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Characteristics of Soil Fertility Affecting the Rice Fields Productivity in Bogor Regency

AUTHORS INFO

Yunus Arifien
University of Nusa Bangsa Bogor
yunus@unb.ac.id
+6281242330531

Sari Anggarawati
University of Nusa Bangsa Bogor
sari@unb.ac.id
+6281808328

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Abstract

The purpose of this study was to determine the parameters of soil fertility in rice fields and the effect of soil fertility on paddy productivity in Bogor Regency. This research was conducted in the districts of Cileungsi, Darmaga and Leuwiliang, Bogor Regency. The location selection was done deliberately based on the location of rice production facilities with Ciherang and Inpari varieties. Sampling was conducted at several sampling points at each location. Each sub-district was taken 8 samples or 24 in total, then analyzed in the laboratory. Data processing using multiple regression with a dummy. The results showed that the soil in Bogor Regency was generally acidic, where soil fertility characteristics with organic C content were low to moderate, nitrogen was very low to moderate, P was low to high, K was very low to moderate, CEC was moderate to high, and saturation bases (KB) are moderate to high. Soil biology, namely total bacteria, total fungi, total solvent P bacteria, Azotobacter sp., And Rhizobium sp. Are generally low to moderate. Variable characteristics of soil fertility in the form of organic C, Nitrogen (N), K2O HCl 25%, and CEC significantly influence rice productivity. Soil fertility in the three districts is almost the same and does not affect the productivity of rice fields. While the productivity of rice fields with Inpari varieties is higher than those grown by Ciherang varieties. To increase the productivity of rice fields in Bogor Regency, it is recommended to plant Inpari variety rice by applying N fertilizer

Keywords: Soil fertility and rice fields productivity

A. Introduction

Rice is a vital staple food for more than 200 million people of Indonesia, so the rice self-sufficiency program is very important. The establishment of new paddy fields and intensification programs is an effort by the government so that Indonesia can be self-sufficient in rice. Achievement of the national rice production target is 70.6 million tons of GKG (an increase of 7%) in 2011 and rice stock reaches a surplus of 10 million tons in 2015. The Ministry of Agriculture requires hard work for all agricultural stakeholders and the application of technology to accelerate rice production. The nutrient requirements of each plant are very specific depending on the nature of the soil, climatic conditions and types of plants.

In 2018 Bogor Regency was able to produce 353,150 tons of rice from a harvest area of 85,966 hectares. The existing number is only able to meet 61 percent of the 5.8 million rice needs of the population. Rice production continues to decline while food needs such as rice are getting higher, so it is necessary to take action to monitor the status of soil fertility, so that it can provide fertilizer recommendations in accordance with the location and needs of the crop being cultivated, by conducting a research study on the status of soil fertility in Bogor Regency (Ali, 2019).

For this reason, the empowerment of land resources must also be able to take advantage of the role of biological soil conservation which has a high ability to increase soil fertility. The use of varieties suitable for fertility and climatic conditions will affect rice productivity, so it is necessary to determine varieties with land type and height for each region. In Java in particular, many farmers use several new varieties and local varieties including IR 64, Ciherang, Inpari Sidenuk, Wangi and others.

Based on the description above, it is necessary to evaluate the status of soil fertility in cultivated land, in Bogor Regency so that the supply and food security for Bogor Regency can continue. That is why knowing the status of soil fertility is important in increasing crop production and influencing agriculture in the future. The aim of this study is to find out the parameters of soil fertility in paddy fields, and find out the effect of soil fertility on paddy productivity in Bogor Regency.

B. Literature Review

Soil is a growing medium for plants, as a warehouse and supplier of nutrients. Soil based on particle size is a mixture of sand, dust and clay. The finer the particle, the wider the surface area of the particles per unit weight. Thus, clay is the most extensive surface soil fraction compared to 2 other fractions. It is on the surface of these particles that various soil chemical reactions occur, which then affect soil fertility (Hanafiah & Ali, 2005). Fertile soil is soil that has a deep profile (very deep depth exceeding 150 cm); loose structure; pH 6.0 to 6.5; the content of the nutrients available to plants is sufficient; and there are no limiting factors in the soil for plant growth (Sutedjo, 2002).

