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Carbon sequestration and its impact on rice farming economic value: The quasi-experiment

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A B S T R A C T

The increasing level of the number of carbon dioxide will raise temperature on the earth and causes global climate changes. Paris agreement has responded global warming by doing mitigation, and Indonesian Government has ratified the suggestion. This research aims to determine the rice cultivation technology system which effectively could absorb the carbon dioxide into the form of biomass and C-organic in the earth. Applying the quasi-experiment by three types of technological systems – and it was conducted in farming area of Sukakarya District, Bekasi Regency, Indonesia – the research proved the T_2 (IPAT-TS planting system) – in which it applies a minimum spacing of 30 cm × 30 cm and a maximum of 50 cm × 50 cm, in aerobic soil conditions – yields the highest number of biomass straw, C-Organic, and harvest dry grain and economically gives the highest profit margin. Therefore, the research recommends the adoption of T_2 as mass common farming practice especially in *entisolic* soil types.

1. Introduction

The phenomenon of global warming is the big problem. The case of global warming that led to climate change is very dangerous, because it can result in high sea level and pollution. Some researchers suggest human activities that cause gas emissions have a significant impact on climate change. The consequence, the earth was felt to be getting hotter and there was a shift in seasons that resulted food crises, natural disasters until the emergence of new diseases (Aqualdo, Eriyati & Indrawati, 2012). While the burning of fossil fuels, the greenhouse effect and fog transportation drastically triggered an increase global gas emission (Harris, Roach & Codur, 2015; Florides & Christodoulides, 2009). About 72% of gas emissions are produced from CO2, then methane (CH4), nitrous oxide (N2O) and fluorinated gases, which each contributes 19%, 6% and 3% respectively (Olivier, Schure & Peters, 2017). The worst condition was in 2013, where total global gas emissions were 9.776 billion tons, and around 42% of this emission came from burning coal, 33% from liquid fuels, and natural gas accounted for 19%, and 6% of the cement production process (Crippa et al., 2019). To respond this problem, the international union agreed on Paris Agreement 2015 to strengthen the global response to the threat of climate change with the main goal is to limit global temperature rise below 2°C and making efforts to limit it to below 1.5°C (Dobes, Jotzo & Stern, 2014; Delpero, 2015). The results in 2016, the increase of gas emissions slowed, due to lower use of coal and the adoption of renewable electricity generator (Bhatt, 2019). Uncertainty about future climate change, and how big the biophysical impact of these changes, climate scientists have reached a strong consensus in significantly reducing global gas emissions (Nunn et al., 2019). Also followed by policy makers who are aggressively seeking solutions to reduce gas emissions and determine solutions to adapt drastic climate change (Dobes, Jotzo & Stern, 2014). The consideration of reducing gas emissions will face the complexity of the problem of allocation of economic and political resources from unprecedented difficulties (Heal, 2017). Everyone in the world has suffered from past gas emissions, then the addition of current emissions which has the potential to cause major

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disasters in the future (Stern, 2008). In discussing global gas emissions, the Department of Economics of the University of Bologna-Rimini Campus held a 2017 international workshop on understanding the impact of emissions and the design of efficient policies (Agliardi & Xepapadeas, 2019). Meanwhile, in Indonesia the aim of Paris Agreement has been ratified by Law Number 16 of 2016 which targets a reduction of gas emissions by 29% (Hermawan et al., 2018). The President of Indonesia also conveyed a commitment to reduce gas emissions in the energy sector with a reduction in emissions of 314 million tons of carbon (Supriadi et al., 2016). The very diverse potentials of increasing gas emissions in Indonesia, such as forest fires, industrial processes, biochemical degradation of waste and burning of fossil fuels are challenges in policy making (Suryani, 2013). The Second National Communication Report said CO2 emissions rose to 6.4% per year from 2000-2005, from the consumption of fossil fuels in the procurement of electricity, petroleum and gas refining (35%), manufacturing and construction (27%), transportation (23%) and settlement (9%) (Dewi et al., 2010). While, in Asian countries, agricultural activities also have an impact on increasing gas emissions more than 90% (Rajkishore et al., 2015). The agriculture aspect – for more clear -- produces emissions of 110.5 million tons of CO2 (Hermawan et al., 2018; Supriadi et al., 2016) and it is mostly relied on the plantation sector and food crops (GDP) (BPS, 2016).

