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Correlation between Soil Carbon Potential and Soil Quality Index in Various Types of Dry Land Use in Aceh Besar District

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ABSTRACT

Soil quality is a useful concept when assessing the sustainability of an agricultural business and demonstrating the ability of soil to maintain plant and animal productivity, improve water and air quality, and to protect human health. SQI is a soil variable with the following characteristics: 1) well correlated with ecosystem processes; 2) integration of physical, chemical and biological soil properties; 3) good sensitivity to human-induced soil changes; 4) simple measurement and interpretation; and 5) Reproducibility Soil quality index (SQI) is a diagnostic procedure to evaluate soil function and overall health. This research was carried out on a unit of land in a dry area in Aceh Besar District with a study area of 239,439.63 ha. Analysis of biomass samples and soil samples was carried out at the Laboratory of Soil and Plant Sciences and Soil Physics Laboratory, Faculty of Agriculture, University of Syiah Kuala. The tools used in this study include a set of computers with the Microsoft Windows 10 operating system that are equipped with several software for analysis, writing instruments, and other supporting tools. The main materials used in this study were soil samples, tree diameter measurement data, and land use maps, including geology, climate, slope class, soil, and topography. The results of the correlation analysis test showed a value of 0.6358. This shows that the relationship between soil C potential and soil quality index is in a strong correlation. The distribution of carbon in the soil also has a close relationship with the soil quality index and as an effort to maintain carbon stocks in the soil. C - organic content is a very important parameter in compiling soil quality index criteria. Soil quality can be affected by many factors, such as: parent material, environmental factors, land use type and human activities. The percentage of soil organic C is an indicator of the percentage of soil organic matter (BOT), BOT is able to improve soil structure and aggregates. Soil organic carbon (SOC) concentration is closely related to soil quality and vegetation productivity. This relationship occurs because of the many contributions of soil carbon to soil properties such as improvement of soil structure and water retention, provision of cation exchange capacity and supply of plant nutrients through mineralization. This effect is especially important in small-scale tropical farming systems where use of external inputs is often limited, and SOC concentrations have been positively correlated with yield levels for a variety of tropical soils.

Keywords: *Soil carbon, Corelations, Soil Quality Index, dry land, land use type*

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1. INTRODUCTION

Soil and plants are two key elements of terrestrial ecosystems (Jiao et al., 2014), and interactions between plants and soil are very important in carrying out ecosystem functions (Jiao et al., 2014). Vegetation and soil both interact by means of feedback mechanisms in the plant-soil system (Jiao et al., 2014; Mora & Lázaro, 2013). Feedback mechanisms can be seen in plants that grow in extreme environments. In the arid (including hyper-arid) and semi-arid zones, which cover about 36% of the global land area (Yang & Williams, 2015), the highly variable vegetation structure is the result of feedbacks between plants and soil that occur in these areas. river flow (Liu et al., 2019).

Changes in land use that are not suitable can cause damage to natural ecosystems, soil erosion, land degradation, and poor soil quality (Bruun et al., 2015). Several studies have shown that land degradation caused by unwanted land use changes negatively affects soil attributes as well as soil quality and health (Pirastru et al., 2013); Toohey et al., 2018). The pattern of conversion of primary forest to agricultural land causes loss of soil organic carbon (SOC) and this can have a direct negative impact on soil quality indicators by affecting soil physical, chemical, biological properties (Qi et al., 2018; Sun et al., 2015; Tellen & Yerma, 2018). Soil organic carbon plays a key role in determining soil aggregates, increasing pore space and connectivity, increasing air and water infiltration, and decreasing soil erodibility. In addition, KOT directly affects the stability and size distribution of soil aggregates (Karami et al., 2012). Loss of KOT will lead to a decrease in aggregate stability, total porosity and water storage as well as an increase in soil density. This will tend to reduce soil infiltration, hydraulic conductivity and water availability (Ghorbani-Dashtaki et al., 2016). Among the different sizes of aggregates present in the soil, macro-aggregates are very sensitive to disturbances such as changes in land use and cultivation practices of agricultural cultivation. In addition, the loss of KOT through cultivation is related to the destruction of macro aggregates. Soil becomes more susceptible to erosion when the macro aggregates are disturbed. Furthermore, planting and tillage practices can result in a 7 and 21-fold increase in surface runoff and soil erosion (Davari et al., 2020).