The nutrients needed by plants that are provided by the soil to support their growth and reproduction are called soil fertility. Fertile soils have balanced nutrients, water and air and are available according to the needs of plants, both physically, chemically and biologically. The state of soil physics includes texture, structure, effective depth, humidity and soil air system. Soil chemical conditions include soil reaction (soil pH), nitrogen, phosphorus, potassium, cation exchange capacity, base saturation, organic matter, and other nutrients. Whereas soil biology, among others, includes the microbial activity of organic material remodeling in the process of humification and binding of air nitrogen (Damanik, Hasibuan, Fauzi, Sarifuddin & Hanum, 2010)

To increase soil fertility, fertilizer is applied. P and K fertilization has been continuously applied by farmers, so that the soil has high P and K nutrient status. This results in an imbalance of nutrients in the soil and decreased land productivity (Puja, Supadma, & Mega, 2013). On intensive agricultural land with tillage, inorganic fertilizers and intensive pesticides can suppress the development of populations of microorganisms such as microbes and soil fauna which have a very important role in metabolic activities in the soil. Empowerment of soil biological resources can also increase soil productivity by providing appropriate soil media to support the activities of each organism in the soil and can take place sustainably.

C. Methodology

The research was conducted in the v of Leuwiliang, Darmaga and Cileungsi, Bogor Regency. The research was also carried out in the Soil Bogor Research Center's soil laboratory which was conducted from March to August 2019.

1. Population and Sample

The population in this study is rice fields in Bogor Regency. Whereas the samples in this study were rice fields in Leuwiliang, Darmaga and Cileungsi Districts, Bogor Regency. Site selection is done deliberately with the consideration that the location is a production center both from IR 64 and Ciherang varieties. Soil sampling was carried out at several sampling points at each location to obtain an overall sample of 24 sample units.

2. Data Types and Data Sources

Primary and secondary data of this study include:

a) Analysis of soil fertility, such as: pH (H_2O), organic C (%), Nitrogen (N) (%), P_2O_5 Bray (ppm P), P_2O_5 25% HCl (mg / 100 g), exchanged K (cmole / kg), K_2O HCl 25% (me / 100 g), CEC (me/ 100 g), Base Saturation (KB) (%), Total Bacteria (x 10^8), Total Fungi (x10^2), Total Solvent B Bacteria (P x10^3), Azotobacter sp. (x 10^3), Rizobium sp. (x 10^3)
b) Rice fields productivity (ton / ha) based on interviews with farmers, traders, rice mills, retail rice traders and the Agriculture Service officials to accuracy the data obtained

3. Data analysis

The data obtained from the results of laboratory analysis are used to see the level of fertility of rice fields in Bogor Regency. To determine the effect of fertility characteristics in three districts with two rice varieties on rice productivity in Bogor Regency, then using multiple regression analysis, the models to be estimated are:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + \ldots\ldots\ldots + b_{14}X_{14} + d_1D_1 + d_2D_2 + d_3D_3$$

Where :

Y = Soil productivity (ton / ha)

X = namely X_1: pH (H_2O), X_2: C organic (%), X_3: Nitrogen (N) (%), X_4: P_2O_5 Bray (ppm P), X_5: P_2O_5 25% HCl (mg / 100 g), X_6 : K exchanged (cmole / kg), X_7: K_2O HCl 25% (me / 100 g), X_8: CEC (me / 100 g), X_9: Base Saturation (KB) (%), X_{10}: Total Bacteria (Bacteria) x 10^8), X_{11} Total Fungi (x 10^2), X_{12}: Total Solvent Bacteria P (x 10^3), X_{13}: Azotobacter sp. (x 10^3), X_{14}: Rizobium sp. (x 10^3)