For the food crop sector, rice cultivation is a source of increasing CO2 gas emissions due to non-peat paddy fields in anaerobic conditions (BAPPENAS, 2010). In addition, rice cultivation also produces around 1.5% methane (CH4) emissions and around 5% nitrous oxide which potentially contributes global warming (Nazaries et al., 2013; Bhatia, Pathak & Aggarwal, 2004). Efforts to reduce gas emissions need synergy of scientific thinking in understanding the condition of the earth and making economic activities more transition to low emissions development (Shahbazi & Nasab, 2016). Some researchers emphasized, carbon sequestration have great potential to reduce the increase of CO2 concentration in the atmosphere and it is one of the potential strategies to reduce the impact of global warming (Rajkishore et al., 2015; Amundson, 2001). The carbon sequestration is the process of capturing CO2 gas from the atmosphere (Sarwono, 2016); and by this process, the carbon can be stored in soil or plant photosynthesis, which is to absorb carbon dioxide into a form of biomass (Pambudi, Rahardjanto, Nurwidodo & Husamah, 2017; Hong-zhu et al., 2015).

Referring to Setyanto (2008), the findings of the Indonesian Agricultural Environment Research Institute (Balingtan) as an effort to support the reduction of gas emissions, indicates: 1) intermittent irrigation of rice fields resulted a reduction in CH4 emissions by 78%; 2) using the rive variety of Maros, Muncul, Way Apoburu, and Fatmawati can reduce CH4 emissions up to 66.10%. 3) using herbicides with active ingredients of paraquat and glyphosate also reduces CH4 emissions up to 60%. The study of Tyagi et al. (2010) indicated clearly, water drainage system is also one of the most important tools in rice farming to reduce the effects of methane (CH4) and nitrous oxide. Boateng et al. (2017) pointed out the chronic lack of data on rice cultivation which causes the impact of emissions in Ghana and African countries becomes a barrier to the design of mitigation appropriate to local conditions. The next study of Chirinda et al. (2018) in Latin American and Caribbean regions pointed out the intermittent irrigation and drying of rice fields are an alternative way to reduce about 25-70% of CH4 emissions by binding C carbon into biomass according to the specific conditions of the region. In the light of the above mentioned studies related to mitigate emissions from rice cultivation, it needs further research to determine the most effective of technological steps of rice cultivation to provide biomass. The biomass is produced by green plants where sunlight energy is stored in chemical bonds and processed into plant material through photosynthesis (Papilo et al., 2015). The experience of research in East Asia, the biomass contains the economic benefit in each scale and level of analysis (Caputo et al., 2005). Therefore, by the aim of reducing rice cultivation costs, it is necessary to determine an effective planting system in the process of binding carbon C to be converted into rice plant biomass, then how much is the economic value of the biomass produced based on that rice cultivation technology.

2. framework analysis

Mitigation of gas emissions is a topic that has long been discussed in many countries. For the Asian region, almost 90% of agricultural activities result the impact of increased gas emissions (Rajkishore et al., 2015). The activity of burning fossil fuels and changes of land use are the two main factors that cause an increase of atmospheric carbon dioxide (CO2) concentrations (Zhao et al., 2020). Agroecosystems are intimately connected to atmospheric CO2 levels through photosynthetic fixation of CO2, sequestration of C into biomass and soils, and the subsequent release of CO2 through respiration and decomposition of organic matter (Cheng, 2007). Carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are the most important gases that contribute to global warming (Stocker et al., 2013). Intensive rice cultivation systems can also have a negative impact on increasing atmospheric gas emissions in the form of methane (CH4) and nitrous oxide (N2O) (Sutrisna, Surdianto & Marbun, 2016). Rice cultivation is the main agricultural commodity needed on a large scale in Indonesia, especially in Java (Siswanti, Syahidah & Sudjino, 2018). On this basis, Indonesia ranks 18th in the world by its contribution of gas emissions; and Indonesian government is committed to reduce until 20% of greenhouse gas emissions by 2020 (Sutrisna, Surdianto & Marbun, 2016; BAPPENAS, 2010). Therefore, the concept of reducing global warming has been applied to agricultural land by considering radiation nature of all gas emissions associated with agricultural production (Zhang et al., 2016). A series of mitigations, such as carbon sequestration in agricultural production systems have been widely implemented (Kane, 2015). The term "carbon sequestration" is used to describe both natural and deliberate processes by which CO2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils, and sediments), and geologic formations (USGS, 2008; Ghosh, Bardhan & Roy, 2017). The mitigation in this case is pulling carbon out of the atmosphere and holding it in ground or converting it into biomass in photosynthesis (FAO, 2015). In this regard, rice cultivation has high photosynthetic capacity which can bind carbon into biomass (Smidansky et al., 2003). The biomass is fortunately an important component of growth, because it shows the addition of dry weight of plants, increase the number of cells and plant cell size (Anhar, Doni & Advinda, 2011). The rice straw is one of the stores of carbon in the atmosphere in the form of biomass and is very useful as organic fertilizer (Najmulmunir, Kamilah & Amaliah, 2019). But, oppositely, the farmers frequently took action to burn rice straw which greatly impacted the acceleration of loss of organic matter and increased CO2 emissions causing air heating (Ghoneim, 2008). To overcome the problem of nutrient loss and increase soil fertility, rice straw waste can be used as material in composting (Rhofita, 2016). The study of Danapriatna et al. (2012) pointed out straw compost can be combined with biological fertilizer to restore health and improve soil organic C. The experience of subtropical China rice indicated, the cultivation supported by organic inputs of vegetation ground cover or outside resources is very important to maintain the cycle and absorption of organic C in the soil (Wu, 2010).

