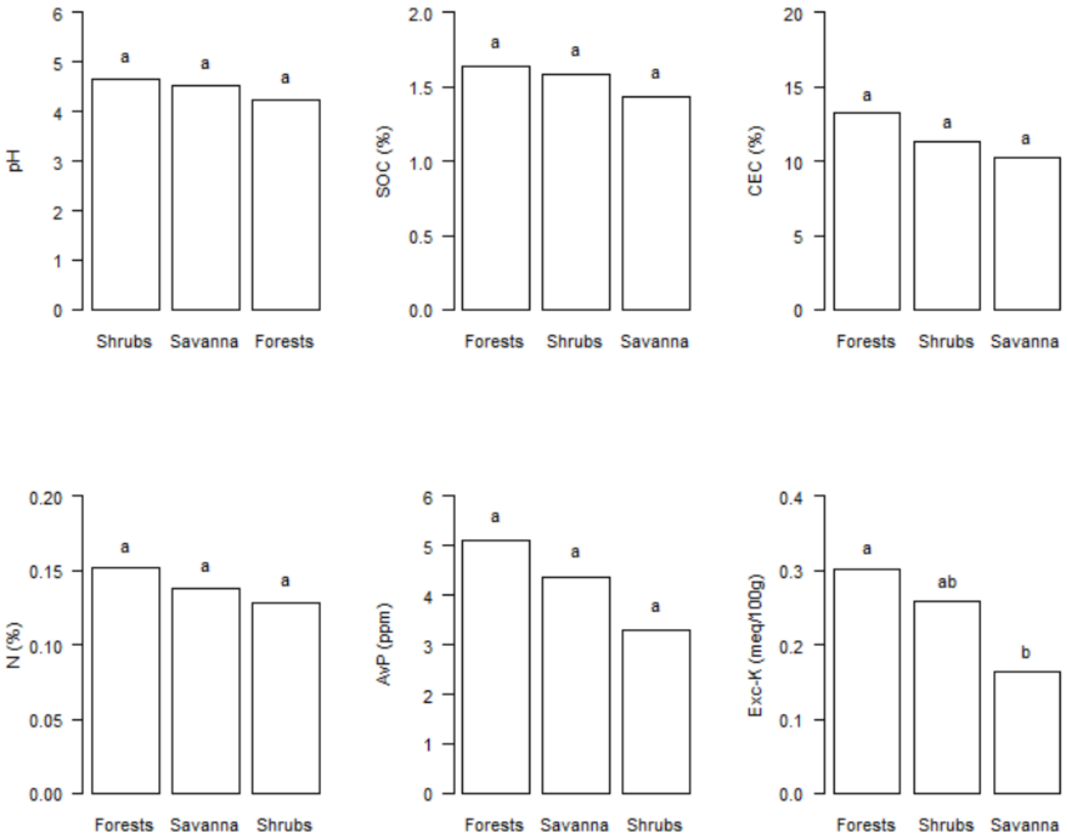

Figure 2. Comparison means soil quality among land covers. A similar letter above the bar graph indicated not a significantly different.

The higher availability nutrients in Forests 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 literatu[illegible]onfirm 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.