D_1 = dummy variety (Ciherang = 0 and Inpari = 1)

D_2 = District dummy (Leuwiliang = 1 and other districts = 0)

D_3 = District dummy (Darmaga = 1 and other districts = 0)

D. Results and Discussion

1. General Conditions of Bogor Regency

Bogor Regency is located at position 6°19' LS and 6°47' LS, and 106°01' and 107°103' BT. The width of Bogor Regency is 2,663.81 km2 and has various types of regional morphology, from relatively low plains in the North to highlands in the South, which is around 29.28% at an altitude of 15-100 meters above sea level, 42, 62% are at an altitude of 100 - 500 meters above sea level, 19.53% are at an altitude of 500 - 1,000 meters above sea level, 8.43% are at an altitude of 1,000 - 2,000 meters above sea level and 0.22% are at an altitude of 2,000 - 2,500 meters above sea level .

2. Soil fertility

Soil has an important role on plant growth and crop production, because the land in addition to functioning as a place / media for growing plants, holding and providing water for plants also plays a role in providing nutrients needed by plants to support plant growth. Land formation is influenced by various factors such as climate, parent material, topography / relief, organisms and time. Therefore in general the status of soil fertility in a land will be different with different physical environments.

Characteristics of Some Soil Chemical Properties

The results of the analysis of some of the chemical properties of the soil in the rice fields, Bogor Regency can be seen in Table 1. Most of the values of the chemical properties in some locations show very low to moderate. Based on the results of laboratory analysis shows that soil CEC in rice fields in the District of Cileungsi is in the range of 24.28 - 56.76 me / 100 g of land (classified as high - very high), Darmaga District is in the range of 22.60 - 51.11 me / 100 g of land (classified as moderate - very high), Leuwiliang District is in the range of 22.89 - 48.77 me / 100 g of land (classified as moderate - very high). This situation is due to the presence of soil constituent particles dominated by clay fraction which has a large colloidal surface area, so that the soil CEC is also high. From Table 1 shows the results of laboratory analysis and calculation of the number of cations shows that the saturation of the base (KB) of the soil in the rice fields respectively ranged between 47-67%, 61-68% and 61-64% (classified as moderate to high) .

Table 1. Characteristics of some Soil Chemical Properties, Bogor Regency

Soil Chemistry	Cileungsi District		Darmaga District		Leuwiliang District	
	Value	Status	Value	Status	Value	Status
pH (H_2O)	4,12 - 4,93	SM – M	4,20 - 5,19	SM – M	4,48 - 6,03	SM – M
C organic (%)	1,81 - 2,65	R – S	1,43 - 2,80	R – S	1,38 - 2,44	R – S
Nitrogen (N) (%)	0,14 - 0,28	R – S	0,00 - 0,25	SR – S	0	SR
P_2O_5 Bray (ppm P)	0,53 - 18,24	SR – ST	0,00 - 27,41	SR – ST	0	SR
P_2O_5 HCl 25% (me/ 100 g)	6 – 178	SR – ST	9 – 182	SR – ST	49 – 88	T – ST
K Exchanged (cmole/kg)	0	SR	0	SR	0	SR
K_2O HCl 25% (me/ 100 g)	5 – 31	SR – S	10 – 37	R – S	6 – 16	SR- R
KTK/CEC (me/100 g)	24,28 - 56,76	T – ST	22,60 - 51,11	S – ST	22,89 - 48,77	S – ST
Saturation Based (KB) (%)	47 – 67	S – T	61 – 68	T	61 – 64	T

Based on the results of laboratory analysis Table 1 shows that the organic C content of soil in the rice fields in the District of Cileungsi is in the range of 1.81 - 2.65% (classified as low to moderate), Darmaga District is in the range of 1.43 - 2.80% (classified as low to moderate) and Leuwiliang Subdistrict are in the range of 1.38 - 2.44% (classified as low to moderate). Variation of organic C content (organic material) on these lands is due to differences in the type and amount of vegetation that grows on these lands. Munawar (2013) stated that soil organic matter is all the carbon in the soil that comes from the dead plants / plants and animals that have died. Most sources of soil organic matter are plant tissue. Different sources and amounts of organic matter will have different effects on organic material donated to the soil.