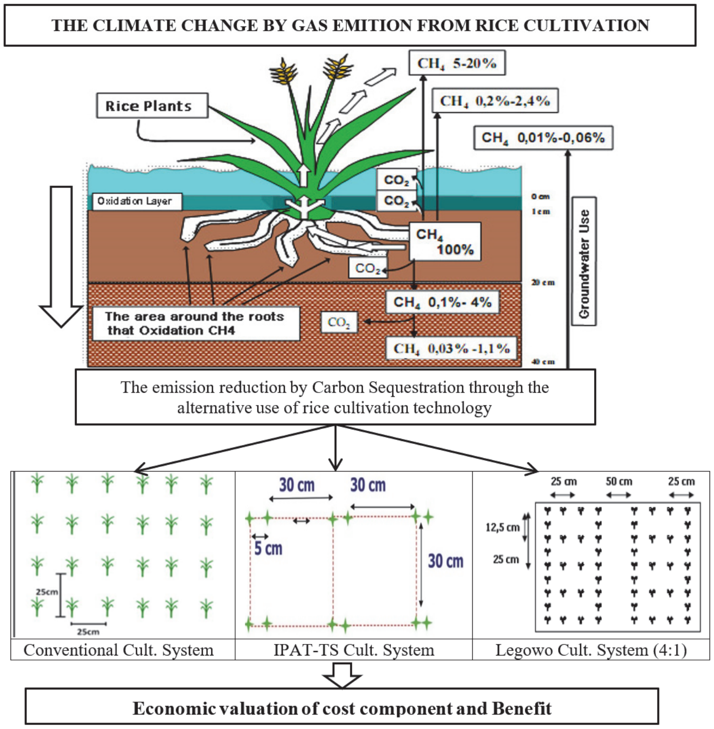

Fig. 1. Framework Analysis of Carbon Sequestration in Rice Paddy Field

In the light of above-mentioned fact, the rice cultivation with a variety of technologies could probably play a role in the formation of straw biomass in carbon binding. However, the magnitude of the benefits of carbon sequestration in promoting environmental quality through sustainable rice cultivation systems should furtherly be explored. In addition, the biomass contained in rice straw has a very large economic value. Cheewaphongphan et al. (2018) emphasized, rice straw has potential to serve as a fuel supply for the radii about 24, 36, 48 km and 60 km. Therefore, the principles and elements of carbon sequestration model in rice cultivation process could hypothetically reduce the demands and impacts of emissions on environment, and this carbon sequestration into straw biomass by certain rice cultivation technology methods could probably provide the economic added value (Fig. 1). In this case there are three models of rice cultivation systems that are predicted to have a significant effect on increasing carbon sequestration into the straw biomass, including conventional systems, IPAT-TS; and *legowo* system. The conventional planting system is a row planting system that is commonly practiced by farmers, i.e. spacing 25 × 25 cm2 with stagnant water and using chemical fertilizers and pesticides (Lin & Fukushima, 2016). The IPAT-TS is a planting system applies a minimum spacing of 30 cm × 30 cm and a maximum of 50 cm × 50 cm, in aerobic soil conditions (wet but not logged soil) (Antralina, Yuwariah & Simarmata, 2014). While the "legowo" system - referring to Darmawan (2016) - is a cultivation technique with a large space (extending in one direction between two rows of plants) with stagnant water (Fig. 1). The determination of alternative technologies must also be seen from the aspect of economic value generated from each planting system. At the same time, researchers, engineers and entrepreneurs are developing a series of uses of alternative planting systems that can turn rice straw into commodities around sustainable value chains that can be built to benefit rural communities (Hung et al., 2019). According to Hegab (2017), the economic impact of straw that is beneficial to farmers is related to the cost efficiency of nutrient replacement and the cost of timeliness (i.e. costs associated with potential delays in carrying out farming activities). For this reason, the economic valuation is needed for decision makers to estimate the economic efficiency of natural resource utilization (Santoso, Hadi & Warella, 2013). Therefore, the C sequestration process on rice straw biomass needs to use economic valuation techniques to estimate value of money generated from these resources. The economic value of the C sequestration of this rice plant can be approached with the Total Economic Value (TEV) framework, in which it consists of valuation methods that express the values of non-market resources in monetary terms (Jantzen, 2006). The valuation methods are based on either consumer preferences elicitation or use stated preferences techniques. Suharti et al. (2016) reported that TEV in mangrove ecosystem consist of indirect values contribute the highest portion to total income (52.43%), followed by direct values (46.26%), existence value (0.90%) and option value (0.41%) respectively; and this research innovatively could adopt the TEV framework analysis.