Land use change is one of the most important human activities affecting ecosystem function and impacting soil quality and health. Thus, tropical agriculture has a direct impact on the chemical, physical, and biological properties of soil when compared to native cover soils. In addition, soil texture is largely determined by the granulometric fraction which influences soil function to change the intensity of soil ecological processes (Vinhal-Freitas et al., 2017).

In general, soil quality is the ability of the soil to provide nutrients for plants, maintain and improve water and air in the soil, and support human needs. Today, soil quality is rapidly declining in many areas around the world. There are many reasons for the decline in soil quality, including changes in land use from forest to agricultural land and the consequences of intensive land use (Jamala, 2013). Improvements in soil quality due to different types of land use or crop rotation can be measured by changes in soil indicators and other parameters. Various studies have been conducted to evaluate soil quality indicators such as different land use types (Kalu et al., 2015). The most popular indicators used to assess soil quality are soil organic carbon (SOC), total nitrogen (TN) and soil acidity (pH). SOC is very important for soil fertility and is a strong indicator of the health of soil biological, chemical and physical processes. Total nitrogen is the main nutrient used for vegetation growth and is also used as a key quality assessment (Ren et al., 2014). Soil pH is one of the most important and important soil parameters for agricultural production. Most agricultural plants develop best in soils with a pH from 5.5 to 6.5 (Pham et al., 2018).

High soil fertility indicates high soil quality. Soil quality is the capacity of the soil which functions to maintain plant productivity, maintain and maintain water availability and support human activities. Good soil quality will support the function of the soil as a medium for plant growth, regulate and distribute water flow and support a good environment as well. Soil quality is measured based on observations of the dynamic conditions of soil quality indicators. Measurement of soil quality indicators produces a soil quality index. The soil quality index is an index calculated based on the value and weight of each soil quality indicator. Soil quality indicators are selected from the properties that indicate the functional capacity of the soil. Soil quality indicators are the properties, characteristics or physical, chemical and biological processes of the soil that can describe soil conditions. Soil quality indicators must (1) show the processes that occur in ecosystems, (2) combine soil physical properties, soil chemistry and soil biological processes, (3) be accepted by many users and can be applied in various land conditions, (4) sensitive to various variations in soil management and climate change, and (5) whenever possible, these characteristics are components that are commonly observed in basic soil data (Juarti, 2016). Soil quality is a useful concept when assessing the sustainability of an agricultural business and demonstrating the soil's ability to nourish crops and

animal productivity, improve water and air quality, and to protect human health. SQI is a soil variable with the following characteristics: 1) well correlated with ecosystem processes; 2) integration of physical, chemical and biological soil properties; 3) good sensitivity to human-induced soil changes; 4) simple measurement and interpretation; and 5) reproducibility (Sione et al., 2017). Soil quality index (SQI) is a diagnostic procedure to evaluate soil function and overall health. SQI usually integrates physical, biological, and chemical properties into a single numerical weight. The soil properties selected must be relevant to the soil process, consistent, reproducible, and relatively easy and affordable for sampling. The physical properties examined for assessing the success of restoration are related to soil structure, and include texture, specific gravity, water holding capacity, infiltration rate, penetration resistance, available moisture content, and aggregate stability. Biological properties refer to macro and micro organisms in the soil, such as microbial biomass, respiration, community composition, and enzymatic activity, as well as processes related to soil organic matter and activated carbon (Abdullah, Endiyani, et al., 2022). This research is the basis of a study conducted by Lubis & Rusdiana, (2013) regarding the estimation of the correlation between soil characteristics and carbon stocks in secondary forests. Therefore it is necessary to study the correlation between the potential of soil carbon and the index of soil quality in various types of dry land use in Aceh Besar district.

