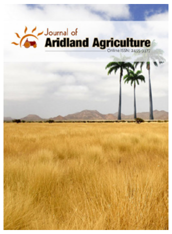
Journal of Aridland Agriculture 2023, 9: 31-38
doi: 10.25081/jaa.2023.v9.8065
https://updatepublishing.com/journal/index.php/jaa

Research Article



ISSN: 2455-9377

A comparison of the dynamics and carbon stocks in rice fields with different management systems and soil types

Hery Widijanto*, Refena Sita Amalia, Jauhari Syamsiyah, Suntoro

Department of Soil Science, Faculty of Agriculture, Sebelas Maret University, Surakarta, 57126, Indonesia

Received: October 31, 2022
Revised: June 18, 2023
Accepted: June 22, 2023
Published: July 14, 2023

***Corresponding author:**
Hery Widijanto
E-mail: herywidijanto@staff.uns.ac.id

ABSTRACT

Paddy fields in Indonesia, on average, have a very low content of organic matter (organic C < 2%). This organic matter's low content will affect the carbon stock. The management system as well as soil type could affect carbon stock in the soil. This study aims to determine the dynamics and carbon stock in paddy fields with different management systems and soil types. The research was conducted in Karanganyar Regency; Sukoharjo Regency and Klaten Regency. Factors observed include organic, semi-organic, inorganic management systems and soil types (i.e., ultisol, vertisol and inseptisol). Soil sampling was carried out 3-5 days after harvest. Each combination of the management system and soil type was taken with three soil sample points at two depths (0-20 cm and > 20 cm) with three repeats. The parameters hedied include organic C, dissolved organic C, microbial C, pH_{H2O}, total N, CEC, soil texture and bulk density. Soil depth and the interaction of management systems and soil types affect the total organic C. Total organic carbon is highest in vertisol soils with an organic management system (2.59%) and a depth of 0-20 cm (2.24%). Carbon stock (82.62 tons ha^{-1}) in vertisol soils with organic management systems is higher than in vertisol soils with semi-organic and inorganic management systems, with a C stock of 71.19 tons ha^{-1} and 68.4 tons ha^{-1}.

Keywords: Organic carbon, Dissolved organic carbon, Carbon stock

INTRODUCTION

Indonesia is an agricultural country where most of the population works as farmers. Indonesia also has a large potential land for agriculture, especially rice fields. Rice fields are quite easy to find in various regions in Indonesia because rice fields are used to grow rice, the main food source. Paddy fields include a relatively stable land ecosystem and have very high sustainability. Paddy fields in Indonesia, on average, have a low to very low organic matter content (C-organic < 2%) (Wihardjaka & Harsanti, 2021). The low content of organic matter occurs due to low fertilization using organic fertilizers (Wahyuni *et al.*, 2020). Soil organic carbon comes from the decomposition of plants and animals. The value of soil organic carbon determines the fertility, productivity and quality of the soil. The low use of organic fertilizers followed by intensive tillage reduces fertility and nutrient content in the soil, especially the organic carbon content of the soil. Soil organic carbon circulation will also affect the carbon cycle and long-term climate change (Gunadi *et al.*, 2020).

BMKG (2021) states that CO_2 gas is the largest contributor to the composition of greenhouse gases in the atmosphere, around 80%. Due to low carbon stock, the agricultural sector accounts for 10-12% of total anthropogenic greenhouse gases (Lintangrino & Boedisantoso, 2016). Carbon stock is the amount of carbon that does not emit CO_2 into the atmosphere. Carbon stock in each land use is different, depending on the management system, soil type, plant diversity and density (Susanti *et al.*, 2021). Land with good soil fertility has a greater carbon stock, the amount of carbon stock in plant biomass is determined by the amount of carbon stock in the soil (Hairiah & Rahayu, 2007).

In research Syam'ani *et al.* (2012), different land management systems affect carbon stock and land biomass. No research has been conducted comparing this study site's rice field management system. Research on carbon stock in management systems differs Hábová *et al.* (2019), Asigbaase *et al.* (2021), Yunianti *et al.* (2021) and Arunrat *et al.* (2022) is only carried out on organic and inorganic management systems, not including semi-organic management systems. The research carried out by Yulnafatmawita *et al.* (2011) and Gunadi *et al.* (2020) analyzes several land uses, while this research focuses on using paddy fields only.

Previous studies have only observed different land uses and different management systems. Our research covers a more complex component, where the observations focused on the value of soil carbon in paddy fields with different management systems and soil types. The management systems in our study area include organic, semi-organic, and inorganic, while soil types consist of ultisols, vertisols, and inceptisols. The purpose of the research we want to achieve is to determine the dynamics and storage of soil carbon in rice fields with different management systems and soil types, then identify the influence of the diversity of cultivation systems and soil types on soil dynamics and carbon stocks.

MATERIAL AND METHOD

Study Site

This research was conducted in July-December 2021 in three locations: Karanganyar Regency (7°42'16.35" S 111°00'17.46" E), Sukoharjo Regency (7°48'20.24" S 110°46'28.78" E) and Klaten Regency (7°38'04.02" S 110°36'23.15" E) (Figure 1). Karanganyar Regency is administratively bordered by Sragen Regency (north), East Java Province (east), Wonogiri Regency and Sukoharjo Regency (south), Surakarta City and Boyolali Regency (west). Karanganyar Regency has an altitude between 80 to 2,000 meters above sea level. Karanganyar Regency has a tropical climate with air temperatures ranging from 18-31 °C. Sukoharjo Regency is administratively bordered by Surakarta City and Karanganyar Regency (north), Gunung Kidul Regency and Wonogiri Regency (south), Karanganyar Regency (west), Boyolali Regency and Klaten Regency (east). Sukoharjo Regency has an altitude of 89-125 meters above sea level. Sukoharjo Regency has a tropical climate with air temperatures ranging from 23-34 °C. Klaten Regency is directly bordered by Boyolali Regency (north), Sukoharjo Regency (east) and Yogyakarta Special Region (south and west). Klaten Regency is located between Mount Merapi and the Thousand Mountains, with an altitude between 75-160 meters above sea level. Klaten Regency has a tropical climate with rainy and dry seasons alternating throughout the year. The average air temperature is 28-30 °C.

Karanganyar Regency represents ultisol soil types which are generally brownish yellow to red, have low organic matter content, cation exchange capacity (CEC) and low soil biological activity (Tando, 2020). Sukoharjo Regency represents vertisol soil, generally jet black or grey-black, with relatively high soil pH and CEC (Santoso & Sajidan, 2013). Klaten Regency represents an inceptisol soil with a black or grey to dark brown colour with medium to high CEC (Sebayang *et al.*, 2015).