3. Research methodology

The purpose of this paper is to reveal an effective planting system in C sequestration into rice straw biomass and economic assessment of rice straw biomass. This research uses quasi-experimental -- an experiment in which the treatment has occurred in nature. This quasi-experiment adopts a non-equivalent control group of pre-test post-test (Almeida et al., 2016). According to White and Sabarwal (2014), the quasi-experimental designs aims to a causal hypotheses test, whether in an experiment (e.g., randomized controlled trials) or technological 'interventions' in which the treatments is evaluated and tested for how well it achieves its objectives, measured by a predetermined set of indicators. In this experiment, the research forms three analysis groups, one control and two experiment units. The first group is placed as a control unit in which it receives a traditional cultivation technology which has commonly been adopted by farmers. The second and third are the experimental unit in which each group receives "legowo" and "IPAT-TS" cultivation system. The control group is symbolized by T1 in which it is a traditional practice in accordance with the habit of the farmer, i.e. a spacing of 25 × 25 cm^2 with stagnant water and fertilizing according to recommendations for the local area. The T2 is "IPAT-TS" planting system, namely two plants per planting hole with a spacing of 30 × 30 cm^2, applying N fertilizer at 75% of the recommended dose and application of 400 g per ha of biological fertilizer plus 2 tons per ha of hay compost, and a controlled aerobic water management. While, the T3 is "Legowo" row planting system, i.e. spacing of 25 × 25 cm^2, applying N fertilizer system of 75% of the recommended dose, application of 400 g per ha of biological fertilizer, 2 tons of straw compost per ha and water management is according to local farmers' habits (flooded). For the selection of research location, the research considered the magnitude of potential of rice fields, rice production, and access to the nearest site. For such regard, the research chooses Sukakarya District, Bekasi Regency, Indonesia – not far from Jakarta -- as a place of research because this location yields an abundant amount of rice production so as to produce very abundant rice straw as well. The type of soil in this site is *entisol*, which is suboptimal soil that needs to be developed to increase the availability of food and feed, but has physical and chemical soil constraints (Gusnidar, Fitri & Yasin, 2019). The recommended fertilizer dosage for Sukakarya sub-district is 300 kg urea (source N), 100 Kg SP-36 and 50 kg KCl per ha and the rice varieties planted by farmers are local "Ciherang" types (Jamil, Abdulrachman & Syam, 2014). The observation of the research result for each area of the study adopts a diagonal way taken at 3 different places. Grain and straw harvest in five tiles of 2.5 m^2 in each plot in the physiological ripe phase by weighing the harvest, then the grain is taken (dry grain harvest/GKP) and straw harvest in the dry field. The first stage of data analysis is using analysis of variance with the hypothesis: H1 = the three treatment technologies have a real and significant effect on increasing carbon sequestration in the form of rice straw biomass; H2 = the three treatment technologies have a real and significant effect on C-Organic; and H3 = the three treatment technologies have a real and significant effect on the grain yields based on Chi Square test at 5% error level. Furthermore, the observed data are the cost component and benefit component of biomass, in the form of rice grains and rice straw through the calculation of economic values based on direct use value (DUV) and indirect use value (IUV) [Jantzen, 2006; Freeman III, 2014). The DUV is the benefit obtained from the use of rice cultivation technology related to rice grains; while the IUV is the amount of indirect benefits obtained from the use of rice cultivation technology systems including straw biomass yield, N, P, K, C content of straw. To see the differences in the three types of technology, the research adopts Kruskal Wallis analysis with is equipped by using SPSS version 20.00 for Windows.

