Identification of Land Fertility on the Productivity of Lowland Rice and Vegetable Crops in Mudung Laut Village, Pelayangan District, Jambi City

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Abstract. The availability of agricultural land is increasingly limited due to the continued conversion of functions into settlements and other non-agricultural infrastructure, it is necessary to identify the remaining fertility of the land. It aims to maintain and increase crop productivity by using more appropriate and environmentally friendly technological inputs. The location of the research was determined to focus purposively on paddy fields (for lowland rice) and dry land (for several types of vegetable crops). The results of soil analysis showed that all land planted with lowland rice and vegetables had an acidic pH (4.60 – 5.05), moderate to high organic C (2.71% – 3.94%), medium N (0.24% – 0.38%), moderate C/N (10.00 – 12.00), very low to very high P_2O_5 (2.90 ppm – 66.10 ppm), high to very high K (46.40 ppm – 240.40 ppm), and low to moderate CEC (15.27 – 18.32). For plant variables, the productivity of lowland rice was 5.22 tons ha^{-1}, chili 15.00 tons ha^{-1}, long beans 14.00 tons ha^{-1}, cucumber 30.00 tons ha^{-1}, and eggplant 12.50 tons ha^{-1}. The productivity achieved is higher than at the provincial and national levels, but still cannot reach the potential yield from the description of the existing superior varieties. It was concluded that the agricultural land in the Mudung Laut village is very potential for the development of lowland rice and various types of vegetable crops. However, to achieve the potential yield according to the description it is still necessary to improve soil pH to increase soil pH to near neutral which is more optimal for the growth and development of all types of plants.

Keywords: Fertility · Productivity · Lowland rice · Vegetable

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1 Introduction

Indonesia, which is dubbed as an agricultural country, should be able to realize food independence and sovereignty in line with its increasing population. Population growth must be in line with economic development in meeting food needs and a better quality of life for the community. This of course must also be balanced with efforts to maintain land fertility in a sustainable manner. In Law No. 12 of 1992 it has been regulated about the system of plant cultivation as part of agriculture which is based on benefits, is sustainable, and sustainable. Furthermore, Law No. 22 of 2019 also mandates that in principle a sustainable agricultural system must be able to integrate four interests, namely economic, social, cultural, and environmental.

The challenge faced in agriculture today is the limited amount of potential land. In line with the opinion of [1] stated that agricultural land in the tropics experienced a lot of degradation and decreased fertility. The problem of loss of nutrients, the limited use of organic fertilizers, and the lack of knowledge of farmers will have an impact on decreasing land quality and crop productivity. The impact of agricultural intensification activities that rely on the continuous use of high doses of chemical fertilizers has finally been proven to lead to inefficient use of chemical fertilizers and land degradation. This fact encourages the emergence of the concept of conservative soil management and combines the use of natural organic matter so that the soil remains fertile and more efficient in the use of chemical fertilizers and obtains optimal crop production in the long term. Conservation-based tillage combined with the addition of nutrients and biomass from crop residues could improve the physical and chemical properties of the soil, namely lower bulk density, higher pH, and higher organic C, and increased yields [23].

Conservation-based agricultural land management is needed to maintain and improve the quality of land fertility. The results show that conservation-based land management can significantly improve soil quality and increase the availability of nutrients, and in the long term can increase the efficiency of using chemical fertilizers [10].

The results of [13] showed that the application of plant waste (litter) can increase C-organic and soil microbial populations. This result is reinforced by [12] that the application of organic fertilizers can significantly increase the amount of humic acid and soil macropores. Soil organic matter can be a major indicator of soil quality because it plays a role in soil ecological stability. Furthermore, the results of research by [9] showed that the application of organic matter in the form of 8% biochar can significantly increase soil pH in all types of soil incubated, with an increase in pH of around 1.17.

In increasing crop yields in a sustainable manner, often the need for nutrients for plants is not enough just to rely on the provision of organic fertilizers, so that the combination of the use of organic fertilizers and chemical fertilizers can interact positively in supporting plant growth and development so as to increase crop yields. The results of the research of [18] showed that the application of chemical fertilizers (in the form of NPK and liming) combined with manure can increase the uptake of P and K elements compared to using only chemical fertilizers.

The lack of information on soil fertility has severely hampered its management program to increase crop yields [16]. The level of fertility of agricultural land is a problem that cannot be separated from efforts to increase crop production and productivity. In response to this, it is necessary to identify the quality of soil fertility, including the physical and chemical properties of the soil, which can be used as recommendations for the addition of soil enhancers in the long term to maintain its fertility.