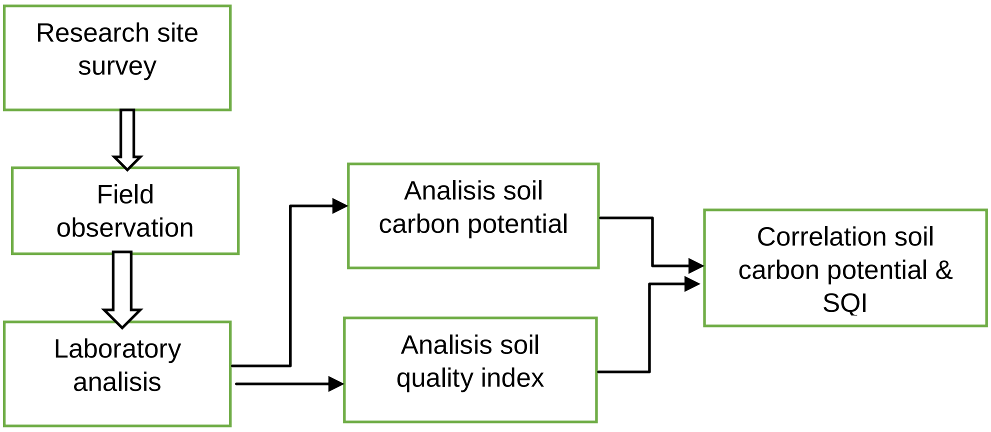
2. MATERIALS AND METHODS

This research was carried out on a unit of land in a dry area in Aceh Besar District with a study area of 239,439.63 ha. Analysis of biomass samples and soil samples was carried out at the Laboratory of Soil and Plant Sciences and Soil Physics Laboratory, Faculty of Agriculture, University of Syiah Kuala.

The tools used in this study included a set of computers with the Microsoft Windows 10 operating system equipped with several software for analysis, writing tools, and other supporting tools such as GPS, 30 m tape measure, sewing tape, compass, earth ring, drill. soil, oven, scales, tally sheets, label paper, plastic bags, brown envelopes, calculator, machete, and knife. Some of the software used are: a. Microsoft Office Excel 2010 for calculations and tabulations. b. Statistical Package for the Social Sciences 25 (SPSS 25) for analysis of the correlation between soil characteristics studied and carbon stored. The main materials used in this study were soil samples, tree diameter measurement data, and land use maps, including geology, climate, slope class, soil, and topography.

The plots were determined and made five plots measuring 20 m x 20 m. The plots were used for measurements of vegetation such as stakes, poles, trees and soil samples. Meanwhile, for the sampling of undergrowth and seedlings, ten sub-plots were made with a size of 1 m x 1 m. The vegetation in the plots was measured as a whole or a census of saplings, poles and trees. Dimensions measured were diameter at breast height (DBH = 1.3 m from the ground), total height and branch-free height. Sampling of Undergrowth and Litter. All undergrowth and litter above the soil surface in the 1 m x 1 m sub-plot were taken and weighed to determine the wet weight. After that, the undergrowth and litter were put into a brown envelope, then heated in the oven to determine the dry weight and moisture content.

