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Total Carbon Sequestration on Soil and Plant Biomass Under Different Farming Systems of Organic, Semi-Organic and Conventional Rice Fields

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ABSTRACT

Rice fields have the potential for carbon sequestration, but on the other hand, also as a source of carbon transfer to the atmosphere depending on land management practices. The condition of flooded paddy fields causes agricultural activities to contribute large amounts of emission gases such as methane (CH_4). It is important to adopt rice field management that increases carbon sequestration as a mitigation effort against global warming. This research is survey research with a descriptive exploratory approach that is carried out through direct field observations and laboratory analysis. The observed variables used were soil organic C, microbial C biomass, bulk density, pH, clay content, C rice biomass and rice biomass weight. Sampling method by purposive sampling. Data were processed by calculating total carbon sequestration and statistical tests with One Way ANOVA and Pearson's correlation. The results showed that different rice field management affect the total carbon sequestration on rice fields. The highest total sequestration was found in organic rice fields at 45.89 tons/ha followed by semi organic rice fields at 38.03 tons/ha and conventional rice fields being the lowest at 34.36 tons/ha. Factors determining the amount of carbon sequestration are soil organic carbon and microbial biomass carbon. The suggested land management recommendations are to increase organic fertilizers in semi-organic and conventional rice field management systems, maintain the soil tillage and application of fertilizers in organic systems and expand organic rice fields.

1. INTRODUCTION

Increasing levels of greenhouse gases, emissions have resulted in global warming and climate change, adversely affecting food production. Climate change might limit crop production (the amount of a crop that is harvested in a farm, region, state, or country in kilograms or tons) in many areas. Temperature increases affect most plants, leading to crop yield reduction and complex growth responses. Nevertheless, the impact of increasing temperatures can vary widely between crops and regions. Plant biodiversity and stoichiometry can influence vegetation production, C sequestration, and other ecosystem processes. Chen et al. [1] quantified effects of climate, soils, human impacts, and ecosystem traits (species diversity and plant production) on soil organic carbon (SOC) stock based on field measurements from forests, shrub lands and grass lands across the country. They found that favorable climate (high temperature and precipitation) was directly associated with reduced SOC in forests and shrub-lands but not grasslands. In addition, favorable climate (particularly high precipitation) was associated with high species richness and below ground biomass, which in turn enhanced SOC stock in the ecosystems, thus off setting the direct negative effects of favorable climate on SOC. They suggested that ecosystem management can increase soil C sequestration by increasing plant diversity and productivity. Tang et al. [2] present the first study of large-scale patterns of C, N, and P stoichiometry in plant leaf, shoot, and root at the community level across China's forests, shrub lands, and grass lands. They found that vegetation grossprimary productivity (GPP) was closely coupled with leaf N and P content for all three ecosystems and documented the magnitude and distribution of the leaf N and P productivity across the country, with an overall mean of 250 gC GPP/gN·yr and 3,158 gCGPP/gP·yr, respectively. Leaf N and P productivity increased with both temperature and precipitation, suggesting that global warming could enhance GPP even without added N and P.

Rice plants form the most extensive wetland on earth that can be a carbon sequestration site [1] and a source of atmospheric carbon, depending on land management practices [3]. As a storage site, productive rice fields have great potential for carbon sequestration in soil and plant biomass [4]. As a carbon source, paddy fields contribute emissions in the form of CH_4 [5] due to the activity of methanogenic bacteria under anaerobic conditions [6]. Carbon sequestration is one of the mitigation strategies to reduce the increasing amount of CO_2 in the atmosphere by storing carbon in soil and plant biomass [7]. The condition of flooded paddy fields creates anaerobic conditions for microbes, thus weakening microbial activity in decomposing organic matter and thus paddy fields can be more efficient in carbon storage compared to non-flooded upland soils. Furthermore, it was explained that although paddy fields are more efficient in carbon storage, the stored carbon is less stable and easily lost, so proper management is needed [1]. Rice field soil management can be carried out by conserving rice field soil, fertilizing, irrigation, crop rotation, returning crop residues and planting resistant varieties. Research by Bessam and Mrabet [8] explained that no-till systems can significantly increase by 0.66 $kg.hm^{-2}.a^{-1}$ carbon sequestration. In addition, drainage plays an important role in suppressing GHG caused by CH_4. Research by Lee et al. [9] stated that drainage treatment by incorporating green manure can reduce CH_4 emissions of paddy soil.