Based on the results of laboratory analysis showed that the rice fields in the District of Cileungsi P_2O_5 HCl 25% ranged from 6 - 178 me / 100 g (classified as very low to very high) and P_2O_5 Bray content ranged from 0.53 - 18.24 ppm P (classified as very low to very high), Darmaga District content of P_2O_5 HCl 25% ranging from 9 - 182 me / 100 g (classified as very low to very high) and content of P_2O_5 Bray ranging from 0.00 - 27.41 ppm P (classified as very low to very high), and Leuwiliang District content of P_2O_5 HCl 25% ranges from 49 - 88 me / 100 g (classified as high to very high) and P_2O_5 Bray content ranges from 0 ppm P (classified as very low). This situation is caused because the soil is formed from parent material (rock / mineral) which is poor in P element and the P content in organic matter is also low As stated by Munawar (2013) that P in the soil comes from the disintegration of P-containing minerals such as apatite, and decomposition organic matter. The solubility of inorganic P compounds and organic P in the soil is generally very low, so that only a small portion of soil P is in the soil solution (total P).

Laboratory analysis results show that rice fields in Cileungsi District contain K_2O HCl 25% ranging from 5 - 31 me / 100 g (classified as very low to moderate) and swapped K content ranges from 0 cmole / kg (classified as very low), Darmaga District K_2O HCl 25% content ranges from 10 - 37 me / 100 g (classified as very low to moderate) and the exchanged K content ranges from 0 cmole / kg (classified as very low), and Leuwiliang District K_2O HCL 25% content ranges from 6-16 me / 100 g (classified as very low content to low) and the exchanged K content ranges from 0 cmole / kg (classified as very low). This situation is caused by the rocks / minerals making up the soil in the area are poor in base cationic content, besides that it can also be caused because in Bogor Regency has high rainfall, so the base cations have been leached.

Soil Biological Characteristics

Soil biological characteristics include soil organic matter, flora and fauna of the soil (especially important microorganisms such as bacteria, fungi and Algae), interaction of soil microorganisms with plants (symbiosis) and soil pollution. Land is said to be fertile if it has high biological diversity and diversity. Soil organisms (microorganisms) are important in soil fertility because: 1) Play a role in the energy cycle. 2) Has a role in the nutrient cycle, 3) Has a role in the formation of soil aggregates. and 4) Determine soil health (suppressive / conducive to the emergence of diseases, especially diseases of soil borne pathogen).

Table 2. Characteristics of some Soil Biological Traits, Bogor Regency

Soil Biology	Cileungsi District		Darmaga District		Leuwiliang District	
	Value	Status	Value	Status	Value	Status
Total Bakteri (x 10^8)	1,5 - 2,4	S	1,7 - 2,7	S	1,8 - 2,6	S
Total Fungi (x 10^2)	1,8 - 26,0	S – T	1,0 - 2,2	S	0,5 - 0,8	R
Total Bakteri Solvent P (x10^3)	0 – 8	S	0 – 2	R	0 – 3	R
Azotobacter (x 10^3)	1 - 24	T	1 - 80	T	1 – 2	R
Rizobium sp (x 10^3)	0 – 17	T	0 - 2	S	0 – 3	S