Soil samples were taken using two methods: 1. Disturbed (composite) soil samples and 2. Undisturbed (intact) soil samples. oven. Baking is carried out to find the dry weight and moisture content of the undergrowth and litter at 800 C for 48 hours. If the wet weight of the sample to be baked in the oven is less than 200 grams, then the wet weight is the weight. Meanwhile, if the wet weight is more than 200 grams, then the wet weight taken is as much as 200 grams. Not only understoreys and litter in the oven, but also undisturbed soil samples in the oven. This undisturbed soil sample was carried out to obtain the dry weight, bulk density, and soil porosity. The soil samples were left undisturbed in the oven at 1050C for 24 hours. Then the samples were weighed as dry weight and ring weight. This data will be used to obtain bulk density and soil porosity. Estimation of Standing Biomass and Carbon. Estimation of standing biomass was carried out using a non-destructive method using allometric equations that have been tested based on previous studies (Lubis & Rusdiana, 2013).



Picture 1. Flowchart of the research implementation process correlation relationship between soil carbon potential and soil quality index

To see the criteria for the correlation test analysis can be seen in Table 1 (Leonardo Manurung & Dewanto, 2021).

Table 1. Correlation test analysis criteria.

No.	Correlation value	Information
1	0	There is no correlation between the two variables
2	> 0 – 0,25	The correlation is very weak
3	> 0,25 – 0,5	Correlation enough
4	> 0,50 – 0,75	Strong correlation
5	> 0,75 – 0,99	The correlation is very strong
6	= 1	The perfect correlation is positive
7	= -1	Negative perfect correlation

3. RESULTS AND DISCUSSION

Table 2. Correlation Analysis between Soil C Potential and Soil Quality Index

No	TPL	Potency C 0- 30 cm	IKT
1	Primary forest	207.798	0.7630
		204.452	0.7101
		201.106	0.7644
2	Secondary forest	73.268	0.6737
		74.294	0.6692
		70.856	0.6406
3	Pine forests	61.4295	0.6271
		57.741	0.5972
		64.506	0.5913
4	Eucalyptus forest	70.414	0.6396
		69.236	0.5929
		71.592	0.5899
5	Teak forest	55.3875	0.5471
		57.148	0.5390
		53.246	0.5025
6	Forest bush	42.800	0.6298
		43.524	0.6477
		44.248	0.6291
7	Shrubs	44.862	0.5393
		45.396	0.4303
		44.328	0.4895
8	Reeds	72.8145	0.5831
		73.9805	0.5867
		71.6485	0.5923
9	Mixed garden	65.720	0.4542
		68.152	0.6121
		67.912	0.4220
10	Moor	40.811	0.4566
		41.632	0.5081
		42.453	0.4716
11	Rainfed fields	31.882	0.5966
		32.833	0.5946
		30.931	0.6073
12	Open field	40.963	0.5650
		40.119	0.5673
		41.807	0.5503

Table 3. Correlation Value between Soil C Potential with Soil Quality Index

	C Land 0 -30 cm	Soil Quality Index
Potency C Tanah 0 – 30 cm	1	
Soil Quality Index	0.6358	1

In Tables 2 and 3 it can be seen that the results of the correlation analysis test show a value of 0.6358. This shows that the relationship between soil C potential and soil quality index is in a strong correlation. The distribution of carbon in the soil also has a close relationship with the soil quality index (Martunis, 2016; Sufardi et al., 2020) and as an effort to maintain carbon stocks in the soil (Marín-Spiotta & Sharma, 2013). C - organic content is a very important parameter in compiling soil quality index criteria (Hamdi et al., 2021). Soil quality can be affected by many factors, such as: parent material, environmental factors, land use type and human activities (Hao et al., 2020). The percentage of soil organic C is an indicator of the percentage of soil organic matter (BOT), BOT is able to improve soil structure and aggregates. An increase in the BOT content which functions as a binder in the formation of soil aggregates can cause more space between aggregates (macro pores) and pore space in the aggregate (micro pores) to form more so that the aeration pores and available water pores of the soil increase with the amount of BO content. So that the correlation between soil C-organic and unit weight is negative (Pramono & Prahesti, 2016), (Kurniawan et al., 2021). The results of research by Saifulloh et al., (2017) suggested that the soil quality parameters which were the limiting factors in mixed garden land in Tegallalang District were low soil texture, C-Organic, CEC, KB, N and C-biomass. The recommended land management guidelines for mixed gardens to improve soil quality in the Tegallalang sub-district are a tillage system with a hoe, as well as the addition of organic matter, Urea fertilizer and the addition of dolomite. The low organic C content in the soil is due to the lack of input of organic matter given to the soil. Organic matter functions in improving the overall soil properties including the physical, chemical and biological properties of the soil. According to (Arifin et al., 2017) that soil with high organic matter content and quality will provide better conditions for plant growth and development. This is related to the role of organic matter in improving the physical, chemical and biological properties of soil. Its role in physical properties involves maintaining stability, improving the distribution of pore sizes and the capacity of soil to store water, and increasing water retention.