If the amount of carbon stored in soil and plant biomass is increased through organic farming, the amount of carbon in the atmosphere can be reduced, reducing the impact of climate change. But the application of organic rice cultivation systems is still minimal. Increased demand for rice is thought to be the push factor in applying conventional agriculture with intensive inorganic fertilization inputs [10]. In a short time, rice productivity increases, but it causes a decrease in organic C content in the soil [11], decreases the soil C/N ratio, and increases carbon transfer to the atmosphere through increased microbial activity [2]. If this continues, the soil may soon become degraded and vulnerable to climate change, so that food security will be threatened.

Land management that causes organic C loss in the soil must be minimized because a decrease in carbon sequestration can significantly impact increasing carbon concentrations in the atmosphere [12]. The amount of carbon sequestration in agricultural land is measured in units of land, namely in soil, in plants, and in crop residues. Meanwhile, carbon in paddy fields tends to decompose quickly. Land management is usually aimed at achieving certain production yields, but it will also affect carbon sequestration in paddy fields so that the paddy field farming system needs to be considered in measuring carbon sequestration. Different rice field cultivation systems can influence carbon sequestration in rice fields.

The research of carbon sequestration has been conducted in forests with cover of annual vegetation. Over the previous 50 years, the agricultural sector has been exposed to climate changes in the dynamics of temperature and rainfall, resulting in plant stress and decreased crop yield [13]. In a research, Adhikari et al. [14] reported that no-tillage paddy fields have greater soil carbon sequestration compared to conventional tillage, so reducing the form of tillage can be a practice to reduce the impact of global warming in the long run. Haque at al. [15] in his research explained that the use of organic fertilizers (vermicompost, poultry manure and cowdung) increased CO_2 absorption compared to anorganic fertilizers. Benbi et al. [16] reported that organic farming systems have higher carbon sequestration than conventional farming systems. Indonesia is an agricultural country and rice is the primary staple food, but land productivity has declined along with declining soil organic C content. The ability of soil to store carbon differs according to soil type, climate and form of land management (fertilization) [17]. Therefore, it is important to determine the C dynamics under different rice cultivation systems [18] to draw conclusions on the appropriate form of rice cultivation systems on the role of soil for food security [19] and climate. Very little research has been done to understand the dynamics of carbon sequestration in soil and plant biomass in organic, semi-organic and conventional cultivated rice fields in Indonesia. The concept of determinant factors is an indicator of observations that determine total carbon sequestration, and then used as a basis for formulating land management and maintaining soil organic and total carbon sequestration focusing on rice fields.

Rice fields have the potential to sequester carbon through mechanism of rice plants capture CO_2 during photosynthesis, soil organic carbon accumulation by roots and other below-ground plant components, and the alternate wetting and drying (AWD). While rice fields emit considerable amounts of methane, they can absorb carbon in several ways. Adopting suitable management methods can help increase carbon sequestration while lowering methane emissions, contributing to climate change mitigation efforts in agriculture. This study aims to: (1) determine the total carbon sequestration in soil and rice plant biomass under different farming systems of rice field, (2) determinant factors of carbon sequestration in soil and plant biomass, (3) provide land management recommendations to increase carbon sequestration in rice fields.

2. METHODOLOGY

2.1 Study area

The research was conducted in Giriwoyo District, Wonogiri Regency, Central Java, Indonesia (Figure 1). Giriwoyo District is located at coordinates 7°58′52.82″ – 8°5′27.26″ LS dan 110°52′0.08″ – 111°1′52.19″ LU. The soil type in the study area is Inceptisol. Agricultural land production is about 1,466.90 hectares in the area, which are used as rice fields, and about 8,593.23 hectares are used as settlements, shrubs, plantations, moorland, and water bodies. The research was conducted on organic, semi-organic, and conventional rice field cultivation systems. The organic rice field cultivation system has been started since 2019 using cow manure of 5 tons/hectare. The semi-organic rice field cultivation system uses 1-2 tons per hectare of cow manure, 160 kg/hectare of petroganic fertilizer, 100 kg/hectare of urea fertilizer and 80 kg/hectare of phonska fertilizer. The conventional rice field cultivation system uses 150 kg/hectare of urea fertilizer, 100 kg/hectare of phonska fertilizer and 50 kg/hectare of ZA fertilizer. During the rice plant phase, irrigation water is supplied to the complete rice field farming system. There were 2 different rainfalls of 1,706 mm/year (low) and 2,276 mm/year (medium) and conducted on slopes of 0-8% and 8-15%. Laboratory analysis included physical, chemical, and biological analysis conducted at the Laboratory of Chemistry and Soil Fertility and Laboratory of Physics and Soil Conservation, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta, Indonesia.