The organic management system is a management system where land is only given natural ingredients or organic fertilizers without synthetic chemicals. The organic management system in Sukoharjo Regency has been carried out since 2014, in Klaten Regency since 2016, and in Karanganyar Regency since 2015. The semi-organic management system is transitioning from inorganic to organic, where it takes 1-2 years until the land can use organic fertilizer in full and certify it as an organic rice field. The fertilizer application in each management system at each research location can be seen in Table 1.

Sampling is carried out by purposive sampling (intentionally), which represents the type of soil and management system, each sample point is taken at two depths, namely 0-20 cm and >20 cm, this is supported according to Yulnafatmawita *et al.*

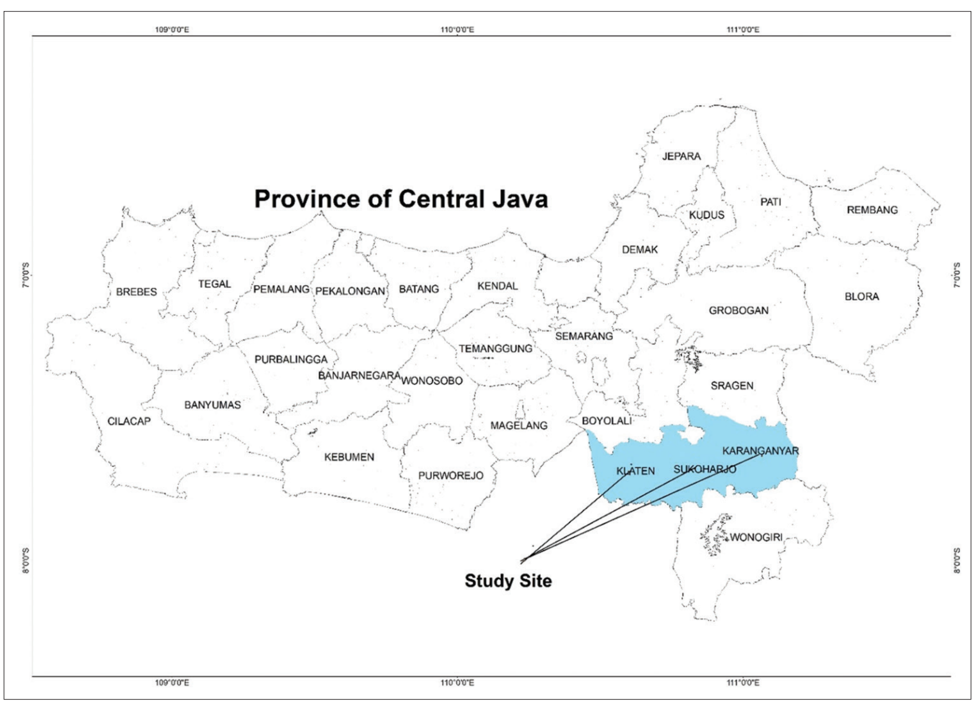


Figure 1: Map of the Study Area

Table 1: Types and Doses of Fertilizers in Several Management Systems at the Research Site

	Karanganyar Regency	Sukoharjo Regency	Klaten Regency
Organic Management System	Organic fertilizer 2.4 tons ha^{-1} MOL solution of 5 L ha^{-1} POC 15 L ha^{-1}	Manure 1.4 tons ha^{-1} MOL solution of 5 L ha^{-1} POC 15 L ha^{-1}	Manure 2.7 tons ha^{-1} Petroganic 120 kg ha^{-1}
Inorganic Management System	Urea 120 kg ha^{-1} Phonska 150 kg ha^{-1} SP36 120 kg ha^{-1}	Urea, Phonska and SP36 125 kg ha^{-1}	Urea 100 kg ha^{-1} Phonska 100 kg ha^{-1} SP36 50 kg ha^{-1}
Semi-Organic Management System	Manure 1.5 tons ha^{-1} Urea, Phonska and SP36 60 kg ha^{-1}	Manure 700 kg ha^{-1} MOL solution of 2.5 L ha^{-1} POC 7.5 L ha^{-1} Urea, Phonska and SP36 60 kg ha^{-1}	Manure 1.2 tons ha^{-1} Petroganic 40 kg ha^{-1} Urea and Phonska 50 kg ha^{-1} SP36 10 kg ha^{-1}

(2011) that the depth of the soil profile affects the content of soil organic matter. Sampling activities are carried out 3-5 days after harvest. Disturbed soil samples were taken by composite technique. This soil composite aims to combine soils in the same area to represent the state of the land (Suryono *et al.*, 2011). Fifty-four soil samples will be taken (3 tests for each sample point).

The laboratory analysis carried out includes soil organic C with the Walkley and Black method (Disniwati *et al.*, 2021), dissolved organic C with the Spectrophotometry method (Prokushkin *et al.*, 2005), soil microbial C with fumigation and extraction methods (Anui & Banjarnahor, 2022), total soil N with the Kjeldahl method (Disniwati *et al.*, 2021), soil CEC with ammonium acetate saturation 1N pH 7 (Fitriani *et al.*, 2018), soil pH with potentiometric method (Fitriani *et al.*, 2018), soil texture with pipette method (Syofiani *et al.*, 2020), bulk density with chunk method (Yulina *et al.*, 2019) and soil carbon stock with calculations using the formula (Yulnafatmawita & Yasin, 2018) as follows:

Ct=BV x Kd x %Corg

Description:
Ct : Soil C content
BV : Bulk density (g cm^{-2})
Kd : Sample depth (cm)

Statistical Analysis

Statistical analysis includes ANOVA, Duncan and correlation with IBM SPSS Statistics 26. An ANOVA analysis with a 95% confidence level was carried out to determine the effect of the management system on two depths in each soil type on carbon dynamics and stock (Rahman *et al.*, 2021). Duncan's further test with a 95% confidence level was carried out to determine the influence of the management system and soil type on the parameters (Tilaki *et al.*, 2022). Correlation analysis was carried out to determine the relationship between each parameter (Bai *et al.*, 2020).

RESULT AND DISCUSSION

Total Soil Organic Carbon

Figure 2 shows that soils with organic management systems with vertisol soil type have higher total soil organic carbon (2.59%) compared to soils with management systems with other soil types. Soils with an organic management system with vertisol soil type have a high total soil organic carbon content due to the addition of organic fertilizers to the soil. Adding this organic fertilizer impacts the increase in organic matter, one of whose components is carbon (Sitorusdan & Sembiring, 2014).