Soil organic carbon (SOC) concentration is closely related to soil quality and vegetation productivity. This relationship occurs because of the many contributions of soil carbon to soil properties such as improvement of soil structure and water retention, provision of cation exchange capacity and supply of plant nutrients through mineralization. This effect is especially important in small-scale tropical farming systems where use of external inputs is often limited, and SOC concentrations have been positively correlated with yield levels for a variety of tropical soils. The maintenance of SOC ponds plays an important role not only in advancing food security in developing countries but also in terms of future net carbon budgets whereby small changes in the size of the SOC pool can change atmospheric CO2 concentrations (Bruun et al., 2015). Soil type and soil depth affect soil volume weight, % soil carbon, carbon potential and soil carbon stock. Efforts to manage land use in an effort to improve soil SOC need to be carried out and carried out thoroughly with various parties. Dry land management efforts in Aceh Besar district also serve to preserve the environment and keep the carbon cycle in good condition. Therefore, it is necessary to maintain the availability of soil carbon stocks for sustainable land management, including in the agricultural aspect (Abdullah, Sufardi, et al., 2022).

SOC and phosphorus levels are two important indicators in determining soil quality. Soil quality, in turn, has different roles in nutrient cycling, depending on the biophysical conditions of the site and soil management factors (Schröder et al., 2016). While soil quality is determined by many other internal and external factors, and its assessment depends on the purpose of the evaluation, phosphorus content and SOC level are among the soil properties most assessed in soil quality evaluation and monitoring. Underground biodiversity, an important constituent of soil quality and a supplier of genetic diversity in general, is directly conditioned by the amount of decomposed and transformed organic matter in the soil. The higher the soil organic matter content in organic farming systems which can cause the soil to hold more water which results in better crop yields during droughts, reduces soil erosion, increases plant nutrient retention and increases biodiversity. The higher the soil organic matter content causes greater soil nitrogen retention, greater microbial biodiversity, and increases the presence and growth of arbuscular mycorrhizal fungi that penetrate plant roots and facilitate the movement of plant nutrients from soil to plant crops resulting in better plant growth and yields. Carbon levels Higher soils also hold soil particles together so that less soil erosion occurs (Pimentel & Burgess, 2013; Hagyó & Tóth, 2018).

Soil organic matter provides the basis for productive organic farming and sustainable farming systems. The abundance of soil organic matter and water in organic farming systems makes the soil more tolerant to drought. Large amounts of soil organic matter significantly increase soil biodiversity. Soil organic matter is an important source of nutrients and can help increase biodiversity providing important ecological services, increasing plant protection and nutrient recycling. For example adding compost and other organic matter to the soil reduces the incidence of plant diseases, and increases the number of soil microbial species. Organic farming systems can avoid the use of toxic pesticides and commercial fertilizers, minimizing the harmful effects of these chemicals on soil organisms (Pimentel & Burgess, 2013).