2.2 Soil and plant sampling

This research is survey research with an exploratory, descriptive approach conducted through direct observation in the field, laboratory analysis, and interviews with farmers. Sampling of soil and plant tissue was carried out by purposive sampling during the maturation phase of rice based on the Land Map Unit (LMU) that had been prepared. The preparation of the Land Map Unit is by overlaying the

Indonesian Land Map (RBI) of Giriwoyo District, Wonogiri Regency, with the Environmental Diversity Source Map consisting of rice field cultivation systems (organic, semi-organic, and conventional), rainfall (1706 mm/year and 2276 mm/year) and slope (0-8% and 8-15%). About 12 Land Map Units (LMU) were generated and repeated 3 times, resulting in 36 sampling points (Figure 2).

Soil sampling was carried out by the boring method at a depth of 0-20 cm, while plant tissue sampling was carried out by the destructive method (sampling by harvesting, carried out by uprooting the plant until the roots are picked up) with as much as 1 clump in the maturation phase of rice. Sampling was considered at the depth of the tillage layer (0-20 cm) because the content of nutrients, water and symbiotic organisms [20] is mostly at that depth and it is the place where the roots of rice plants are anchored. Rice plant tissue samples used include straw, roots, and rice grains with a size of 80-120 cm (root to shoot of plant). Soil samples that had been taken were partially stored in cold storage to determine microbial biomass C. The other part was air-dried, crushed and filtered with a 2mm sieve to analyze soil organic C, pH, and clay content. Rice plant tissue samples used include straw, roots, and grain with a size of one clump at each sampling point. The plant samples that have been separated are dried in the sun and then oven at 65°C until constant weight for the weight of plant biomass. The samples are then crushed to determine the organic C of plant biomass.