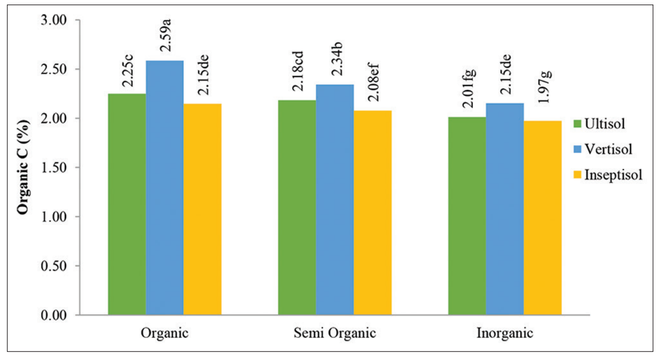


Figure 2: Total organic C levels of soil on various management systems and soil types. Numbers followed by the same letter shows a markedly different result on the DMRT test (α = 0.05).

Organic fertilizers will provide a large amount of activated organic carbon and carry the same amount of NPK elements as chemical fertilizers (Zhao *et al.*, 2021). Applying organic fertilizers will also impact the higher content of soil organic matter, increasing the nutrient supply and soil buffer capacity and contributing to higher carbon sequestration in the soil (Voltr *et al.*, 2021). According to Urmi *et al.* (2022), soil applied with organic fertilizer will increase the presence of carbon in the soil. Vertisol soil types with a high clay content (51.87%) also support the high presence of total soil organic carbon because the clay fraction in the soil accumulates more soil organic carbon than other fractions (Zhong *et al.*, 2018). This is supported by Rakhsh *et al.* (2020), that clay and soil surface area are used to determine the soil's ability to absorb organic carbon, soil absorbs organic carbon due to the strong bonds formed between organic matter and mineral surfaces. This is also in line with the research of Triharyanto *et al.* (2022) that vertisol soil has an organic carbon content of 1.9% and increases to 2.10% due to the use of liquid organic fertilizer.

Soils at a depth of 0-20 cm have a higher total organic carbon content of the soil compared to a depth of > 20 cm

(Figure 3). The total organic carbon content of the soil will decrease along with the increasing depth of the soil (Magar *et al.*, 2020). The high organic carbon at a depth of 0-20 cm occurs due to the addition of organic matter to the soil surface, the addition of organic matter finally has an impact on increasing the total organic carbon of the soil and the low content of organic carbon in the soil which is deeper due to reduced root activity at a depth of > 20 cm (Murphy *et al.*, 2019). The results of research by Raghuwanshi *et al.* (2022) show that total organic carbon at a depth of 0-15 cm is higher than the depth of 15-30 cm and 30-45 cm. Soil total organic carbon has a positive and very strong correlation with total N (r= 0.853**) shown in Table 2, the presence of N in the soil will increase the amount of carbon in the soil and reduce decomposition activity (Mayer *et al.*, 2020).

Dissolved Organic Carbon

Dissolved organic carbon (DOC) on vertisol soils with a depth of 0-20 cm is higher than with a combination of soil types at other soil depths (Figure 4). Soils with vertisol soil types have a high content of dissolved organic carbon because vertisol soils, which have a high clay content, absorb a greater amount of organic carbon than soils with low clay content. Soils dominated by clay fractions will have a larger surface area to absorb dissolved organic carbon (Singh *et al.*, 2016). In line with the research of Gmach *et al.* (2020) and Aumtong *et al.* (2023) that soils with high clay content will have high dissolved organic carbon as well. A soil depth of 0-20 cm has a higher content of dissolved organic carbon than a depth of > 20 cm. This is also influenced by the high presence of organic carbon at a depth of 0-20 cm. The high carbon supply will encourage soil organic carbon decomposition and facilitate an increase in dissolved organic carbon (Xiao *et al.*, 2020).

Table 2: Correlation between Total Organic C and Total N

	r-value	p-value
Total N	0.853**	0.000

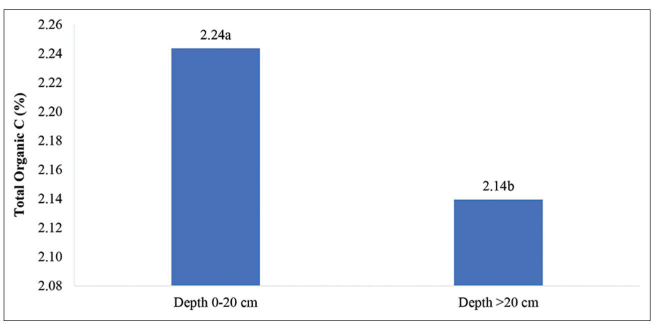


Figure 3: C levels of total organic soil at different depths. Numbers followed by the same letter shows a markedly different result on the DMRT test (α = 0.05)

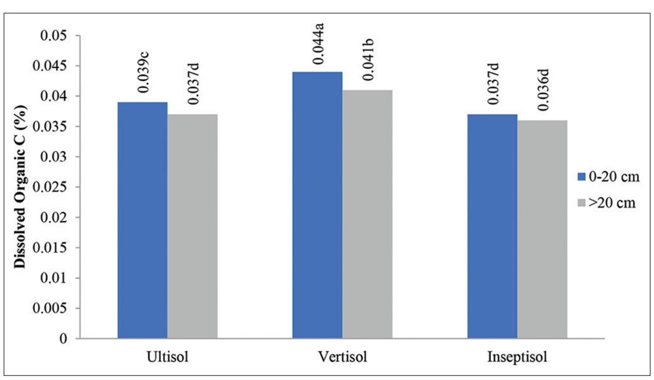


Figure 4: Dissolved organic C levels at different soil types and soil depths. Numbers followed by the same letter shows a markedly different result on the DMRT test (α = 0.05)

Soil-dissolved organic carbon has a strong positive correlation with soil total organic carbon (r = 0.886**) shown in Table 3. The same result was also put forward by Arifin *et al.* (2017), which state that organic matter that undergoes degradation and decomposition is a source of soil-dissolved organic carbon. Soil-dissolved organic carbon has a strong positive correlation with soil microbial carbon (r = 0.697**) shown in Table 3. This is supported by the results of research Zhang *et al.* (2020) that an increase will follow the increase in dissolved organic carbon soil microbial carbon, whereas Potapov *et al.* (2017) state that dissolved organic carbon is a food source of microorganisms.