4. CONCLUSIONS

The results of the correlation analysis test showed a value of 0.6358. This shows that the relationship between soil C potential and soil quality index is in a strong correlation. The distribution of carbon in the soil also has a close relationship with the soil quality index and as an effort to maintain carbon stocks in the soil. C - organic content is a very important parameter in compiling soil quality index criteria. Soil quality can be affected by many factors, such as: parent material, environmental factors, land use type and human activities. The percentage of soil organic C is an indicator of the percentage of soil organic matter (BOT), BOT is able to improve soil structure and aggregates. Soil organic carbon (SOC) concentration is closely related to soil quality and vegetation productivity. This relationship occurs due to the many contributions of soil carbon to soil properties such as improvement of soil structure and water retention, provision of cation exchange capacity and supply of plant nutrients through mineralization.

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REFERENCES

Abdullah, U. H., Endiyani, E., Agustina, S., Irhami, I., Anwar, C., & Irmayanti, I. (2022). Analysis of Soil Quality Index type of land use on dry land in Blang Bintang sub-district, Aceh Besar Regency. *Jurnal Agronomi Tanaman Tropika*, *4*(1), 194–206.

Abdullah, U. H., Sufardi, S., Syafruddin, S., & Arabia, T. (2022). Soil organic carbon of grassland and bush forest on dryland in Aceh Besar District, Indonesia. *Biodiversitas*, *23*(5), 2594–2600. https://doi.org/10.13057/biodiv/d230541

Arifin, Z., Susilowati, L. E., & Kusuma, B. H. (2017). Perubahan indeks kualitas tanah di lahan kering akibat masukan pupuk anorganik- organik. *Jurnal Agroteksos*, *26*(2), 1–17. https://agroteksos.unram.ac.id/index.php/Agroteksos/article/view/81

Bruun, T. B., Elberling, B., de Neergaard, A., & Magid, J. (2015). Organic carbon dynamics in different soil types after conversion of forest to agriculture. *Land Degradation and Development*, *26*(3), 272–283. https://doi.org/10.1002/ldr.2205

Davari, M., Gholami, L., Nabiollahi, K., Homaee, M., & Jafari, H. J. (2020). Deforestation and cultivation of sparse forest impacts on soil quality (case study: West Iran, Baneh). *Soil and Tillage Research*, *198*(November 2019), 104504. https://doi.org/10.1016/j.still.2019.104504

Ghorbani-Dashtaki, S., Homaee, M., & Loiskandl, W. (2016). Towards using pedotransfer functions for estimating infiltration parameters. *Hydrological Sciences Journal*, *61*(8), 1477–1488. https://doi.org/10.1080/02626667.2015.1031763

Hagyó, A., & Tóth, G. (2018). The impact of environmental policy on soil quality: Organic carbon and phosphorus levels in croplands and grasslands of the European Natura 2000 network. *Journal of Environmental Management*, *223*(May), 9–15. https://doi.org/10.1016/j.jenvman.2018.06.003

Hamdi, F. H., Juniarti, J., & Agustian, A. (2021). Indeks Kualitas Tanah Pada Satuan Lahan Yang Ditanami

Jagung Di Kenagarian Mungka, Kabupaten Lima Puluh Kota. *Jurnal Tanah Dan Sumberdaya Lahan*, *8*(2), 553–560. https://doi.org/10.21776/ub.jtsl.2021.008.2.25

Hao, H. xin, Wei, Y. jie, Cao, D. ni, Guo, Z. lu, & Shi, Z. hua. (2020). Vegetation restoration and fine roots promote soil infiltrability in heavy-textured soils. *Soil and Tillage Research*, *198*(December 2019), 104542. https://doi.org/10.1016/j.still.2019.104542

Jamala, G. Y. (2013). Soil Profile Characteristics As Affected By Land Use Systems In The Southeastern Adamawa State, Nigeria. *IOSR Journal of Agriculture and Veterinary Science*, *6*(4), 04–11. https://doi.org/10.9790/2380-0640411