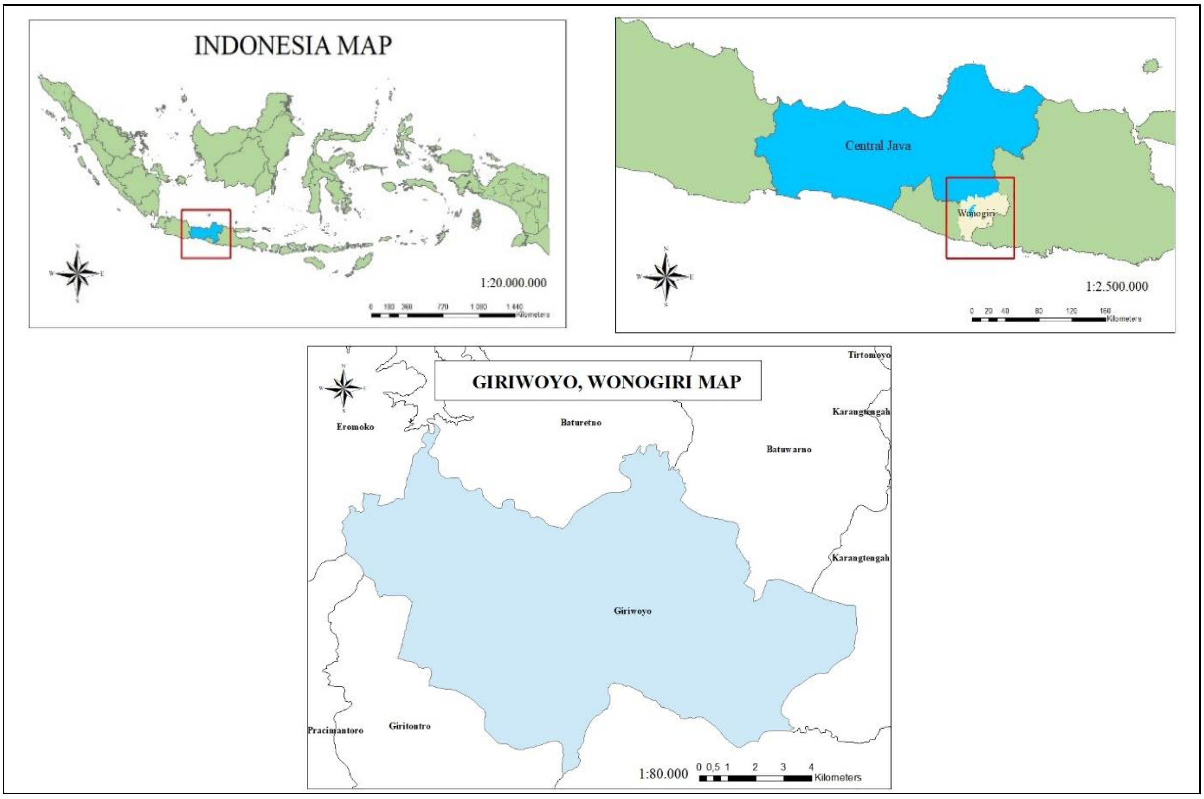

Figure 1. Study area

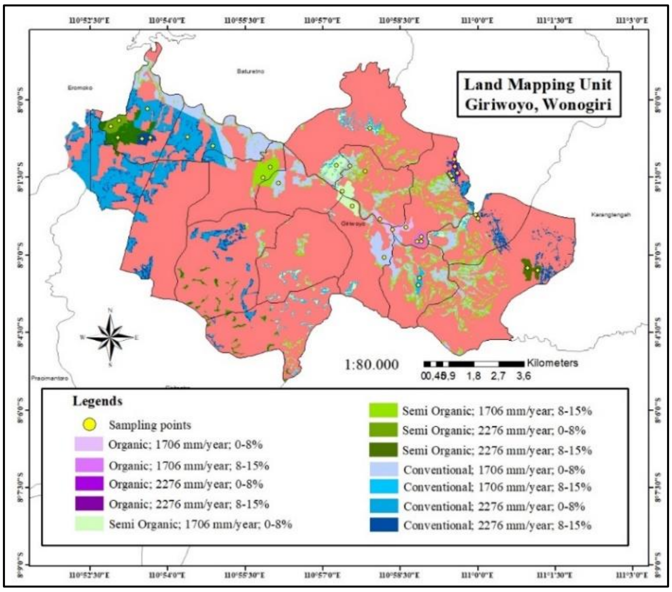

Figure 2. Land mapping unit Giriwoyo, Wonogiri

2.3 Sample analysis

2.3.1 Soil

Soil analysis include soil organic C by the Walkey and Black method [21], microbial biomass C by the Fumigation and extraction method [22], bulk density by the clod method [23], clay content by pipette method [24], pH by potentiometric method [25]. Soil carbon sequestration was calculated for 0-20 cm soil depth according to the equation [26].

$$\text{SOC stock (tons/ha)} = [\text{SOC }\%] \times \text{BD} \times \text{D} \quad (1)$$

where, SOC is the total organic carbon concentration (g C/kg), BD is the soil bulk density (g/cm^3), and D is the soil depth, in this study which is 20 cm.

2.3.2 Plant

Plant tissue analysis include organic C of plant biomass by using Walkley and Black method and plant dry weight after oven. The equation calculates the carbon sequestration of plant biomass in each part of the plant, including grain, straw, and roots [27].

$$C = B \times \%\ C \text{ biomass} \quad (2)$$

where, C is the amount of carbon (kg), B is the weight of plant biomass (kg), and %C biomass is the percentage value of carbon content based on laboratory measurements. Total carbon sequestration is obtained by summing Eqs. (1) and (2).

2.4 Data analysis

The statistical analysis test used One Way-Analysis of Variance (ANOVA) to determine the effect of different rice field cultivation systems on carbon sequestration. It continued with Duncan's Multiple Range Test (DMRT). Pearson correlation test was used to determine the relationship between soil observation variables and carbon sequestration to determine which factors play a significant role in deciding carbon sequestration. These factors are used as reference materials in proper land management to increase soil organic C and carbon sequestration in the soil.

3. RESULTS AND DISCUSSION

Carbon sequestration is the process of capturing atmospheric C through biomass production and storing it in the soil [28]. Lal [7] mentioned that carbon sequestration is one of the mitigation efforts made to reduce the increase in the amount of CO_2 in the atmosphere through the process of carbon storage into soil and plant biomass. The calculation of carbon sequestration in this study was carried out on different rice cultivation systems, rainfall and slope. This was done to determine whether or not there was an influence of the three sources of diversity on carbon sequestration.