Soil Microbial Carbon

The carbon cycle and nutrient availability occur in the soil with the role of soil microorganisms. The formation of biomass of these soil microorganisms is influenced by the presence of organic matter in the soil. Soil microbial carbon is an indicator to determine the amount of microorganisms' biomass to measure the microorganisms' activity in the soil.

In addition to organic management systems, the type of vertisol soil at a depth of 0-20 cm has the highest microbial carbon compared to others (Figure 5). Applying soil organic fertilizer will add carbon, one of the variables that spur the activity of soil microorganisms (Pratiwi *et al.*, 2013). The results of research by Rahman *et al.* (2022) also show that the application of organic fertilizers increases soil microbial carbon. Microorganisms use organic matter as an energy source, the more organic matter available in the soil, the population of microorganisms will also increase (Giri *et al.*, 2020). The high activity of microorganisms sourced from the high presence of organic matter will impact increasing microbial carbon (Tabroni *et al.*, 2018). Vertisol soils also support the high carbon content of soil microbes because of the physicochemical content in soils with high clay content, such as the soil's ability to retain water and the total volume of pores filled with water is the main driver of the composition of microbial communities (Rakhsh *et al.*, 2020; Olagoke *et al.*, 2022).

Soils with organic management systems on vertisol soil types also show higher microbial carbon at 0-20 cm depth than at a depth of > 20 cm. This can happen because the soil has more organic matter content at a depth of 0-20 cm. The high content of organic matter in the layer of 0-20 cm will also impact the high carbon of soil microbes because microbial carbon is strongly influenced by organic matter in the soil

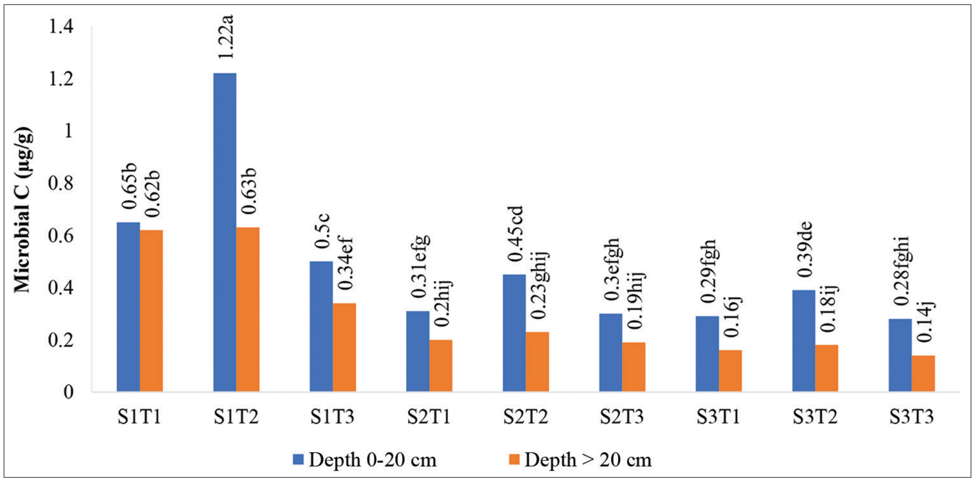


Figure 5: C levels of soil microbial in various management systems, soil types and depths
Description: The number followed by the same letter shows a markedly different result on the DMRT test (α = 0.05). S1: organic management system; S2: semi-organic management system; S3: inorganic management system; T1: ultisol soil; T2: vertisol soil; T3: inseptisol soil

(Lepcha & Devi, 2020) this research also has the same result that soil microbial carbon is higher in the upper soil layer than subsoil. The low content of organic matter at a depth of >20 cm, followed by changes in the quality of organic matter, will have an impact on reducing the level of decomposition carried out by microorganisms because microorganisms have to invest large amounts of carbon and nitrogen into the production of exoenzymes (Spohn *et al.*, 2016).

Soil microbial carbon has a strong positive correlation with soil pH (r= 0.577**) shown in Table 4. The same is also stated by Wu *et al.* (2019), who stated that soil pH and microorganisms work together in controlling soil carbon turnover, and soil pH will affect soil microbial function related to carbon decomposition. Soil microbial carbon also has a very strong positive correlation with the total soil N (r = 0.889**) shown in Table 4. This happens because microorganisms need nitrogen to form proteins, a limited amount of nitrogen will affect the growth of microorganisms (Wahyuni *et al.*, 2020).

Carbon Stock

Carbon stock describes the amount of carbon stored in the soil and biomass that has not been cycled back into the atmosphere (Arfina *et al.*, 2020).

Vertisol soils with an organic management system have the highest carbon stock of 82.62 tons ha^{-1} (Figure 6). Vertisol soils have the highest carbon stock in all management systems compared to other soil types. As Ly *et al.* (2022) researched, soils with high clay content will have high carbon stocks as well. This is because the soil carbon supply will be stored in the pore space of the soil so that the rate of carbon loss will be reduced due to the high clay content in vertisol soils (Siringoringo, 2007). The higher the clay content of the soil, the greater the soil's ability to withstand carbon. The organic matter in the soil will be coated by the smallest type of clay (clay platelets) and form stable aggregates that will protect the organic matter from

Table 3: Correlation of DOC with Total Organic C and Soil Microbial C

	r-value	p-value
Total Organic C	0.886**	0.000
Soil Microbial C	0.697**	0.000

Table 4: Correlation of Soil Microbial C with Soil pH and Total N

	r-value	p-value
Soil pH	0.577**	0.000
Total N	0.889**	0.000

microbial decomposition (Siringoringo, 2014). Clay in the soil functions as a water holder and impacts poor air exchange, soil microbial activity is hampered in stacking organic matter (Budiadi, 2020). Soils with organic management systems also have high carbon stock compared to other management systems. In line with Gross and Glaser (2021) research that the use of organic fertilizers will increase carbon stocks by up to 40%. Adding organic matter to the organic management system will increase the soil's carbon content, where the soil's high carbon content means that carbon stock will also increase (Asbur & Ariyanti, 2017). Applying organic matter to the soil is one way to increase the storage of organic matter in the soil (Cotrufo *et al.*, 2019).

Based on Pearson's correlation test, carbon stock has a positive and strong correlation with total soil organic carbon (r = 0.882**) shown in Table 5. Soils with high organic carbon will also have higher carbon stock in these soils (Hickmah *et al.*, 2021). Carbon stock has a positive correlation to soil pH (r = 0.263). This happens because a higher soil pH will reduce CO_2 concentrations due to the inhibition of microbial respiration (Xu *et al.*, 2021). Carbon stock has a very significant positive correlation with soil volume weights (r = 0.911**) shwon in Table 5. This is because the weight of soil volume strongly influences carbon sequestration in the soil, changing the porosity of the soil (Dheri & Nazir, 2021).