Bacteria are prokaryotic single-celled organisms with the highest number of groups and are found in each terrestrial ecosystem. Although their size is smaller than actinomycetes and fungi, bacteria have more diverse metabolic abilities and play an important role in soil formation, decomposition of organic matter, remediation of polluted soils, nutrient transformation, mutual integration with plants and also as a cause of disease (Rasti, Hasan, & Simanungkalik, 2007). From the results of the study it can be seen in Table 2 that the total Bacteria of paddy soils in the District of Cileungsi amounted to between 1.5 - 2.4 x 108 (classified as moderate), Darmaga numbered between 1.7 - 2.7 x 108 (classified as moderate) and Leuwiliang amounted between 1.8 - 2.6 x 108 (classified as moderate). While the total landfill fungi in the district of Cileungsi amounted to between 1.8-26 x 108 (classified as moderate), Darmaga numbered between 1.0-2.2 x 108 (classified as moderate) and Leuwiliang numbered between 1.8-2.6 x 108 (classified as medium).

Azotobacter sp. is one of the bacterial inoculants that is important for increasing soil N availability and increasing crop yields. Azotobacter sp. is a rhizobacteria that is always found in cereal plants. From the results of the study it can be seen that Azotobacter sp Sawah soil in the district of Cileungsi amounted between 1 - 24 x 103 (classified as high), Darmaga amounted between 1-80 x 103 (classified as high) and Leuwiliang amounted between 1-2 x 103 (classified as low).

Rizobium sp. is a group of bacteria capable of providing nutrients for plants, especially legume plants. This bacterium is able to infect plant roots and form nodules that function to take N in the atmosphere and distribute it as nutrients needed by the host plant. From the results of the study found Rhizobium Rice fields in the District of Cileungsi amounted between 0-17 x 103 (classified as high), Darmaga amounted between 1-80 x 103 (classified as high) and Leuwiliang numbered between 1-2 x 103 (classified as low).

3. Rice Field Productivity

Rice productivity is the yield per unit area and time. One effort to increase productivity can be done by improving genetic potential and plant resistance to biotic constraints (pests and diseases) and abiotics (drought and poisoning), improvement of site-specific cultivation (integrated crop management and prescription farming). The acceleration and expansion of dissemination and adoption of technological innovations. Increased national rice productivity is very possible when viewed from the potential development of superior varieties and rice technology readiness in the Agency for Agricultural Research. From the results of the study it can be seen that the productivity of paddy soils in Cileungsi District amounts between 5.5 - 8.75 tons / ha, Darmaga amounts between 5.5 - 7.0 tons / ha and Leuwiliang amounts between 5.5 - 7.5 tons / Ha.

Intensive paddy soil is characterized by yields that can be achieved in excess of 8 tons / ha with one or more growing seasons in one year. In this intensive rice field, there will be a decrease in nutrients available in the soil. The availability of adequate irrigation water throughout the year has encouraged farmers to grow rice continuously on their land. The use of superior seeds stimulates the use of inorganic fertilizers even more, while organic fertilizers are increasingly abandoned due to various obstacles in transportation and procurement.

4. Effect of Soil Fertility Characteristics on Soil Productivity

To determine the effect of fertility characteristics in three districts with two rice varieties on rice productivity in Bogor Regency, a statistical method will be used, namely by using multiple regression analysis, the models to be estimated are:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + \ldots\ldots\ldots + b_{12}X_{12} + d_1D_1 + d_2D_2 + d_3D_3$$

To qualify for the multiple regression analysis classic test assumptions are carried out as follows:

1) Test for normality
   The value of skewness ratio and kurtosis ratio of this study are between -2 and +2, so it can be concluded that the data distribution is normal ..
2) Autocorrelation test
   Based on the DW table with α = 5%, n = 24 so that the DW value is at dU <1,777 <(4 - dU), the model in this study does not contain autocorrelation (nonautocorrelation).
3) Multicollinearity test
   The results of the analysis of independent variables have VIF values ranging from 1.550 to 6.393 which are smaller than 10, it can be concluded that this model does not contain multicollinearity.
4) Heterokedastisitas Test
   It is seen that there is no statistically significant when the independent variables are made regression with the dependent variable abresid, it can be concluded that this model does not experience heterocedasticity problems.