Jiao, S., Zhang, M., Wang, Y., Liu, J., & Li, Y. (2014). Variation of soil nutrients and particle size under different vegetation types in the Yellow River Delta. *Acta Ecologica Sinica*, *34*(3), 148–153. https://doi.org/10.1016/j.chnaes.2014.03.003

Juarti, J. (2016). Analisis Indeks Kualitas Tanah Andisol Pada Berbagai Penggunaan Lahan Di Desa Sumber Brantas Kota Batu. *Jurnal Pendidikan Geografi*, *21*(2), 58–71. https://doi.org/10.17977/um017v21i22016p058

Kalu, S., Koirala, M., Khadka, U. R., & C, A. K. (2015). Soil Quality Assessment for Different Land Use in the Panchase Area of Western Nepal. *International Journal of Environmental Protection*, *5*(1), 38–43. https://doi.org/10.5963/ijep0501006

Karami, A., Homaee, M., Afzalinia, S., Ruhipour, H., & Basirat, S. (2012). Organic resource management: Impacts on soil aggregate stability and other soil physico-chemical properties. *Agriculture, Ecosystems and Environment*, *148*, 22–28. https://doi.org/10.1016/j.agee.2011.10.021

Kurniawan, M. F., Rayes, M. L., & Agustina, C. (2021). Analisis Kualitas Tanah Pada Lahan Tegalan Berpasir Di Das Mikro Supiturung, Kabupaten Kediri, Jawa Timur. *Jurnal Tanah Dan Sumberdaya Lahan*, *8*(2), 527–537. https://doi.org/10.21776/ub.jtsl.2021.008.2.23

Leonardo Manurung, P., & Dewanto, O. (2021). Perhitungan dan Korelasi Nilai Total Organic Carbon (TOC) di Daerah Cekungan Jawa Timur Utara. *Journal of Geoscience, Engineering, Environment, and Technalogy*, *xx*(xx), 1–7.

Liu, Q., Liu, G., Huang, C., & Li, H. (2019). Soil physicochemical properties associated with quasi-circular vegetation patches in the Yellow River Delta, China. *Geoderma*, *337*(September 2018), 202–214. https://doi.org/10.1016/j.geoderma.2018.09.021

Lubis, S., & Rusdiana, O. (2013). Pendugaan Korelasi antara Karakteristik Tanah terhadap Cadangan Karbon (Carbon Stock) pada Hutan Sekunder. *Jurnal Silvikultur Tropika*, *03*(01), 14–21.

Marín-Spiotta, E., & Sharma, S. (2013). Carbon storage in successional and plantation forest soils: A tropical analysis. *Global Ecology and Biogeography*, *22*(1), 105–117. https://doi.org/10.1111/j.1466-8238.2012.00788.x

Martunis, et all. (2016). Soil Quality Index Analysis of Dryland areas in Aceh Besar District, Aceh Province. *J. Budidaya Pertanian*, *12*(1), 34–40.

Mora, J. L., & Lázaro, R. (2013). Evidence of a threshold in soil erodibility generating differences in vegetation development and resilience between two semiarid grasslands. *Journal of Arid Environments*, *89*, 57–66. https://doi.org/10.1016/j.jaridenv.2012.10.005

Pham, T. G., Nguyen, H. T., & Kappas, M. (2018). Assessment of soil quality indicators under different agricultural land uses and topographic aspects in Central Vietnam. *International Soil and Water Conservation Research*, *6*(4), 280–288. https://doi.org/10.1016/j.iswcr.2018.08.001

Pimentel, D., & Burgess, M. (2013). Maintaining sustainable and environmentally friendly fresh produce production in the context of climate change. In *Global Safety of Fresh Produce: A Handbook of Best Practice, Innovative Commercial Solutions and Case Studies*. Woodhead Publishing Limited. https://doi.org/10.1533/9781782420279.2.133