2 Material and Methods

The research was conducted in the Mudung Laut village, Pelayangan sub-district, Jambi city which has a composition of 141.75 ha of dry land and 20.75 ha of rice fields, and a potential land area for agriculture of 57.00 ha. The time of the research is from April to October 2021. The location of the research was determined purposively on the grounds that this region has several farmer groups belonging to 'GAPOKTAN' with various kinds or types of agricultural commodities cultivated, especially lowland rice and vegetables.

The data collected in this study are primary data from the results of regional surveys, especially for the analysis of chemical and physical properties of the soil, and interviews with respondent farmers using a structured questionnaire for crop productivity data. Each farmer group took 20% of its members as a sample which was determined using the Stratified Random Sampling method based on the area of land ownership and types of farming commodities. Furthermore, secondary data is supporting data obtained from related agencies.

Soil samples obtained from the location of paddy fields and dry land were analyzed in the laboratory regarding the physical and chemical properties of the soil, then the results were compared with the standard criteria for land quality and fertility. The data obtained from the questionnaire was tabulated and presented descriptively.

3 Result and Discussion

The results of soil sampling in the Mudung Laut village are related to the chemical properties of the soil both on paddy fields for rice plants and on dry land for several types of vegetable crops, and after an analysis in the laboratory is then compared with the criteria set by the Bogor Soil Research Institute, it can be concluded interpreted the quality of soil fertility (Table. 1).

The results (Table 1) showed that all locations in paddy fields planted with rice and dry land planted with various types of vegetables had an acid pH, which was between 4.60 to 5.20, and there was a tendency for soil pH to be slightly higher in dry land than in paddy fields. Soil pH is the main variable that controls many chemical and biochemical processes in the soil [18]. Soil pH regulates the availability of nutrients by controlling the chemical form of nutrients that will affect their chemical reactions. Added by [12] that soil pH plays a role in biological activities that occur in the soil, such as CO emissions, nitrogen fixation, mineralization of organic matter, and distribution of beneficial microbes [18] also stated that fertility and low soil pH were limiting factors for growth and yields.

Soil pH is considered the main variable in soil chemistry because it has a very large influence on the availability of nutrients for plants [20]. The limiting factors for increasing crop production are acid pH, Al toxicity, low organic C, low N, and low CEC [16]. Therefore, the addition of lime is the most efficient method to increase the pH of

Table 1. The results of the analysis of the chemical properties of the soil on agricultural land in the Mudung Laut village, Pelayangan sub-district, Jambi city

Variable	Paddy field (rice plants)		Dry land (vegetable plants)			
	Location-1	Location-2	Location-1	Location-2	Location-3	Location-4
pH (H_2O)	4.60	4.90	4.90	5.20	5.00	5.00
C-org Kumies (%)	3.81	3.29	3.94	3.15	2.83	2.71
N Kjeldahl (%)	0.34	0.30	0.38	0.26	0.26	0.24
C/N	11.00	11.00	10.00	12.00	11.00	11.00
P_2O_5 Bray 1 (ppm P)	4.80	11.40	4.10	39.30	2.90	66.10
K Morgan Venema (ppm)	103.60	80.30	73.20	95.50	46.40	240.40
Al_{ex} Cmol (+)/kg	3.32	2.05	3.74	0.76	4.33	2.04
H_{ex} Cmol (+)/kg	1.34	1.02	1.43	0.47	1.46	0.79
CEC Cmol (+)/kg	16.60	16.60	18.32	15.27	15.27	15.30

acidic soils and can reduce the toxic effects of Al [12]. Furthermore, [16] stated that to increase crop yields in a sustainable manner it is necessary to add lime to acid dry land.

According to [14] that the application of agricultural lime in the form of CaO, $CaCO_3$, Ca $(OH)_2$, and CaMg $(CO_3)_2$ increased the average yield of various types of plants by 13.20, 34.30, 29.20, and 66.50%, respectively.

Variable C-organic in the research land obtained moderate to high measurement results, the lower C-organic criteria were found in two locations on dry land, while in paddy fields all locations had high C-organic. For variables N and C/N both are included in the moderate criteria at all locations, both on paddy fields and on dry land. There is also a trend in the three dry land locations that have lower N values. Furthermore, the measurement results on the P_2O_5 variable have a very high variation. For P_2O_5 obtained in dry land (Location-2 and Location-4) is very high, while at Location-3 is very low, as well as in rice fields for Location-1 is very low and Location-2 is high. The K status ranges from high to very high. The CEC values in paddy fields and dry land are not much different, but in paddy fields all are in the medium criteria, and in dry land mostly in the low criteria.