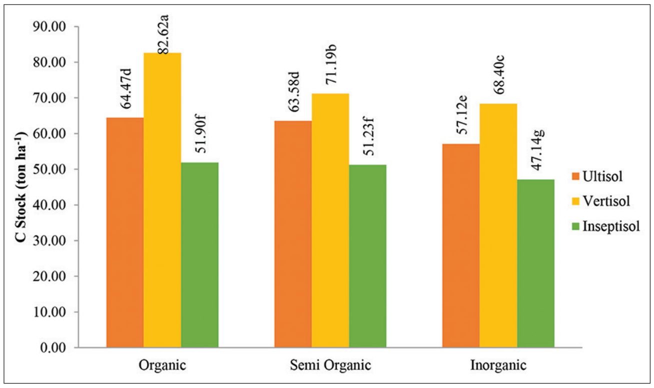


Figure 6: Carbon stock in various management systems and soil types. Numbers followed by the same letter shows a markedly different result on the DMRT test (α = 0.05).

Table 5: Correlation of Carbon Stock with Total Organic C and Soil Volume Weights

	r-value	p-value
Total Organic C	0.882**	0.000
Soil Volume Weights	0.911**	0.000

CONCLUSIONS

Carbon stock in vertisol soils with organic management systems (82,62 tons ha^{-1}) is higher than those of semi-organic (71,19 tons ha^{-1}) and inorganic (68,4 tons ha^{-1}) management systems. Carbon stock have a positive correlation with total organic carbon (r = 0.882**) and bulk density (r = 0.911**). In all soil types with three management systems, the average total organic carbon of the soil is higher at a depth of 0-20 cm by 2.24% compared to a depth of > 20 cm, which is 2.14%. Dissolved organic carbon in vertisol soils is 0-20 cm depth higher (0.044%) than depth > 20 cm (0.041%).

The dynamics and carbon stocks in each land use in previous studies show different conditions, but it is not yet known the conditions in rice fields with diverse cultivation systems and soil types, and whether the diversity of land characteristics can affect and relate to the dynamic conditions and carbon stocks in rice fields. Meanwhile, today knowing information on the dynamics and stock of carbon in the managed area is important related to its relationship to land productivity, to future climate conditions. Therefore, in our research we combined sources of diversity of cultivation systems and soil types and their reactions to dynamics and carbon stocks. The results of the research we found are carbon stocks in vertisol soils with organic management systems (82,62 tons ha^{-1}) is higher than those of semi-organic (71,19 tons ha^{-1}) and inorganic (68,4 tons ha^{-1}) management systems. Carbon stock have a positive correlation with total organic carbon (r = 0.882**) and bulk density (r = 0.911**). In all soil types with three management systems, the average total organic carbon of the soil is higher at a depth of 0-20 cm by 2.24% compared to a depth of > 20 cm, which is 2.14%. Dissolved organic carbon in vertisol soils is 0-20 cm depth higher (0.044%) than depth > 20 cm (0.041%). From the results of the research that has been found, the summarized data and information can be used as guidelines for local stakeholders to maximize efforts to increase carbon stocks in agricultural land, especially rice fields, and reduce carbon emissions by maintaining existing carbon stocks for the future.

REFERENCES

Anui, T. V., & Banjarnahor, D. R. V. (2022). Pengaruh Sistem Tanam Kentang (Solanum tuberosum L.) dan Kacang Babi (Vicia faba L.) Terhadap C-Mik Tanah. *Agritech, 24*(1), 1-6. https://doi.org/10.30595/agritech.v24i1.8430

Arfina, N., Hidayat, M., & Nisa, K. (2020). Simpanan Karbon pada Tanah di Kawasan Geothermal Ie Brok Seulawah Agam Desa Meurah Kecamatan Seulimeum Kabupaten Aceh Besar. *Prosiding Seminar Nasional Biotik*, 71-77.

Arifin, S., Hartono, A., Murtilaksono, K., Anwar, S., Sunarti, S., Kuztakov, Y. (2017). Hubungan Karbon Organik Terlarut Dengan Sifat Tanah Pada Toposekuen Di Taman Nasional Bukit Duabelas. *Journal of Soil Science and Environment*, *19*(2), 51-59. https://doi.org/10.29244/jitl.19.2.51-59

Arunrat, N., Sereenonchai, S., Chaowiwat, W., Wang, C., & Hatano, R. (2022). Carbon, Nitrogen and Water Footprints of Organic Rice and Conventional Rice Production over 4 Years of Cultivation: A Case Study in the Lower North of Thailand. *Agronomy*, *12*(2), 380. https://doi.org/10.3390/agronomy12020380

Asbur, Y., & Ariyanti, M. (2017). Peran KOnservasi Tanah terhadap Cadangan Karbon Tanah, Bahan Organik dan Pertumbuhan Kelapa Sawit (Elais guineensis jacq.). *Kultivasi*, *16*(3), 402-411. https://doi.org/10.24198/kultivasi.v16i3.14446

Asigbaase, M., Dawoe, E., Lomax, B. H., & Sjogersten, S. (2021). Biomass and Carbon Stocks of Organic and Conventional Cocoa Agroforests, Ghana. *Agriculture, Ecosystems & Environment*, *306*, 107192. https://doi.org/10.1016/j.agee.2020.107192

Aumtong, S., Chotamonsak, C., & Glomchinda, T. (2023). Study of the Interaction of Dissolved Organic Carbon, Available Nutrients, and Clay Content Driving Soil Carbon Storage in the Rice Rotation Cropping System in Northern Thailand. *Agronomy*, *13*(1), 142. https://doi.org/10.3390/agronomy13010142

Bai, Y., Zha, X., & Chen, S. (2020). Effects of The Vegetation Restoration Years on Soil Microbial Community Composition and Biomass in Degraded Lands in Changting County, China. *Journal of Forestry Research*, *31*, 1295-1308. https://doi.org/10.1007/s11676-019-00879-z

BMKG. (2021). *Buletin Gas Rumah Kaca*. In BMKG. Retrieved from https://iklim.bmkg.go.id/publikasi-klimat/ftp/buletin/2021/BULETIN%20GAS%20RUMAH%20KACA%20Vol-01%20No-01.pdf