Table 1. C-stock value, crop carbon sequestration, total carbon sequestration

LMU	FS	Rainfall (mm/th)	Slope (%)	C-Org (%)	BD (g/cm^3)	C-Stock (ton/ha)	Plant Biomass Weight (kg)/clump			C-Biomass of Plant (%)/clump			Plant Carbon Sequestration (ton/ha)	Total Carbon Sequestration (ton/ha)
							Grain	Straw	Root	Grain	Straw	Root		
1	O	1706	0-8	1.81	1.17	42.20	0.049	0.038	0.023	9.64	42.10	9.13	5.70	47.89
2			8-15	1.63	1.17	38.29	0.038	0.033	0.026	9.88	44.00	9.10	5.11	43.40
3		2276	0-8	1.72	1.24	42.48	0.045	0.050	0.025	9.89	45.74	9.64	7.42	49.90
4			8-15	1.71	1.13	38.63	0.033	0.024	0.016	9.03	43.48	8.88	3.76	42.38
5	SO	1706	0-8	1.33	1.27	33.79	0.026	0.029	0.011	8.56	35.97	8.58	3.46	37.25
6			8-15	1.38	1.28	35.31	0.040	0.035	0.016	7.90	36.60	8.21	4.30	39.61
7		2276	0-8	1.37	1.28	35.07	0.018	0.014	0.012	9.02	34.22	8.55	1.83	36.90
8			8-15	1.34	1.30	34.77	0.037	0.028	0.010	8.83	38.01	7.56	3.59	38.36
9	C	1706	0-8	1.19	1.38	32.93	0.020	0.022	0.009	6.10	32.72	6.30	2.25	35.18
10			8-15	1.24	1.21	30.24	0.023	0.023	0.013	6.27	33.06	5.93	2.46	32.69
11		2276	0-8	1.14	1.35	30.76	0.016	0.015	0.017	7.65	32.22	6.70	1.82	32.58
12			8-15	1.24	1.35	33.45	0.019	0.036	0.010	9.21	32.51	7.89	3.54	36.99

Note: FS = Farming System; O = Organic; SO = Semi Organic; C = Conventional.

3.1 Soil carbon stock

Table 1 shows that C-stock in each rice field cultivation system has different values. C-stock in the organic rice field cultivation system ranged from 38.29-42.48 tons/ha with an average of 40.40 tons/ha. C-stock in semi-organic rice field cultivation system ranged from 33.79-35.31 tons/ha with an average of 34.73 tons/ha. C-stock in the conventional rice field cultivation system ranged from 30.24-32.93 tons/ha with an average of 31.84 tons/ha. Based on Table 1, it can be seen that different rice field cultivation systems produce different C-stock with the highest C-stock found in organic rice fields followed by semi-organic and the lowest is conventional.

3.2 Plant biomass carbon sequestration

Plant biomass is one of nature's carbon sinks. Similar to carbon sequestration in soil, plant carbon sequestration is highly dependent on land management practices. Table 1 shows that the highest plant carbon sequestration was found in LMU 3 at 7.42 tons/ha with an organic rice field cultivation system, 2276 mm/year rainfall and located on a 0-8% slope. The lowest plant carbon sequestration was found at LMU 11 at 1.82 tons/ha with a conventional rice field cultivation system, 2276 mm/year rainfall and located on a 0-8% slope. The difference in the value of plant carbon sequestration in the two LMU is caused by differences in the rice field cultivation system. Organic rice field cultivation system can produce higher plant carbon sequestration than conventional cultivation system.

3.3 Total carbon sequestration

The results presented in Table 1 show that the highest total carbon sequestration was found at LMU 3 at 49.90 tons/ha with an organic rice field cultivation system, 2276 mm/year rainfall and located on a 0-8% slope. The lowest total carbon sequestration was found at LMU 11 at 32.58 tons/ha with a conventional rice field cultivation system, 2276 mm/year rainfall and located on a 0-8% slope. The difference in the total value of carbon sequestration at the two LMU was caused by differences in the rice field cultivation system. The organic rice field cultivation system produces higher total carbon sequestration compared to the conventional cultivation system.

Table 2. Effects of farming systems on carbon sequestration

	C-Stock *P-Value (sig.)*	Plant Carbon Sequestration *P-Value (sig.)*	Total Carbon Sequestration *P-Value (sig.)*
Farming System	0.000**	0.000**	0.000**

Note: ** = highly significant (p<0.01).