C-organic is an indicator of the presence of organic matter in the soil which can be sourced from the application of various organic materials such as manure and crop waste. The higher the C-organic of the mineral soil, the better the quality of the mineral soil, because C-organic plays a role in improving the physical properties of the soil, increasing the biological activity of the soil, and the availability of nutrients for plants

Table 2. Criteria for assessing the results of soil analysis [9]

Variable	Value				
pH (H_2O)	< 4.50 too acid	4.50–5.50 acid	5.50 - 6.50 slightly acid	6.60 -7.50 neutral	7.60 - 8.50 slightly alkaline
C-org Kumies (%)	< 1.00 very low	1.00 – 2.00 low	2.00 – 3.00 currently	3.03.03.03.03.0–5.00 Height	> 5.00 very height
N Kjeldahl (%)	< 0.10 very low	0.10 - 0.20 low	0.21 - 0.50 currently	0.51 - 0.75 Height	> 0.75 very height
C/N	< 5.00 very low	5.00 -10.00 Low	11.00 – 15.00 Currently	16.00 – 25.00 height	> 25.00 very height
P_2O_5 Bray 1 (ppm P)	< 4.00 very low	5.00 – 7.00 Low	8.00 – 10.00 Currently	11.00 – 15.00 Height	> 15.00 very height
K Morgan Venema (ppm)	< 10.00 very low	Low	21.00 – 40.00 Currently	41.00 – 60.00 Height	> 60.00 very height
Al_{ex} Cmol (+)/kg	-	-	-	-	-
H_{ex} Cmol (+)/kg	-	-	-	-	-
CEC Cmol (+)/kg	< 5.00 very low	5.00 -16.00 low	17.00 – 24.00 currently	25.00 – 40.00 Height	> 40.00 very height

[3] stated that there is a positive correlation between organic C and total porosity, N-total, and CEC.

[9] stated that the addition of organic matter in the form of biochar can induce changes in soil pH, CEC, Ca^{2+}, K^{+}, Mg^{2+} are exchanged. The results of the research by [1] which combine the use of organic fertilizers and chemical fertilizers (N and P) can increase wheat grain yields by 50–100%. Likewise, the results of research by [18] that the combination of adding organic matter in the form of manure and lime can increase soil pH, nutrient uptake, number of root nodules, and productivity of soybean plants. Further research results [10] showed that conservation-based land management can provide lower soil density, increased organic C, and available N, as well as savings in N fertilization by 30% and K 50% in wheat. [11] added that after two months of application of biochar on ultisol soils it could significantly increase pH, available P, organic C, total N, C/N.

The results of other studies show that when compared with the application of chemical fertilizers alone, the combination of manure and chemical fertilizers can increase crop yields up to 64%. This is due to an indirect effect through increasing organic C, the availability of N and P nutrients for plants [4]. The application of biochar 8 tons ha-1 and biological fertilizers can also increase soybean yield and yield index by 51% compared to control, besides that it also affects soil N, CEC, pH, and electrical conductivity [2].

Table 3. The results of the analysis of the physical properties of the soil on agricultural land in the Mudung Laut village, Pelayangan sub-district, Jambi city

Variable	Paddy field (rice plants)		Dry land (vegetable plants)			
	Location-1	Location-2	Location-1	Location-2	Location-3	Location-4
Texture						
• Sand (%)	11.00	1.00	1.00	6.00	1.00	2.00
• Dust (%)	31.00	32.00	23.00	39.00	35.00	38.00
• Clay (%)	58.00	67.00	77.00	55.00	64.00	60.00
Volume weight (g/cc)	0.99	*Flooded land*	1.05	1.23	1.00	1.15
Specific gravity (g/cc)	2.61	*Flooded land*	2.37	2.08	2.53	2.88
Total pore space (%)	62.15	*Flooded land*	55.54	40.64	60.33	60.02
Permeability (cm/h)	6.21	*Flooded land*	0.38	5.92	1.93	12.96

The results of the measurement of soil samples in the research area showed that in all paddy fields and dry land, clay particles, dust, and very little sand were dominated with volume weight (VW) ranging from 0.99 to 1.23, and specific gravity (SG) between 2.08 to 2.88, total pore space 40.64 to 62.15% (very high), and permeability 0.38 to 12.96 (very low to moderate).