4. Results and discussion

4.1 Carbon Sequestration Through Alternative Rice Cultivation Technologies

The use of good rice cultivation systems globally has great potential for atmospheric CO2 absorption and reducing the impact of gas emissions (Rajkishore et al., 2015). Among all terrestrial ecosystems, rice soil has the highest carbon density and is therefore an important carbon stock. For the most part of the Asian region, rice is a very important crop. Rice harvested area in Indonesia in the January-December 2018 period is 10.90 million hectares (BPS, 2016). The agricultural sector in Indonesia faces a number of challenges, including the application of environmentally friendly technology suitable with climate change. The intensive rice cultivation can be the main driver for long-term decline of soil quality. The carbon sequestration solution in agricultural land is a complex process that should be supported by agricultural practices, climate, and several other environmental factors (Hong-zhu, et al., 2015). However, the carbon sequestration in soils is an important option to reduce CO2 emissions in the atmosphere and of course will reduce the negative environmental impacts (Arunrat, Pumijumnong & Phinchongsakuldit, 2014). In addition, the carbon sequestration in the form of biomass has a strategic value as an efficient alternative to reduce emissions. The carbon could be stored on the ground; and of course, it is beneficial for mitigating the climate change, improving soil health and minimizing farmer production costs (Najmulmunir, Kamilah & Amaliah, 2019). To meet the needs of agricultural land resources and its preservation, the biomass is one of the factors suitable to support this demand. For this reason, this research specifically focuses merely on rice biomass produced by farmers from rice planting areas. Biomass is a term for the weight of living material, usually expressed as dry weight, for the whole or part of an organism's body. Plant biomass is the amount of dry weight of all parts of living plants; and to make it easier sometimes the biomass is divided into leaf, branch, and root biomass. The source of biomass available in rice fields is straw. The carbon sequestration can be increased through the implementation of improved agricultural management technology; and the role of microorganisms around the roots is very important to capture carbon from the air into biomass. Therefore, the knowledge of biomass is very important in functional aspects of land such as primary productivity, nutrient cycles and energy flow (Yahman, 2013). The scientific interest in understanding what types of agricultural systems increases biomass and soil organic C is frequently a focus of research. Some agricultural systems have emerged the potential to increase soil carbon, although the important details about increasing biomass and organic soil C must be carefully explored. The experimental tests in this research were arranged in a randomized block design consisting of three treatment types of technology to explore the suitable way to capture the carbon into biomass, including T1 (conventional planting systems), T2 (IPAT-TS planting system), and T3 (Legowo row planting system) [4:1]. The results of experiments using 3 typologies of technology packages are presented in Table 1.

Table 1
The Effect of Planting Type Technology to the Parameters of Wet Paddy Field

Parameter	Unit	Technology Type			Chi-Square	Asym. Sig.
		T_1	T_2	T_3		
Biomass Straw	ton/ha	10.400	13.467	11.867	7.610	0.027*
C-Organic	ton/ha	3.9635	5.399	4.450	5.538	0.063
Grain yield/ Harvest Dry Grain/HDG	ton/ha	8.64	10.84	10.36	6.938	0.031*

* Asymp. Sig. < 0.05 (one-tailed test).

The results of T1, T2, and T3 treatments using Ciherang rice varieties, entisol soil type in Sukakarya District, Bekasi Regency, Indonesia for the period of 2018-2019, and with Chi Square test, showed significant differences between the three groups of rice cultivation planting systems on straw biomass and yield of rice grains/HDG, in which the hypothesis H1 and H3 is accepted. Likewise, there is a difference in the organic C-content of straw, although it is not significant at an error rate of 5%, in which the H2 is rejected. Compared to conventional and legowo systems, IPAT-TS adoption is able to increase rice yield significantly, especially in research locations where rice productivity is still relatively low. The diversity of yield increases is closely related to input management, especially water management and integrated fertilization technique. The provision of water is still anaerobic system (0-1 cm inundation). The results of the testing of the land height setting showed that the adoption of IPAT-TS was able to increase the yield efficiency of rice grains/HDG by 10.64 tons/ha compared to conventional methods and legowo systems. In line with the results of Kantikowati's research (Kantikowati, 2014), the IPAT-PT planting technique gave higher results compared to conventional and legowo systems. IPAT-PT planting technique is an alternative to be adopted by farmers with a 30 cm x 30 cm spacing system. Planting in the IPAT-PT system at each planting point allows seedlings to grow more freely in the initial phase of growth compared to planting 3-5 seedlings per dot. In addition, the anaerobic water management and wider spacing allows the development of soil biota, especially algae and photosynthetic bacteria on the surface of land that can increase carbon sequestration. This organism has the role of producing organic compounds (chemical energy sources) needed by other soil biota as a source of energy and sustainability of energy flow in the soil ecosystem. The amount of carbon that can be stored in the form of C-organic in rice biomass sequentially is 3.96, 5,399 and 4,450 tons/ha produced by implementation of each T1, T2 and T3. The T2 could yield the highest amount of biomass straw as well as the C-Organic.