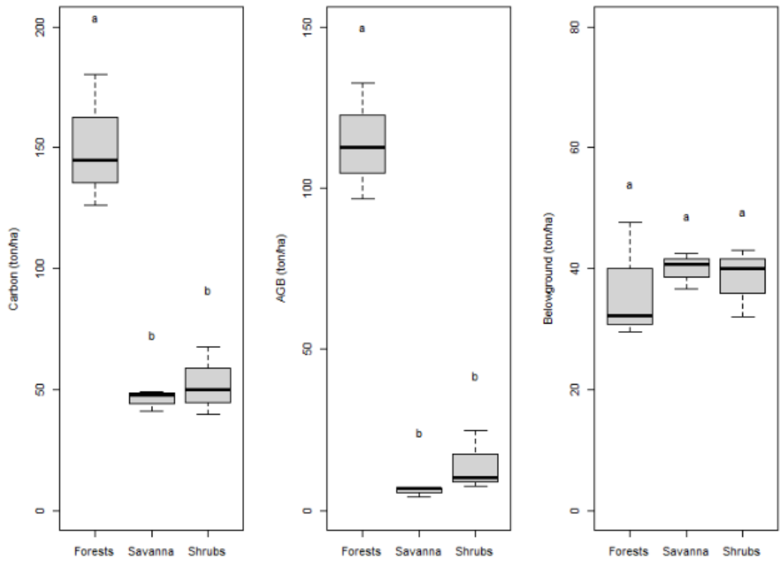

Figure 3. Comparison means carbon storage among land covers. A similar letter above the boxplot indicated not a significantly different.

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	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} (non-significant different),
* (significantly 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.

ACKNOWLEDGEMENTS

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

REFERENCES

Alam S, Purwanto BH, Hanudin EKO, Tarwaca EKA, Putra S. 2020. Soil diversity influences on oil palm productivity in ultramafic ecosystems , Southeast Sulawesi , Indonesia. Biodiversitas J. Biol. Divers. 21: 5521–5530. https://doi.org/10.13057/biodiv/d211161

Amelung W, Bossio D, Vries W, Kögel-Knabner I, Lehmann J, Amundson R, Bol R, Collins C, Lal R, Leifeld J, Minasny B, Pan G, Paustian K, Rumpel C, Sanderman J, Groenigen JW, Mooney S, Wesemael B, Wander M, Chabbi A. 2020. Towards a global-scale soil climate mitigation strategy. Nat. Commun. 11: 1–10. https://doi.org/10.1038/s41467-020-18887-7

Bhandari J, Zhang Y. 2019. Effect of altitude and soil properties on biomass and plant richness in the grasslands of Tibet, China, and Manang District, Nepal. Ecosphere 10: 1–18. https://doi.org/10.1002/ecs2.2915

Carstensen A, Herdean A, Schmidt SB, Sharma A, Spetea C, Pribil M, Husted S. 2018. The impacts of phosphorus deficiency on the photosynthetic electron transport chain. Plant Physiol. 177: 271–284. https://doi.org/10.1104/PP.17.01624

Castellini M, Diacono M, Gattullo CE, Stellacci AM. 2021. Sustainable agriculture and soil conservation. Appl. Sci. 11: 11–16. https://doi.org/10.3390/app11094146

Catoni M, D'Amico ME, Zanini E, Bonifacio E. 2016. Effect of pedogenic processes and formation factors on organic matter stabilization in alpine forest soils. Geoderma 263: 151–160. https://doi.org/10.1016/j.geoderma.2015.09.005

Chandra LR, Gupta S, Pande V, Singh N. 2016. Impact of forest vegetation on soil characteristics: a correlation between soil biological and physicochemical properties. 3 Biotech 6: 1–12. https://doi.org/10.1007/s13205-016-0510-y

Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, Fölster H, Fromard F, Higuchi N, Kira T, Lescure JP, Nelson BW, Ogawa H, Puig H, Riéra B, Yamakura T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: 87–99. https://doi.org/10.1007/s00442-005-0100-x

Costa ACS, Junior IGS, Canton LC, Gil LG, Figueiredo R. 2020. Contribution of the chemical and mineralogical properties of sandy-loam tropical soils to the cation exchange capacity. Rev. Bras. Cienc. do Solo 44: 1–18. https://doi.org/10.36783/18069657rbcs20200019

Estefan G, Sommer R, Ryan J. 2013. Methods of soil, plant, and water analysis. International Center for Agriculture Research in the Dry Areas.