The physical properties of the soil greatly affect the growth and development of plant roots. Soil that contains a lot of clay and dense particles (high volume weight) is often an obstacle for roots to grow deeper and spread widely. [3] stated that there was a correlation between C-organic and soil density, where increasing C-organic would decrease the bulk density of the soil (meaning the soil became more porous). Furthermore, the results of the research by [22] showed that the addition of organic matter in the form of rice husk biochar could reduce the density and specific gravity of the soil, as well as increase the total pore space and available soil water.

The results showed (Table 4) that the productivity of lowland rice was 5.22 tons ha^{-1}, red chili 15 tons ha^{-1}, long beans 14 tons ha^{-1}, cucumber 30 tons ha^{-1}, and eggplant 12.50 tons ha^{-1}. The productivity achieved for all these commodities is higher than at the Jambi provincial and national levels, but still cannot reach the yield potential from the description of the existing superior varieties. The high and low productivity of plants cannot be separated from the condition of the chemical and physical properties of the soil as a growing medium. Based on the results of the analysis of soil chemical properties, it showed that the C-organic, N, P_2O_5, and K content of the soil in some research locations showed moderate to very high criteria, although there were also some very low locations. The various components of the chemical properties of the soil influence each other in their role in plant growth and productivity.

Table 4. Average productivity of lowland rice and some vegetable crops in Mudung Laut village, Pelayangan sub-district, Jambi city, compared to provincial, national, and variety descriptions

Commodities	Productivity (ton ha^{-1})			
	Mudung Laut	Jambi province	Indonesia	Variety description
Paddy rice	5.22	4.46	5.11	6.28 - 8.83 (var. Ciherang)
Long beans	14.00	4.93	6.87	20.00 - 24.00 (var. Sabrina)
Cucumber	30.00	5.67	11.14	39.50 - 43.12 (var. Vanesa)
Red chili	15.00	7.86	9.10	39.50 - 43.12 (var. Kastilo F-1)
Eggplant	12.50	8.51	13.09	50.00 – 60.00 (var. Mustang F-1)

C-organic as an energy source for the proliferation of decomposing microbes that help provide nutrients for plants [19] stated that there is a positive correlation between organic C and the availability of nutrients, especially N and P. Nitrogen is an essential macro nutrient for plant growth [8]. Furthermore, in the process of plant growth there is a metabolic coordination between carbon and nitrogen [5]. Most of the nitrogen absorbed by plants is used to form the 20 types of amino acids that make up proteins. In addition, it is also found as a component of nucleic acids, chlorophyll, and auxin [7].

The maximum availability of P is generally in conditions of near neutral soil pH, but actually P can be absorbed by plants and released by the soil at a much lower optimum pH [20}. P is an essential nutrient and absolutely necessary for plant growth and productivity. Element P functions in the process of photosynthesis, nitrogen fixation, and respiration. Element P is a component of nucleic acids, lipids, and sugars. P also plays a role in the process of seed germination, root growth, shoots, flowers, and seed development [15]. Furthermore, K is also a nutrient that plants need in large quantities. K plays a role in the process of photosynthesis and loading of phloem for long-distance transport of photosynthate to plant parts that require it [21].

In an effort to obtain high yields in a sustainable manner, in addition to the physical properties of the soil and the availability of nutrients for plants, the quality of the seeds or plant seeds must also be considered. [1] state that planting high-yielding varieties accompanied by a balanced application of chemical and organic fertilizers is an approach to increasing crop yields in a sustainable manner, and in the long term is able to minimize nutrient loss and efficient use of fertilizers.

4 Conclusion

Agricultural lands in Mudung Laut village which are planted with rice and vegetables all have an acid pH (4.60 – 5.05), moderate to high organic C (2.71% – 3.94%), medium N (0.24% – 0.38%), medium C/N (10 – 12), very low to very high P_2O_5 (2.90 ppm – 66.10 ppm), high to very high K (46.40 ppm – 240.40 ppm), and low to moderate CEC (15.27 – 18.32). The productivity of lowland rice and vegetables in the Mudung Laut village are all higher than at the Jambi provincial and national levels, but still cannot reach the yield potential from the description of the existing superior varieties. The productivity of lowland rice was 5.22 tons ha^{-1}, red chili 15 tons ha^{-1}, long beans 14 tons ha^{-1}, cucumber 30 tons ha^{-1}, and eggplant 12.5 tons ha^{-1}. Thus, agricultural land in Mudung Laut village is very potential for the development of lowland rice and various types of vegetable crops. However, to achieve the potential yield according to the description it is still necessary to improve soil pH to increase soil pH to near neutral so that the availability of nutrients is more optimal for plant growth and development.

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