4.2 Economic Valuation (Benefits and Costs) of the Rice Cultivation Technology

The use of rice cultivation technology - aside from being able to carry out Carbon Sequestration into the form of straw biomass and soil C-Organic – it is necessary to pay attention economic assessments related to costs and benefits in order to be an effective and efficient solution for farmers. Conclusively, the offered innovations should economically be benefitted for farmers. In the economic valuation, the benefit of rice cultivation is divided into direct and indirect benefits. The direct benefits is in the form of rice grains as food source, while the indirect benefits is in the form of straw and roots that are useful for compost in addition to containing minerals for plant nutrition. The both components have high benefits for farmers. However, the two components have not been fully utilized properly by local farmers. Rice grains have economic value following the market prices (Table 2). This illustrates the direct benefits as the main indicator for rice farmer income. The differences between the use of two types of technology cause differences in the economic value. The most excellences is by using the T2 technological system with the principle of reducing inorganic N fertilizer by 25% or administering N fertilizer by 75%, with a controlled aerobic irrigation system.

Table 2
The Rice Grain Price and Economic Valuation of Cultivation Technology

Use Value	Unit	**T_1 Conventional**	**T_2 IPAT-TS**	**T_3 *Legowo***
Rice Grain / Harvest Dry Grain/HDG	(ton/ha)	8.64	10.84	10.36
Farmers' Average Prices	($/ton)	285.71	285.71	285.71
Economic Value	($/ton/ha)	2,468.57	3,097.14	2,960.00

The economic value of rice grains is based on HPP (Government Purchase Price) or the minimum price that must be paid by the milling party to farmers in accordance with the quality of grain as determined by the Government. The pricing is carried out collectively between the Ministry of Agriculture, the Coordinating Minister for the Economy, and BULOG (Logistic Business Agency). The results of statistical data processing in 2019 show the average price of un-hulled rice according to quality components and HPP at the farmer level in Indonesia is $ 285.71/ton. The Table 2 data shows that the highest average rice productivity per planting season is by the application of the IPAT-TS, in which it is 10.84 tons per hectare with an economic value of $ 3,097.14 per hectare. This income has a huge impact on rural development, particularly in the research location which is expected to be a driving force for regional economic movement, particularly the farmer economy. Regarding the indirect benefits of rice cultivation for Carbon Sequestration (CS) in the form of straw biomass, it is widely available in the field, but unfortunately it has not been used properly; even the actions of farmers are detrimental because of burning straw. Lack of knowledge on treatment in this action is very detrimental to the farmers themselves, because they lose soil organic matter (reduced soil fertility). In fact, straw biomass can be utilized through compost to increase the C/N ratio and is useful for improving soil health which affects the increase rice productivity. The findings of Danapriatna proves, straw biomass composted with application of 400 g per ha of biological fertilizer, combined with N-fixing bacteria (Azotobacter and Azospirillum) can restore soil health, which is indicated by an increase in organic C to above 2%, increase population and bacterial activity as well as reduce urea use by 30%. The straw biomass converted to compost straw contains organic C (about 30-40%) and this is the form of carbon storage in the soil. The biomass also contains complete nutrients, both macro (1.5% N, 0.3-0.5% P2O5, 2-4% K2O, 3-5% SiO2) and micro (Cu, Zn, Mn, Fe, Cl, Mo). The straw compost application of 2 tons/ha can also reduce the use of inorganic fertilizer by 25% (Siregar & Hartatik, 2010). Meanwhile, carbon storage in the form of rice straw biomass as organic fertilizer at a rate of 5 tons per ha had a significant effect on increasing organic C, P, plant height, plant dry weight, N uptake and P Conclusions uptake (Pane, Damanik & Sitorus, 2014). The condition of rice fields in Indonesia is largely integrated, which is characterized by low organic matter content. Besides containing organic C-straw biomass, it is also a source of minerals, especially N, P, and K (Makarim, Sunarno & Suyanto, 2007). The use of straw compost as a source of K contributes nutrients especially N needed by plants, also able to increase nutrient efficiency of N and K inorganic fertilizers (50%) caused by improved soil chemical properties (Sitepu, Anas & Djuniwati, 2017). The different technology systems used have an effect on the differences in mineral content in the biomass of straw; while the economic value of lowland rice straw biomass is contributed by its mineral content. Relating to the economic value of carbon, it can refer to the findings of Hein (Hein, 2011) who presented the amount of carbon stored in the biomass of rice straw in Hoge Veluwe Park, amounting to 3280 tons CO2/year. However, the economic value of carbon is strongly various, depending on the carbon trading price. But, it is clear, the experimentation of three applications of the rice cultivation technology system in this study proves the different result significantly of straw biomass and the amount of minerals (Table 3). The IPAT-TS system (T2) -- two plants per planting hole with a spacing of 30 x 30 cm2 , application of N fertilizer at 75% of the recommended dosage and application of 400 g per ha of biological fertilizer plus 2 tonnes per ha of straw compost, controlled aerobic water management – yields higher carbon values than T1 and T3 systems.