Feng J, Ahmed OH, Jalloh MB, Omar L, Kwan YM, Musah AA, Poong KH. 2022. Soil nutrient retention and ph buffering capacity are enhanced by calciprill and sodium silicate. Agronomy 12: 1–24. https://doi.org/10.3390/ agronomy12010219

Gita M. 2020. Role of litter production and its decomposition, and factors affecting the processes in a tropical forest ecosystem: A review. J. Ecol. Environ. 44: 1–9. https://doi.org/10.1186/s41610-020-0151-2

Grussu G. Testolin R. Saulei S, Farcomeni A, Yosi CK, De Sanctis M, Attorre F. 2016. Optimum plot and sample sizes for carbon stock and biodiversity estimation in the lowland tropical forests of Papua New Guinea. Forestry 89: 150–158. https://doi.org/10.1093/forestry/cpv047

Grzyb A, Wolna-Maruwka A, Niewiadomska A. 2020. Environmental factors affecting the mineralization of crop residues. Agronomy 10: 1–18. https://doi.org/10.3390/agronomy10121951

Hannah K. Rahayu S. 2007. Technical guide carbon storage at different land use type. World Agroforestry Centre, Bogor.

Jacoby R, Peukert M, Succurro A, Koprivova A. 2017. The role of soil microorganisms in plant mineral nutrition — current knowledge and future directions. Front. Plant Sci. 8: 1–19. https://doi.org/10.3389/fpls.2017.01617

Latifah S, Sulistiyono N. 2013. Carbon sequestration potential in aboveground biomass of hybrid eucalyptus plantation forest. J. Trop. For. Manag. 19: 54–62. https://doi.org/10.7226/jtfm.19.1.54

Matatula J, Afandi AY, Wirabuana PYAP. 2021. Short communication: A comparison of stand structure, species diversity, and aboveground biomass between natural and planted mangroves in Sikka, East Nusa Tenggara, Indonesia. Biodiversitas J. Biol. Divers. 22: 1098–1103. https://doi.org/10.13057/biodiv/d220303

Miljaković D, Marinković J, Balešević-Tubić S. 2020. The significance of *Bacillus spp*. in disease suppression and growth promotion of field and vegetable crops. Microorganisms 8: 1–19. https://doi.org/10.3390/microorganisms8071037

Purwanto BH, Alam S. 2020. Impact of intensive agricultural management on carbon and nitrogen dynamics in the humid tropics. Soil Sci. Plant Nutr.

66: 50–59. https://doi.org/10.1080/00380768.2019.1705182

Rambey R. Susilowati A. Rangkuti AB. Onrizal O. Desrita, Ardi R, Hartanto A. 2021. Plant diversity, structure and composition of vegetation around barumun watershed, north Sumatra, Indonesia. Biodiversitas J. Biol. Divers. 22: 3250–3256. https://doi.org/10.13057/biodiv/d220819

Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021a. Soil chemical properties influences on the growth performance of *Eucalyptus urophylla* planted in dryland ecosystems, East Nusa Tenggara. J. Degrad. Min. Lands Manag. 8: 2635–2642. https://doi.org/10.15243/jdmlm.2021.082.2635

Sadono R, Wardhana W, Wirabuana PYAP, Idris F. 2021b. Allometric equations for estimating aboveground biomass of *Eucalyptus urophylla* S.T. Blake in East Nusa Tenggara. J. Trop. For. Manag. 27: 24–31. https://doi.org/10.7226/jtfm.27.1.24

Sales GB, Lessa TAM, Freitas DA, Veloso MDM, Silva MLS, Fernandes LA, Frazão LA. 2020. Litterfall dynamics and soil carbon and nitrogen stocks in the Brazilian palm swamp ecosystems. For. Ecosyst. 7: 1–12. https://doi.org/10.1186/s40663-020-00251-2

Schjoerring JK, Cakmak I, White PJ. 2019. Plant nutrition and soil fertility: synergies for acquiring global green growth and sustainable development. Plant Soil 434, 1–6. https://doi.org/10.1007/s11104-018-03898-7