Pirastru, M., Castellini, M., Giadrossich, F., & Niedda, M. (2013). Comparing the Hydraulic Properties of Forested and Grassed Soils on an Experimental Hillslope in a Mediterranean Environment. *Procedia Environmental Sciences*, *19*, 341–350. https://doi.org/10.1016/j.proenv.2013.06.039

Pramono, I. B., & Prahesti, R. R. (2016). Kualitas Indeks Tanah Sebagai Estimator dari Agroforestry Tanah Kesehatan di Tirtomoyo Sub-DAS, Wonogiri. *Agrosains: Jurnal Penelitian Agronomi*, *18*(2), 38. https://doi.org/10.20961/agsjpa.v18i2.18688

Qi, Y., Chen, T., Pu, J., Yang, F., Shukla, M. K., & Chang, Q. (2018). Response of soil physical, chemical and microbial biomass properties to land use changes in fixed desertified land. *Catena*, *160*(June 2017), 339–344. https://doi.org/10.1016/j.catena.2017.10.007

Ren, T., Wang, J., Chen, Q., Zhang, F., & Lu, S. (2014). The effects of manure and nitrogen fertilizer applications on soil organic carbon and nitrogen in a high-input cropping system. *PLoS ONE*, *9*(5). https://doi.org/10.1371/journal.pone.0097732

Saifulloh, M., Sardiana, I. K., & Supadma, A. A. N. (2017). Pemetaan Kualitas Tanah pada Lahan Kebun Campuran dengan Geography Information System (GIS) di Kecamatan Tegallalang , Kabupaten Gianyar. *E-Jurnal Agroekoteknologi Tropika*, *6*(3), 269–278.

Schröder, J. J., Schulte, R. P. O., Creamer, R. E., Delgado, A., van Leeuwen, J., Lehtinen, T., Rutgers, M., Spiegel, H., Staes, J., Tóth, G., & Wall, D. P. (2016). The elusive role of soil quality in nutrient cycling: a review. *Soil Use and Management*, *32*(4), 476–486. https://doi.org/10.1111/sum.12288

Sione, S. M. J., Wilson, M. G., Lado, M., & González, A. P. (2017). Evaluation of soil degradation produced by rice crop systems in a Vertisol, using a soil quality index. *Catena*, *150*, 79–86. https://doi.org/10.1016/j.catena.2016.11.011

Sufardi, Arabia, T., Khairullah, Karnilawati, & Fuadi, Z. (2020). Distribution of carbon and soil quality in drylands of Aceh Besar, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *458*(1). https://doi.org/10.1088/1755-1315/458/1/012040

Sun, W., Zhu, H., & Guo, S. (2015). Soil organic carbon as a function of land use and topography on the Loess Plateau of China. *Ecological Engineering*, *83*, 249–257. https://doi.org/10.1016/j.ecoleng.2015.06.030

Tellen, V. A., & Yerima, B. P. K. (2018). Effects of land use change on soil physicochemical properties in selected areas in the North West region of Cameroon. *Environmental Systems Research*, *7*(1). https://doi.org/10.1186/s40068-018-0106-0

Toohey, R. C., Boll, J., Brooks, E. S., & Jones, J. R. (2018). Effects of land use on soil properties and hydrological processes at the point, plot, and catchment scale in volcanic soils near Turrialba, Costa Rica. *Geoderma*, *315*(October 2016), 138–148. https://doi.org/10.1016/j.geoderma.2017.11.044

Vinhal-Freitas, I. C., Corrêa, G. F., Wendling, B., Bobuľská, L., & Ferreira, A. S. (2017). Soil textural class plays a major role in evaluating the effects of land use on soil quality indicators. *Ecological Indicators*, *74*, 182–190. https://doi.org/10.1016/j.ecolind.2016.11.020

Yang, X., & Williams, M. (2015). Landforms and processes in arid and semi-arid environments. *Catena*, *134*, 1–3. https://doi.org/10.1016/j.catena.2015.02.011