Table 3

The Indirect Use Value of Rice Straw Biomass

Component	Price ($/ton)	T_1		T_2		T_3	
		(t/ha)	($/ha)	(t/ha)	($/ha)	(t/ha)	($/ha)
C-Organic	10*	3.9634	39,634.00	5.3988	53,988.00	4.4998	44,998.00
N	2.8000**	0.1009	78.32	0.1279	99.33	0.1175	91.21
P	2.8000**	0.0125	12.38	0.0148	14.70	0.0119	11.77
K	2.3333**	0.2454	175.31	0.4000	285.69	0.3121	222.92
Total value		39,900.02		54,387.71		45,323.91	

*http://www.the jakartapost.com/news/2014/04/29

**http://belajartani.com/reportase-inilah-daftar-harga-pupuk-bersubsidi-dan-non-subsidi tahun-2017

Table 4

Economic Total Value of Rice Cultivation Component per Ha

No	Values	Technological System		
		T_1	T_2	T_3
1		Direct Use Value		
	➢ Rice Grain ($/ha)	2,468.57	3,097.14	2,960.00
2		Indirect Use Value		
	➢ C-Organic ($/ha)	39,634.00	53,988.00	44,998.00
	➢ Mineral N ($/ha)	78.32	99.33	91.21
	➢ Mineral P ($/ha)	12.38	14.70	11.77
	➢ Mineral K ($/ha)	175.31	285.69	222.92
	Total Benefit ($/ha)	42,368.59	57,484.85	48,283.91

Based on the advantages of T_2 over T_1 and T_3, it could be an effective alternative to *entisolic* soil types to reduce carbon in the atmosphere and store it in the soil, increase the farmers' income and improve the environmental quality of the rice field ecosystem. However, for more clear about the total economic value of lowland rice carbon sequestration in the application of three rice cultivation technology systems, based on calculation of direct use value of grain yields as staple food and as well as the indirect benefits (Indirect Use Value) of biomass yield of rice straw, it clearly presented in Table 4.

The various factors determine the addition of nutrient content in soil cultivation; and it changes the economic valuation are: (1) increased productivity of rice yields which directly provide economic benefits for farmers, (2) changes of input of production costs, (3) utilization of straw biomass which can be an indirect economic value. In the light of above-mentioned factors, the highest economic value of carbon sequestration is the use of T_2 technology, which has a value per hectare of $ 57,484.9, while the use of T_3 and T_1 technology system, the total benefit of each is $ 48,283.9 and $ 42,368.60. In addition, to manage the rice farming, it is necessary to look at the costs of each component of alternative cultivation system so that it can be a reference for local farmers in carrying out the rice farming that produces maximum profits at affordable costs. Every difference in the use of agricultural technology in the cropping system causes a different allocation of business costs, especially production costs. The alternative way of using the T_1, T_2 and T_3 technological system causes the differences of cost allocation, and the source of difference lies in the cost of the cultivation, nursery, planting, plant maintenance, harvest, irrigation, and land rent; and this research explored these factors. The total cost of rice farming for T_1 technology in $/ha is 974.3, while for T2 is 1.016.9 and T3 is 1.010.7. The research proves, the difference of total costs for T_2 and T_3 technological systems is not high, because the difference lies merely in the harvest phase (Table 5).