Budiadi, B. (2020). Pendugaan Simpanan Karbon pada Kawasan Rehabilitasi Pesisir Selatan Pulau Jawa. *Jurnal Ilmu Kehutanan*, *14*(1), 71. https://doi.org/10.22146/jik.57473

Cotrufo, M. F., Ranalli, M. G., Haddix, M. L., Six, J., & Lugato, E. (2019). Soil carbon storage informed by particulate and mineral-associated organic matter. *Nature Geoscience*, *12*, 989-994. https://doi.org/10.1038/s41561-019-0484-6

Dheri, G. S., & Nazir, G. (2021). A Review on Carbon Pools and Sequestration as Influenced by Long-Term Management Practices in a Rice-Wheat Cropping System. *Carbon Management*, *12*(5), 559-580. https://doi.org/10.1080/17583004.2021.1976674

Disniwati, E., Khalil, M., & Fikrinda, F. (2021). Status Karbon Organik dan Nitrogen Total Tanah serta Pertumbuhan Jagung (Zea mays L.) Akibat Aplikasi Fungi Selulotik Indigenous dan Jerami Padi pada Inceptisol Aceh. *Jurnal Ilmiah Mahasiswa Pertanian*, *6*(4), 664-670. https://doi.org/10.17969/jimfp.v6i4.18437

Fitriani, N. A., Fadillah, G., & Enriyani, R. (2018). Pengujian Kualitas Tanah sebagai Indikator Cemaran Lingkungan di Sekitar Pantai Tanjung Lesung, Banten. *Indonesian Journal of Chemical Analysis*, *1*(1), 29-34. https://doi.org/10.20885/ijca.vol1.iss1.art4

Giri, I. G. A. I., Yusnaini, S., Lumbanraja, J., & Buchari, H. (2020). Pengaruh Sistem Olah Tanah dan Aplikasi Herbisida terhadap Biomassa Karbon Mikroorganisme Tanah (C-Mik) pada Pertanaman Jagung (*Zea mays* L.) Musim Tanam Ke-5 di Gedong Meneng. *Agrotek Tropika*, *8*(1), 1-10. https://doi.org/10.23960/jat.v8i1.3669

Gmach, M. R., Cherubin, M. R., Kaiser, K., & Cerri, C. E. P. (2020). Processes that Influence Dissolved Organic Matter in The Soil: A Review.

Scientia Agricola, 77(3). https://doi.org/10.1590/1678-992x-2018-0164

Gross, A., & Glaser, B. (2021). Meta-analysis on How Manure Application Changes Soil Organic Carbon Storage. *Scientific Reports*, *11*, 5516. https://doi.org/10.1038/s41598-021-82739-7

Gunadi, Juniarti, & Gusnidar. (2020). Hubungan Stok Karbon Tanah dan Suhu Permukaan pada Beberapa Penggunaan Lahan di Nagari Padang Laweh Kabupaten Sijunjung. *Jurnal Solum*, *17*(1), 1-11. https://doi.org/10.25077/jsolum.17.1.1-11.2020

Hábová, M., Pospíšilová, L., Hlavinka, P., Trnka, M., Barančíková, G., Tarasovičová, Z., Takáč, J., Koco, Š., Menšík, L., & Nerušil, P. (2019). Carbon Pool in Soil under Organic and Conventional Farming Systems. *Soil and Water Research*, *14*(3), 145-152. https://doi.org/10.17221/71/2018-SWR

Hairiah, K., & Rahayu, S. (2007). *Pengukuran "Karbon tersimpan" di Berbagai Macam Penggunaan Lahan*. World Agroforestry Centre. Retrieved from https://www.worldagroforestry.org/publication/pengukuran-karbon-tersimpan-di-berbagai-macam-penggunaan-lahan

Hickmah, N., Maslukah, L., Wulandari, S. Y., Sugianto, D. N., & Wirasatriya, A. (2021). Kajian Stok Karbon Organik dalam Sedimen di Area Vegetasi Mangrove Karimunjawa. *Indonesian Journal of Oceanography*, *3*(4), 419-426. https://doi.org/10.14710/ijoce.v3i4.12494

Lepcha, N. T., & Devi, N. B. (2020). Effect of land use, season, and soil depth on soil microbial biomass carbon of Eastern Himalayas. *Ecological Processes*, *9*, 65. https://doi.org/10.1186/s13717-020-00269-y

Lintangrino, M. C., & Boedisantoso, R. (2016). Inventarisasi Emisi Gas Rumah Kaca Pada Sektor Pertanian dan Peternakan di Kota Surabaya. *Jurnal Teknik ITS*, *5*(2). https://doi.org/10.12962/j23373539.v5i2.16528

Ly, N. T. H., Phuong, N. T., Anh, L. N. T., Nguyet, D. A., & Nguyen, H. (2022). Effect of Agricultural Land-Use Patterns on Soil Organic Carbon Stock in the Upper Vietnamese Mekong Delta. *Polish Journal of Environmental Studies*, *31*(6), 5793-5804. https://doi.org/10.15244/pjoes/152029

Magar, L. K., Kafle, G., & Aryal, P. (2020). Assessment of Soil Organic Carbon in Tropical Agroforests in the Churiya Range of Makawanpur, Nepal. *International Journal of Forestry Research, 2020*, 8816433. https://doi.org/10.1155/2020/8816433

Mayer, M., Prescott, C. E., Abaker, W. E. A., Augusto, L., Cécillon, L., Ferreira, G. W. D., James, J., Jandl, R., Katzensteiner, K., Laclau, J.- P., Laganière, J., Nouvellon, Y., Paré, D., Stanturf, J. A., Vanguelova, E. I., & Vesterdal, L. (2020). Influence of forest management activities on soil organic carbon stocks: A knowledge synthesis. *Forest Ecology and Management*, *466*, 118127. https://doi.org/10.1016/j.foreco.2020.118127

Murphy, B. W., Wilson, B. R., & Koen, T. (2019). Mathematical Functions to Model the Depth Distribution of Soil Organic Carbon in a Range of Soils from New South Wales, Australia under Different Land Uses. *Soil Systems*, *3*(3), 46. https://doi.org/10.3390/soilsystems3030046

Olagoke, F. K., Bettermann, A., Nguyen, P. T. B., Redmile-Gordon, M., Babin, D., Smalla, K., Nesme, J., Sørensen, S. J., Kalbitz, K., & Vogel, C. (2022). Importance of substrate quality and clay content on microbial extracellular polymeric substances production and aggregate stability in soils. *Biology and Fertility of Soils*, *58*, 435-457. https://doi.org/10.1007/s00374-022-01632-1