The results show that different rice field cultivation systems can affect carbon sequestration in Giriwoyo. Soil C-stock, plant carbon sequestration, and total carbon sequestration in rice fields were influenced by the rice field cultivation system ($p < 0.01$) (Table 2). This result is that carbon sequestration in agricultural land is well correlated with cultivation practices such as soil management systems and fertilization [29]. Total carbon sequestration in the organic rice field cultivation system was significantly different and became the highest, while the conventional rice field cultivation system became the lowest (Figure 3). High carbon sequestration in the organic rice field cultivation system is due to optimal C input through fertilization. Organic inputs such as straw return and manure use can increase soil carbon accumulation [30]. This condition is determined by study [31] that organically managed land with the addition of manure as a source of nutrients has higher carbon sequestration compared to agricultural land that receives the addition of inorganic fertilizers such as urea.

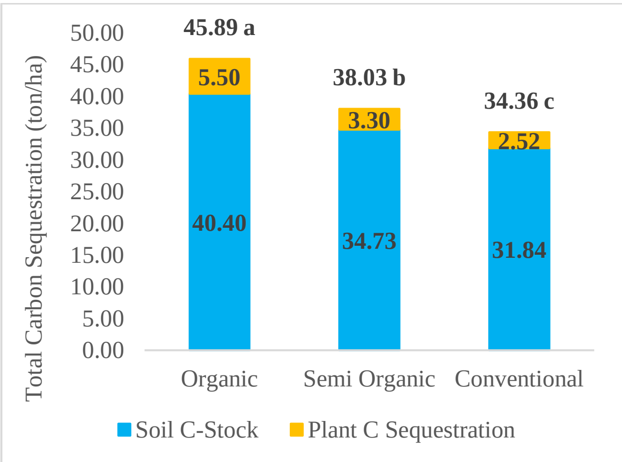

Figure 3. Average total carbon sequestration in different rice cultivation systems

Soil C-stock affects carbon sequestration in plant biomass. The amount of carbon stored in plant biomass is still determined by the amount of carbon stored in the soil, in this case, related to soil fertility [32]. A positive relationship exists between soil and plant carbon when organic C increases and soil fertility increases. As a result, plants growing well produce high biomass to absorb large amounts of carbon [33]. The more fertile the soil is, the greater the biomass growth of a plant, so the more significant the carbon stored [34]. The absorption of CO_2 by plants through the photosynthesis process is directly proportional to the increase in plant biomass [35, 36], which in turn, an increase in soil fertility conditions can result in increased carbon storage on land.

3.4 Determinants factors of soil and plant characteristics on carbon sequestration

Factors that significantly influence carbon sequestration are soil and crop observation variables significantly correlated with total carbon sequestration.

Table 3. Determinant factors of soil carbon sequestration

Parameters		Correlation	P Value
Soil	Soil organic C	0.872**	0.000
	Microbial biomass C	0.721**	0.000
	Clay content	0.118	0.495
	pH	0.074	0.668
	Bulk density	-0.137	0.425
Plant	Dry grain weight	0.736**	0.000
	Dry straw weight	0.649**	0.000
	Dry root weight	0.663**	0.000

Note: * = Significant correlation at level <0.05; ** = Significant correlation at level <0.01.

Understanding the determinants can be used to formulate land management recommendations to increase carbon sequestration in Giriwoyo District. Soil and plant observation variables that are major in determining the total carbon sequestration in paddy fields are soil organic C, microbial C biomass, dry grain weight, dry straw weight, and dry root weight (Table 3). The organic rice cultivation system has the highest soil organic C (Table 1). Increased organic C can improve soil's physical properties such as lower soil bulk density ($r=-0.567^{**}$; P-value= 0.000). The development of plant roots will be disrupted if the soil is compacted because the development of plant roots requires loose soil conditions, the easier the roots penetrate the soil will cause more nutrients and water to be absorbed by plants so that plants can grow optimally.

There was a significant positive correlation between soil organic C and microbial C biomass ($r=0.726^{**}$; P-value= 0.000). Soil microbial biomass C is the total carbon in the living components of soil organic matter that plays an important role in regulating biogeochemical processes in terrestrial ecosystems. Maruapey and Irnawati [32] explained that the high biomass of microbial C in the soil is caused by several supporting factors, namely abundant litter as a food source for microorganisms, land cover density, and soil organic C levels. 1-3% of total soil organic C is microbial biomass C [37]. The increase of microbes in the soil will increase the availability of nutrients needed for plants through the mineralization process. Rice plants need nutrients for their vegetative and generative growth. Increasing soil organic C through organic fertilization can improve soil physical properties and fertilize the soil to support plant growth with high biomass yields.