After testing the classical assumptions and the results meet the requirements for the BLUE model and from several regression models produced where the independent variables have a significant influence on the productivity of paddy fields in Bogor Regency is the 12th model. This can be seen from Sig. t where for each variable has a value smaller than the real level with the results of the estimation of the equation model as follows:

$$Y = 1{,}09 + 0.98\ X_2 + 15{,}12\ X_3 - 0.06\ X_7 + 0{,}03\ X_8 + 3{,}14 D_1$$

the results can be interpreted as follows:

1) Test simultaneously (F-stat)

Based on the estimation results, it can be concluded that the simultaneous test (F test) of soil fertility characteristics variables C organic (%), Nitrogen (N), K_2O HCl 25% (me / 100 g), CEC (me / 100 g) and dummy varieties that significantly influence the productivity of paddy fields in Bogor Regency, or can be interpreted as rejecting the H0 hypothesis and accepting the H1 hypothesis. This can be seen from the F value of 10.987 with Sig. of 0,000 which is still smaller than the significant level of 5% (0.05).

2) R-square (R^2)

It appears that the correlation coefficient (R) of 0.827 and the coefficient of determination (R^2) of 0.684 which means that 68.4% of the variable productivity of wetland can be explained by the variable soil fertility characteristics such as organic C (%), Nitrogen (N), K_2O HCl 25 % (me / 100 g), CEC (me / 100 g) and dummy varieties.

Table 3. Model 12th Results of Multiple Regression Processing (t Test) with backward method

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1,090	1,504		,725	,478
C organik (%)	,984	,509	,441	1,933	,069
Nitrogen (N) (%)	15,119	2,608	1,669	5,797	,000
K_2O HCl 25% (me/ 100 g)	-,059	,021	-,464	-2,812	,012
CEC (me/100 g)	,028	,015	,334	1,895	,074
D_1	3,136	,600	1,751	5,224	,000

3) Partial test (t-stat)

a. Every increase 1 % in organic C will increase the productivity of paddy fields by 0.98 tons / ha, assuming the variable Nitrogen (N), K_2O HCl 25% and CEC remain (constant).
b. Every increase 1 % in Nitrogen (N) will increase the productivity of paddy fields by 15.12 tons / ha, assuming the variable C organic, K_2O HCl 25% and CEC remain (constant).
c. Every increase of 1 mg / 100 g K_2O HCl by 25% will increase the productivity of paddy fields by 0.06 tons / ha, assuming Nitrogen (N), organic C variable, and CEC remain (constant).
d. Every increase of 1 me / 100 g CEC will increase the productivity of paddy fields by 0.03 tons / ha, assuming the variable Nitrogen (N), organic C, and K_2O HCl 25% remain (constant).
e. The influence of dummy varieties on the productivity of paddy fields is for
b) Ciherang Variety: Y = 1.09 + 0.98 X2 + 15.12 X3 - 0.06 X7 + 0.03 X8
c) Inpari Varieties: Y = 4.23 + 0.98 X2 + 15.12 X3 - 0.06 X7 + 0.03 X8

E. Conclusions

Based on the results of the above research it can be concluded

1. Soils in Bogor Regency are generally acidic, where soil fertility characteristics with organic C content are low to moderate, Nitrogen is very low to moderate, P is low to high, K is very low to moderate, CEC / CEC is moderate to high, and Saturation is Basic (KB) moderate to high. Soil biology, namely total bacteria, total fungi, total solvent P bacteria, Azotobacter sp., And Rizobium sp. Are generally low to moderate.
2. Variable characteristics of soil fertility in the form of organic C, Nitrogen (N), K2O HCl 25%, and CEC / CEC significantly influence rice productivity. Soil fertility in the three districts is almost the same and does not affect the productivity of rice fields. While the productivity of rice fields with Inpari varieties is higher than those grown by Ciherang varieties.

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