Potapov, A. M., Goncharov, A. A., Semenina, E. E., Korotkevich, A. Y., Tsurikov, S. M., Rozanova, O. L., Anichkin, A. E., Zuev, A. G., Samoylova, E. S., Semenyuk, I. I., Yevdokimov, I. V., & Tiunov, A. V. (2017). Arthropods in the Subsoil: Abundance and Vertical Distribution as Related to Soil Organic Matter, Microbial Biomass and Plant Roots. *European Journal of Soil Biology*, *82*, 88-97. https://doi.org/10.1016/j.ejsobi.2017.09.001

Pratiwi, T. D., Niswati, A., Arif, M. A. S., & Buchari, H. (2013). Pengaruh Pengolahan Tanah Dan Pemberian Mulsa Bagas Terhadap Kandungan Biomassa Karbon Mikroorganisme (C-Mik) Tanah Pada Lahan Pertanaman Tebu Tahun Kedua. *Jurnal Agrotek Tropika*, *1*(3), 346-351. https://doi.org/10.23960/jat.v1i3.2063

Prokushkin, A. S., Kajimoto, T., Prokushkin, S. G., McDowell, W. H., Abaimov, A. P., & Matsuura, Y. (2005). Climatic Factors Influencing Fluxes of Dissolved Organic Carbon from The Forest Floor in a Continuous-Permafrost Siberian Watershed. *Canadian Journal of Forest Research*, *35*(9), 2130-2140. https://doi.org/10.1139/x05-150

Raghuwanshi, S., Upadhyay, A. K., Yadav, I. R., & Patel, R. (2022). Long-term Impact of Soil Test and Targeted Yield Based Nutrient Management on Vertical Variability in Carbon Fractions of a Vertisol under Rice-wheat Cropping Sequence. *International Journal of Plant & Soil Science, 34*(22), 1134-1139. https://doi.org/10.9734/ijpss/2022/v34i2231477

Rahman, M. M., Islam, M. R., Uddin, S., Rahman, M. M., Gaber, A., Abdelhadi, A. A., & Jahangir, M. M. R. (2022). Biochar and Compost-Based Integrated Nutrient Management: Potential for Carbon and Microbial Enrichment in Degraded Acidic and Charland Soils. *Frontiers in Environmental Science*, *9*, 798729. https://doi.org/10.3389/fenvs.2021.798729

Rahman, M. S., Donoghue, D. N. M., & Bracken, L. J. (2021). Is Soil Organic Carbon Underestimated in The Largest Mangrove Forest Ecosystems? Evidence From The Bangladesh Sundarbans. *Catena*, *200*, 105159. https://doi.org/10.1016/j.catena.2021.105159

Rakhsh, F., Golchin, A., Al Agha, A. B., & Nelson, P. N. (2020). Mineralization of organic carbon and formation of microbial biomass in soil: Effects of clay content and composition and the mechanisms involved. *Soil Biology and Biochemistry*, *151*, 108036. https://doi.org/10.1016/j.soilbio.2020.108036

Santoso, S., & Sajidan. (2013). Keberadaan Bakteri Penghasil Fitase Untuk Perbaikan Kesuburan Tanah Vertisol Pada Berbagai Sistem Budidaya Tanam Di Kecamatan Gondangrejo Kabupaten Karanganyar. *Bioedukasi*, *6*(1), 1-11.

Sebayang, A. M., Damanik, M. M. B., & Lubis, K. S. (2015). Aplikasi Pupuk KCl dan Pupuk Kandang Ayam Terhadap Ketersediaan dan Serapan Kalium Serta PertumbuhanTanaman Jagung (*Zea mays* L.) Pada Tanah Inseptisol Kwala Bekala. *Jurnal Agroekoteknologi*, *3*(3), 870-875. https://doi.org/10.32734/jaet.v3i3.10719

Singh, M., Sarkar, B., Biswas, B., Churchman, J., & Bolan, N. S. (2016). Adsorption-desorption behavior of dissolved organic carbon by soil clay fractions of varying mineralogy. *Geoderma*, *280*, 47-56. https://doi.org/10.1016/j.geoderma.2016.06.005

Siringoringo, H. H. (2007). Potensi Simpanan Karbon pada Jenis Tanah Acrisols dan Ferralsols di Hutan Tanaman Acacia mangium Willd. dan Shorea leprosula Miq. Kabupaten Bogor. *Jurnal Penelitian Hutan Dan Konservasi Alam*, *4*(5), 511-530. https://doi.org/10.20886/jphka.2007.4.5.511-530

Siringoringo, H. H. (2014). Peranan Penting Pengelolaan Penyerapan Karbon dalam Tanah. *Jurnal Analisis Kebijakan Kehutanan*, *11*(2), 175-192. https://doi.org/10.20886/jakk.2014.11.2.175-192

Sitorusdan, L. E., & Sembiring, E. (2014). Pengaruh Aplikasi Kompos Terhadap Emisi CO2 Dan Karbon Organik Tanah. *Jurnal Tehnik Lingkungan*, *18*(2), 124-134. https://doi.org/10.5614/jtl.2012.8.2.3

Spohn, M., Klaus, K., Wanek, W., & Richter, A. (2016). Microbial carbon use efficiency and biomass turnover times depending on soil depth - Implications for carbon cycling. *Soil Biology and Biochemistry, 96*, 74-81. https://doi.org/10.1016/j.soilbio.2016.01.016

Suryono, J., Kusuma, K., & Mulyadi. (2011). Pengambilan Contoh Tanah Untuk Penelitian Kesuburan Tanah. *Teknisi Litkayasa Balitbangtan*, 75-89.

Susanti, A., Khalil, M., & Sufardi. (2021). Evaluasi Cadangan Karbon Tanah pada Beberapa Tipe Penggunaan Lahan Kering di Kecamatan Blang Bintang Kabupaten Aceh Besar. *Jurnal Ilmiah Mahasiswa Pertanian*, *6*(2), 69-78. https://doi.org/10.17969/jimfp.v6i2.16960

Syam'ani, Agustina, A. R., Susilawati, & Nugroho, Y. (2012). Cadangan Karbon di Atas Permukaan Tanah pada Berbagai Sistem Penutupan Lahan di Sub-Sub Das Amandit. *Jurnal Hutan Tropis*, *13*(2), 148-158.