Setiahadi R. 2017. How significant is the existence of forest community contribution in GHG emissions reduction? J. Eng. Appl. Sci. 12: 4826–4830. https://doi.org/10.3923/jeasci.2017.4826.4830

Sugihara S, Shibata M, Mvondo AD, Araki S, Funakawa S. 2014. Effect of vegetation on soil C, N, P and other minerals in Oxisols at the forest-savanna transition zone of central Africa. Soil Sci. Plant Nutr. 60: 45–59. https://doi.org/10.1080/00380768.2013.866523

Taillardat P, Friess DA, Lupascu M. 2018. Mangrove blue carbon strategies for climate change mitigation are most effective at the national scale. Biol. Lett. 14: 1–7. https://doi.org/10.1098/rsbl.2018.0251

Tang G, Li K, Zhang C, Gao C, Li B. 2013. Accelerated nutrient cycling via leaf litter, and not root interaction, increases growth of Eucalyptus in mixed-species plantations with Leucaena. For. Ecol. Manage. 310: 45–53. https://doi.org/10.1016/j.foreco.2013.08.021

Wirabuana PYAP, Sadono R, Juniarso S, Idris, F. 2020a. Interaction of fertilization and weed control influences on growth , biomass , and carbon in eucalyptus hybrid (*E. pellita × E. brassica*). J. Manag. Hutan Trop. 26: 144–154. https://doi.org/10.7226/jtfm.26.2.144

Wirabuana PYAP, Setiahadi R, Sadono R, Lukito M, Martono DS. 2021. The influence of stand density and species diversity into timber production and carbon stock in community forest. Indonesia. J. For. Res. 8: 13–22. https://doi.org/10.20886/ijfr.2021.8.1.13-22

Wirabuana PYAP, Setiahadi R, Sadono R, Lukito M, Martono DS, Matatula J. 2020b. Allometric equations for estimating biomass of community forest tree species in Madiun , Indonesia. Biodiversitas 21, 4291–4300. https://doi.org/10.13057/biodiv/d210947

Xie H, Tang Y, Yu M, Geoff WG. 2021. The effects of afforestation tree species mixing on soil organic carbon stock, nutrients accumulation, and understory vegetation diversity on reclaimed coastal lands in Eastern China. Glob. Ecol. Conserv. 26: 1–14. https://doi.org/10.1016/j.gecco.2021.e01478

The influence of land covers on soil quality and carbon storage in Moramo Education Estate, South Sulawesi

ORIGINALITY REPORT

18%
SIMILARITY INDEX

PRIMARY SOURCES

1	smujo.id Internet	96 words — 3%
2	mail.scialert.net Internet	74 words — 2%
3	jdmlm.ub.ac.id Internet	60 words — 2%
4	biodiversitas.mipa.uns.ac.id Internet	39 words — 1%
5	www.SciRP.org Internet	30 words — 1%
6	www.researchgate.net Internet	25 words — 1%
7	Guofeng Zhu, Dongdong Qiu, Zhuanxia Zhang, Liyuan Sang et al. "Land-use changes lead to a decrease in carbon storage in arid region, China", Ecological Indicators, 2021 Crossref	20 words — 1%
8	www.degruyter.com Internet	19 words — 1%

9	www.mdpi.com Internet	17 words — < 1%
10	Nugroho, W. D., S. Nakaba, Y. Yamagishi, S. Begum, S. N. Marsoem, J.-H. Ko, H.-O. Jin, and R. Funada. "Gibberellin mediates the development of gelatinous fibres in the tension wood of inclined Acacia mangium seedlings", Annals of Botany, 2013. Crossref	13 words — < 1%
11	Anup Das, Rattan Lal, Upender Somireddy, Catherine Bonin, Sudhir Verma, Basant Kumar Rimal. "Changes in soil quality and carbon storage under biofuel crops in central Ohio", Soil Research, 2016 Crossref	12 words — < 1%
12	Siti Maimunah, Ilham Hanafi, Subhan, Ashabul Anhar, Jay H. Samek. "An assessment of tree biodiversity and carbon stocks in mangrove forests, Langsa City, Aceh, Indonesia", IOP Conference Series: Earth and Environmental Science, 2021 Crossref	12 words — < 1%
13	journal.ipb.ac.id Internet	12 words — < 1%
14	Monika Chauhan, Munesh Kumar, Amit Kumar. "Impact of Carbon Stocks of Anogeissus latifolia on Climate Change and Socioeconomic Development: a Case Study of Garhwal Himalaya, India", Water, Air, & Soil Pollution, 2020 Crossref	11 words — < 1%
15	llufb.llu.lv Internet	11 words — < 1%