All plants with chlorophyll have the ability to absorb carbon from the atmosphere through photosynthesis. The biomass accumulated by the plant determines the quantity of carbon stored in the plant. Table 3 shows a significant positive correlation between total carbon sequestration and biomass of rice plants (dry grain weight, dry straw weight, and dry root weight), which means that the ability of plants to store carbon is determined by the amount of plant biomass. These results follow previous research on 10 woody plant species showing that ecophysiological factors such as stem height and stem diameter positively correlate with carbon storage [38]. Research by observing various fertilizer treatments (no fertilizer, anorganic only and balanced manure + anorganic) in rice-rice agro-ecosystem in India showed that the use of balanced manure + anorganic had the highest plant C biomass of 4.26 Mg/ha with plant biomass weight also having the highest value compared to the control and single inorganic treatments [39]. Despite having the same fertilization treatment, namely manure + anorganic (semi-organic), plant C biomass's value can differ. These differences can be caused by location factors such as soil type and climate in each place.

Plants can absorb and store carbon in their biomass through photosynthesis. Photosynthesis is essential for plant growth and environmental sustainability [40], as it can significantly reduce CO_2 emissions from the atmosphere [41]. As much as 45-50% of plant biomass consists of carbon content, where through photosynthesis, plants can absorb CO_2 from the atmosphere, which is then converted into organic carbon in the form of carbohydrates and stored in biomass [42]. The larger the biomass of a plant, the more carbon it can hold.