Syofiani, R., Putri, S. D., & Karjunita, N. (2020). Karakteristik Sifat Tanah Sebagai Faktor Penentu Potensi Pertanian Di Nagari Silokek Kawasan Geopark Nasional. *Jurnal Agrium*, *17*(1). https://doi.org/10.29103/agrium.v17i1.2349

Tabroni, Yusnaini, S., Niswati, A., & Utomo, M. (2018). Pengaruh Sistem Olah Tanah Dan Aplikasi Herbisida Terhadap Biomassa Karbon Mikroorganisme Tanah (C-Mik) Pada Pertanaman Ubi Kayu (Manihot esculenta Crantz) Tahun Ke-2 di Tanah Ultisol Gedung Meneng Bandar Lampung. *Jurnal Agrotek*, *6*(2), 127-132. https://doi.org/10.23960/jat.v6i2.2605

Tando, E. (2020). Upaya Peningkatan Produktivitas Tanaman Kacang Tanah Dan Perbaikan Kesuburan Tanah Podzolik Merah Kuning Melalui Pemanfaatan Teknologi Biochar Di Sulawesi Tenggara. *AGRORADIX : Jurnal Ilmu Pertanian*, *3*(2), 15-22. https://doi.org/10.52166/agroteknologi.v3i2.1953

Tilaki, G. A. D., Rahmani, R., Hoseini, S. A., & Vasenev, I. (2022). The Effect of Land Management on Carbon Sequestration in Salty Rangelands of Golestan Province, Iran. *Acta Ecologica Sinica*, *42*(1), 82-89. https://doi.org/10.1016/j.chnaes.2021.03.001

Triharyanto, E., Setyaningrum, D., & Muhammad, D. M. (2022). Potential of

Liquid Organic Fertilizer on Flowering, Yield of Shallots (Allium cepa L. Aggregatum) and Soil Quality. *Universal Journal of Agricultural Research*, *10*(5), 526-533. https://doi.org/10.13189/ujar.2022.100507

Urmi, T. A., Rahman, M. M., Islam, M. M., Islam, M. A., Jahan, N. A., Mia, M. A. B., Akhter, S., Siddiqui, M. H., & Kalaji, H. M. (2022). Integrated Nutrient Management for Rice Yield, Soil Fertility, and Carbon Sequestration. *Plants*, *11*(1), 138. https://doi.org/10.3390/plants11010138

Voltr, V., Menšík, L., Hlisnikovský, L., Hruška, M., Pokorný, E., & Pospíšilová, L. (2021). The soil organic matter in connection with soil properties and soil inputs. *Agronomy*, *11*(4), 779. https://doi.org/10.3390/agronomy11040779

Wahyuni, T., Kusnadi, H., & Ivanti, L. (2020). Evaluasi Status Kesuburan Tanah Sawah Desa Tebing Kaning Kabupaten Bengkulu Utara. *Prosiding Seminar Nasional Lahan Suboptimal Ke-8 Tahun 2020*, 1172-1178.

Wihardjaka, A., & Harsanti, E. S. (2021). Dukungan Pupuk Organik Untuk Memperbaiki Kualitas Tanah Pada Pengelolaan Padi Sawah Ramah Lingkungan. *Jurnal Pangan*, *30*(1), 53-64. https://doi.org/10.33964/jp.v30i1.496

Wu, R., Cheng, X., & Han, H. (2019). The Effect of Forest Thinning on Soil Microbial Community Structure and Function. *Forests*, *10*(4), 352. https://doi.org/10.3390/f10040352

Xiao, S., Zhang, J., Duan, J., Liu, H., Wang, C., & Tang, C. (2020). Soil organic carbon sequestration and active carbon component changes following different vegetation restoration ages on severely eroded red soils in subtropical China. *Forests*, *11*(12), 1304. https://doi.org/10.3390/f11121304

Xu, T., Zhang, M., Ding, S., Liu, B., Chang, Q., Zhao, X., Wang, Y., Wang, J., & Wang, L. (2021). Grassland degradation with saline-alkaline reduces more soil inorganic carbon than soil organic carbon storage. *Ecological Indicators*, *131*, 108194. https://doi.org/10.1016/j.ecolind.2021.108194

Yulina, H., Devnita, R., & Harryanto, R. (2019). Respon Bobot Isi, Kemantapan Agregat, dan Porositas Tanah pada Tanaman Cabai Merah Setelah Vegetatif Akhir Terhadap Kombinasi Terak Baja Dan Bokashi Sekam Padi pada Andisol, Lembang. *Jurnal Agro Wiralodra*, *2*(1), 9-15. https://doi.org/10.31943/agrowiralodra.v2i1.26

Yulnafatmawita, & Yasin, S. (2018). Organic carbon sequestration under selected land use in Padang city, West Sumatra, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *129*. https://doi.org/10.1088/1755-1315/129/1/012021

Yulnafatmawita, Adrinal, & Hakim, A. F. (2011). Pencucian Bahan Organik Tanah pada Tiga Penggunaan Lahan di Daerah Hutan Hujan Tropis Super Basah Pinang-Pinang Gunung Gadut Padang. *Journal Solum*, *8*(1), 34-42. https://doi.org/10.25077/js.8.1.34-42.2011

Yunianti, I. F., Aprianthina, I. D. A. Y., Kartikawati, R., & Yulianingsih, E. (2021). Emisi Gas Rumah Kaca dan Cadangan Karbon pada Perkebunan Kopi Organik dan Konvensional di Kabupaten Badung, Bali. *Jurnal Tanaman Industri Dan Penyegar*, *8*(1), 9-18.

Zhang, Y., Zou, J., Meng, D., Dang, S., Zhou, J., Osborne, B., Ren, Y., Liang, T., & Yu, K. (2020). Effect of Soil Microorganisms and Labile C Availability on Soil Respiration in Response to Litter Inputs in Forest Ecosystems: A meta-analysis. *Ecology and Evolution*, *10*(24), 13602-13612. https://doi.org/10.1002/ece3.6965

Zhao, Z., Gao, S., Lu, C., LI, X., Li, F., & Wang, T. (2021). Effects of different tillage and fertilization management practices on soil organic carbon and aggregates under the rice-wheat rotation system. *Soil and Tillage Research*, *212*, 105071. https://doi.org/10.1016/j.still.2021.105071

Zhong, Z., Chen, Z., Xu, Y., Ren, C., Yang, G., Han, X., Ren, G., & Feng, Y. (2018). Relationship between soil organic carbon stocks and clay content under different climatic conditions in Central China. *Forests*, *9*(10), 598. https://doi.org/10.3390/f9100598