16 Hiltner, Ulrike. "Analysing the Consequences of Forest Management and Climate Change on Tropical Forest Dynamics Using Empirical Data and Model Simulations.", Friedrich-Alexander-Universitaet Erlangen-Nuernberg (Germany), 2021
ProQuest
10 words — < 1%

---

17 docplayer.net
Internet
10 words — < 1%

---

18 dspace.uevora.pt
Internet
10 words — < 1%

---

19 link.springer.com
Internet
10 words — < 1%

---

20 "Augstuma pieauguma mainība parastās egles (Picea abies (L.) H. Karst.) Tīraudzēs juvenilā vecumā = Variation of height growth of young pure Norway spruce (Picea abies (L.) H. Karst.) Stands", Latvia University of Life Sciences and Technologies, 2020
Crossref Posted Content
9 words — < 1%

---

21 Chunhua Zhang, Guoyong Tang, Yongyu Sun. "Asymmetric and Symmetric Warming–Induced Stability of Organic Carbon in a Calcareous Soil", Soil Science Society of America Journal, 2019
Crossref
9 words — < 1%

---

22 Kirby, K.R.. "Variation in carbon storage among tree species: Implications for the management of a small-scale carbon sink project", Forest Ecology and Management, 20070731
Crossref
9 words — < 1%

---

23 Tolbert, V.. "Guest editorial", Biomass and Bioenergy, 19980401
9 words — < 1%

Crossref

---

24 managementjournal.usamv.ro 9 words — < 1%
Internet

---

25 Gregory P. Asner. "Effects of Morella faya tree invasion on aboveground carbon storage in Hawaii", Biological Invasions, 03/01/2009 8 words — < 1%
Crossref

---

26 R Rambey, A S J Lubis, A Susilowati, A B Rangkuti, Onrizal, N Wijayanto, I Z Siregar. "Plant diversity components of agroforestry in Tanjung Botung, Village, Barumun District, Padang Lawas Regency, North Sumatra", IOP Conference Series: Earth and Environmental Science, 2022 8 words — < 1%
Crossref

---

27 Razie Sanji, Yahya Kooch, Ana Rey. "Impact of forest degradation and reforestation with Alnus and Quercus species on soil quality and function in northern Iran", Ecological Indicators, 2020 8 words — < 1%
Crossref

---

28 Vagen, T.G.. "Sensing landscape level change in soil fertility following deforestation and conversion in the highlands of Madagascar using Vis-NIR spectroscopy", Geoderma, 200608 8 words — < 1%
Crossref

---

29 erepository.uoeld.ac.ke 8 words — < 1%
Internet

---

30 repositorio.unb.br 8 words — < 1%
Internet

---

31 "Conservation Agriculture: A Sustainable Approach for Soil Health and Food Security", Springer Science and Business Media LLC, 2021 7 words — < 1%

Crossref

32	"Soils, Ecosystem Processes, and Agricultural Development", Springer Science and Business Media LLC, 2017 Crossref	7 words — < 1%
33	pubag.nal.usda.gov Internet	5 words — < 1%

EXCLUDE QUOTES	ON	EXCLUDE SOURCES	OFF
EXCLUDE BIBLIOGRAPHY	ON	EXCLUDE MATCHES	OFF