Table 5
Cost Production of Rice Farming Based on Technological System

Component	Technology T_1 ($/ha)	Technology T_2 ($/ha)	Technology T_3 ($/ha)
Cultivation	107.1	107.1	107.1
Nursery	77.5	77.5	77.5
Planting	57.1	57.1	57.1
Plant Maintenance	242.9	257.1	257.1
Harvest	132.5	160.8	154.6
Irrigation	71.4	71.4	71.4
Land rent	285.7	285.7	285.7
Total Costs	**974.3**	**1,016.9**	**1,010.7**

The difference of total cost of rice farming based on the three alternative technologies is not significant. However, to disseminate this farming practice to the farmers and to be developed as a common farming practice, it requires further analysis of the margin value and the ratio. Then it is necessary to compare the components of costs and benefits as measured by the R-C ratio of the effect of the three technologies. The comparison of total benefits and costs for the adopting the cultivation technology for complete carbon sequestration is valuable. This comparation in this research could clearly bee seen in the R/C DUV and R/C TEV indicators with values of 2.5 and 43.5 for T_1; 3.0 and 56.5 for T_2; and 2.9 and 47.8 for T_3 (Table 6). The result of this comparison indicates that T_2 is the most effective and efficient in the effort to carry out the rice farming and Carbon Sequestration process in the form of rice straw biomass. The role of using technological innovations is prioritized to impact soil health through improving soil fertility, increasing overall biomass and increasing the productivity of crops in the form of rice grains. The use of technology in agronomy will continue to have an innovative impact on sustainable agriculture. This is related to the effect of the innovation of the T_2. It can be seen from the difference in TEV values between T_1 and T_2 that is $ 15,116.26. Meanwhile, the superiority of the T_3 on the difference in the value of TEV T_3 and T_1 is $ 5,915. The two alternative innovations can be a reference for farmers in conducting the rice farming on the *entisol* soil type.

Table 6
Economic Analysis of Carbon Sequestration

Values	Unit	Technology T_1	Technology T_2	Technology T_3
Total Economic Value	($/ha)	42,368.6	57,484.9	48,283.9
Economic Value $_{DUV}$	($/ha)	2,468.6	3,097.1	2,960.0
Total Costs	($/ha)	974.3	1,016.9	1,010.7
Profit Margin $_{DUV}$	($/ha)	1,494.3	2,080.3	1,949.3
Profit Margin $_{TEV}$	($/ha)	41,394.3	56,468.0	47,273.2
R/C $_{DUV}$		2.5	3.0	2.9
R/C $_{TEV}$		43.5	56.5	47.8
Innovation Effect $_{TEV}$	($/ha)		15,116.26	5,915.32
Innovation Effect DUV	($/ha)		628.57	491.43

5. Conclusion

The rice plants play a role in absorbing carbon dioxide gas in the atmosphere through photosynthesis which is converted into biomass, which is then stored in the soil in the form of straw compost and will then become C-Organic soil. The biomass consists of Direct Use Value (DUV) and Indirect Use Value (IUV) components, all of which are reflected in the Total Economic Value (TEV). The technological system that has the highest TEV is T_2, which is applying a N fertilizer of 75% of the recommended dose, application of 400 g per ha of biological fertilizer plus 2 tons per ha of hay compost, controlled aerobic water management, planting system IPAT-TS (two plants per planting hole) with a spacing of 30x30 cm2. While, the T_3, which applies technology of the N fertilization system of 75% of the recommended dosage, applies 400 g per ha of biological fertilizer, compost of 2 tons of straw per ha, water management according to local farmers' habits (inundated), *legowo* planting system with a spacing of 25×25 cm^2. The T_1 yield is the smallest because conventional technology is in accordance with local farmers' habits, namely the spacing of 25 × 25 cm^2 with stagnant water, fertilizing according to the recommendations of the research area. The highest profit margin generated in both DUV and TEV components is in the use of T_2 then T_3 and the smallest is T_1. The most efficient biomass is generated by the use of T_2, then T_3 and T_1. The effect of innovation is greatest – indicated both on the DUV value and on TEV – is at T_2, then T_3. Therefore, the T_2 is the most effective for carbon sequestration as well as to become the basis for agribusiness development for sustainable agricultural systems.

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