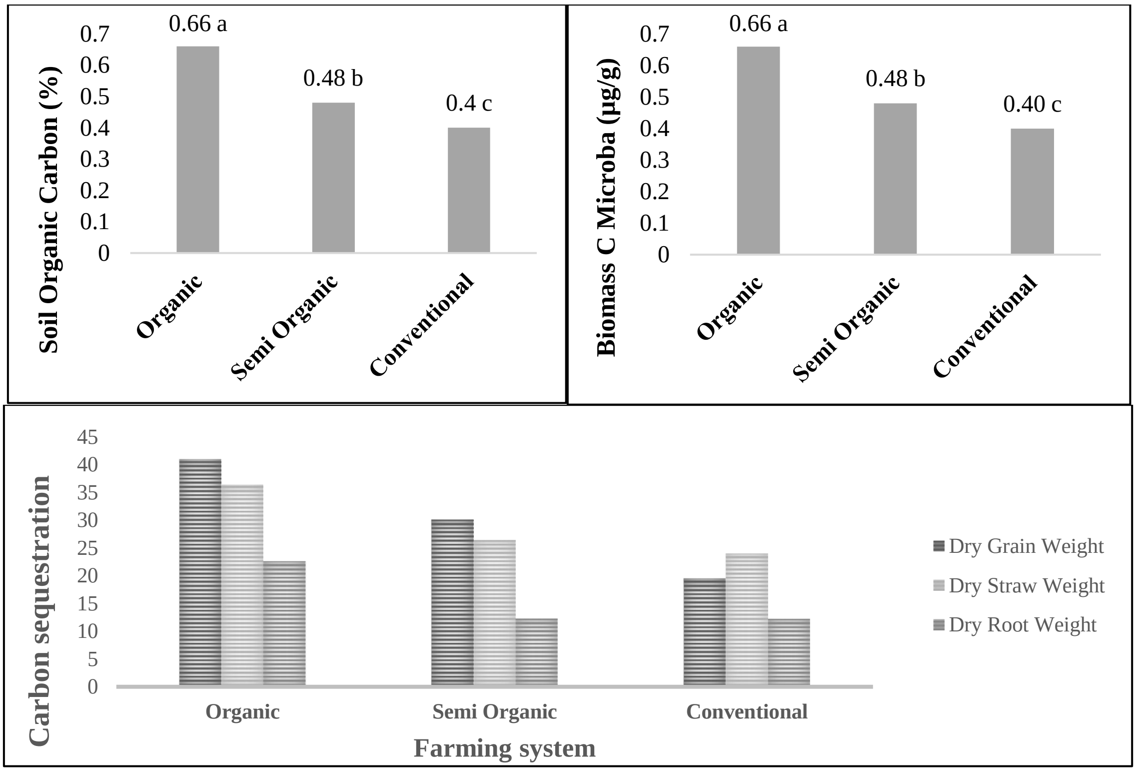

Figure 4. Average of carbon sequestration value

Based on Figure 4, it is known that different paddy field cultivation systems with the addition of organic matter through fertilization significantly affect the value of soil organic C, microbial biomass C, dry grain weight, dry straw weight, and dry root weight, which results in differences in total carbon sequestration in paddy fields. Different rice field cultivation systems significantly affect the 5 determinants factors of carbon sequestration due to the use of different types of fertilizers. Organic rice fields can provide the highest organic C compared to semi-organic and conventional rice field cultivation systems. Organically cultivated rice fields use 100% organic materials in their management. Adding organic matter carried out continuously over a long period can increase the accumulation of organic C in the soil, resulting in high C stocks [3]. Adding a single chemical fertilizer to the soil had the most negligible effect on carbon sequestration compared to soil applied with chemical fertilizer but combined with organic fertilization [43, 44].

Applying organic matter, such as returning crop residues and manure to the soil, can increase soil organic C [45]. Plants' photosynthesis ability is determined by soil fertility [46]. Higher soil organic C causes the soil to be more fertile and produce high plant biomass [44], thus causing more organic carbon input into the soil, ultimately increasing carbon sequestration on land [47]. This condition shows that a slight increase in soil organic C can significantly impact reducing atmospheric C concentrations [28].

3.5 Management recommendations to increase carbon sequestration

Rice field management recommendations to increase carbon sequestration are based on the factors most determining carbon sequestration. The limiting factors of land capability can be the basis for determining land management recommendations [48]. There are two ways to increase carbon sequestration and reduce greenhouse gas emissions on agricultural land: reducing the amount of carbon lost [49] and raising carbon input through organic fertilizers [50]. Increasing carbon sequestration can be done through nutrient management using organic manure and compost, increasing plant fertility through increased soil microbial activity, which has a positive impact on climate change adaptation, namely emissions from agricultural land can be reduced and can improve food security [51].

Organic rice cultivation systems have been able to provide the highest carbon sequestration through the application of organic fertilizers. The potential for carbon sequestration on agricultural land is most significant on fertile land [4]. In addition, compared to other sectors, agriculture is both a source of carbon emissions and a sink [49], so farmers need to pay attention to techniques to improve the carbon stock status of their land. Land management that can cause soil carbon loss needs to be avoided, in this case, the application of conventional cultivation systems. Conventional cultivation systems encourage soil erosion and degradation, thereby accelerating the loss of soil organic C in the top layer so that soil fertility decreases [52]. Applying a single inorganic fertilizer, especially nitrogen fertilizer, can reduce the soil C/N ratio [53], increase microbial activity and accelerate the decomposition process [54], thereby increasing the amount of carbon lost due to decomposition [2].

Semi-organic and conventional rice field management systems have not been able to provide total carbon sequestration equivalent to organic rice field management systems. This condition is due to the intensive use of chemical fertilizers, thus reducing soil organic C. Thus, it is expected that the use of chemical fertilizers will begin to be gradually reduced and the use of organic fertilizers will be increased so that the organic rice field cultivation system can be expanded and maintained.

4. CONCLUSIONS

Increasing greenhouse gas emissions are leading to global warming and climate change, which have a negative impact on food production. Rice fields are one of the sources of greenhouse gas emissions, but can also be a place for carbon sequestration. Different rice field cultivation systems affect carbon sequestration. The organic rice field cultivation system provided the highest carbon sequestration of 45.89 tons/ha. Soil and plant observation variables that are major in determining carbon sequestration in paddy fields are soil organic C, microbial biomass C, dry grain weight, dry straw weight, and dry root weight. Organic fertilization in organic rice field cultivation systems can provide the highest soil organic C compared to semi-organic and conventional rice field cultivation systems. Our research show that soil organic C is positively and significantly correlated with carbon suquestration. We recommend preserving and expanding organically cultivated rice fields to increase carbon sequestration and reduce carbon emissions in the atmosphere. The more carbon stored in soil and plant biomass can help reduce CO_2 gas in the atmosphere, thus helping to reduce the impact of global warming, preserve the environment and support sustainable agriculture. In addition, the application of organic rice field cultivation systems based on biological recycling of soil nutrients, including the use of zero chemicals, is one of the environmentally sustainable cultivation systems that can ensure ecological sustainability.

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