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Research Article

Analysis of soil fertility status on rice (*Oryza sativa* L.) planted land in Polewali District, Polewali Mandar Regency

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ABSTRACT

Rice is the main food commodity in Indonesia. The main abiotic factor affecting rice productivity is soil fertility. This study aimed to determine the soil fertility status (SFS) of paddy fields in Polewali District, Polewali Mandar Regency, West Sulawesi. The research was conducted by surveying soil characteristics supported by soil chemical analysis at the Laboratory of Soil Science and Environmental Conservation, Faculty of Agriculture, Universitas Muslim Indonesia. The research was conducted in Polewali District, with the survey area consisting of 4 land map units (LMU). Soil fertility status was determined based on the criteria of each soil fertility parameter, namely: soil pH, organic C-content, cation exchange capacity, available P, Potassium content, and base saturation. The results showed that the SFS in Polewali District was classified as low. Only the base saturation parameters in LMU-2 and LMU-3 were classified as high. In addition, all parameters were only classified as very low to medium at all LMUs. Low C-organic content and very low P and K content are the main limiting factors for SFS. Recommended land management to improve soil fertility is the addition of organic matter that can increase total nitrogen and C-organic in the soil and the application of manure.

Keywords: *Soil fertility status, paddy fields, rice plants.*

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INTRODUCTION

Rice (*Oryza sativa* L.) is the main food commodity in Indonesia, and is available in various types and is easy to grow, and can be planted in almost all regions of Indonesia (Gunawan et al., 2018). The type of rice that has a fast harvest period is paddy rice or irrigated rice, so this type of rice is the main choice of farmers in farming (Yulina, 2021). Although the land potential is quite extensive, the development of rice cultivation is still not optimal due to the many problems or obstacles faced, including limited data or information on soil characteristics and soil fertility status in rice cultivation areas or areas, making it difficult to increase land productivity such as difficulty in determining the right type and dose of fertilizer to support optimal production (Astuti et al., 2023)

The main abiotic factor affecting rice productivity is soil fertility. Soil fertility is one of the indicators that determine the success of crop production or the scope of agriculture. In addition to the selection of superior seeds, the first thing that must be prepared is the soil used as a planting medium. In simple terms, soil fertility can be defined as the ability of soil to provide adequate amounts of nutrients in an available form (Sasongko et al., 2022). Soil fertility evaluation is used to assess the ability of soil to provide sufficient nutrients for plants in supporting plant growth, as well as knowing the nutrients that are a constraint for plants (Wahyuni et al., 2020)

One way that is often used in assessing soil fertility is through the approach of analyzing soil chemical properties. There are several soil chemical parameters used in this study to assess Soil Fertility Status, namely soil pH, Cation Exchange Capacity (CEC), Base Saturation (BS), C-organic, P_2O_5, K_2O, and soil N-total according to the technical guidelines for soil fertility evaluation (Ministry of Agriculture, 2011). Soil fertility is an important factor needed by plants to survive and produce well. Soil fertility is largely determined by the availability and amount of nutrients in the soil (Saosang et al., 2022). One of the efforts that can be made to increase the availability of nutrients and increase rice productivity is through the application of fertilizers according to the type and amount specifically to the location (Maro'ah et al., 2021).

Data related to the fertility status of paddy fields in Polewali District, Polewali Mandar Regency, West Sulawesi Province is not yet available. Evaluation of soil fertility is one of the activities of analyzing soil chemical properties related to nutrient content in the soil. Knowledge related to soil chemical conditions can be used as a reference for soil management with the right amount of fertilization, right type, and right time to apply it as recommended (Siswanto, 2019). Soil fertility analysis is the key to sustainable planning in a particular area (Khadka et al., 2018). Evaluation of soil fertility status can provide information for improving land management techniques and strategies to achieve sustainable agriculture (Khaki et al. 2017). Determination of soil fertility is based on soil chemical parameters including Cation Exchange Capacity (CEC) and C-organic and macro nutrients including N, P, and K and soil pH (Bagherzadeh et al., 2018; Sumarniasih et al., 2021)

Based on data from the Central Bureau of Statistics of West Sulawesi province (BPS, 2023), rice production in Polewali Mandar Regency, West Sulawesi experienced fluctuations during the 2020-2022 period. The occurrence of fluctuations in rice productivity in West Sulawesi can be caused by many factors including not maximizing the use of agricultural inputs such as seeds, fertilizers, pesticides, and other production technologies. In addition, natural disasters such as floods, droughts, erratic rainfall, and other climate change phenomena also affect and cause agricultural production to fluctuate (Husen et al, 2020).

The increase in planting area is often not in line with the increase in rice production. Although there was an increase in the area planted in Polewali District in 2022 compared to the previous year, the increase in production did not occur significantly. Low productivity can be caused by declining soil fertility. Increasing the productivity of agricultural land can be done by knowing the status of soil fertility because it is a reference in making decisions on efforts to improve soil fertility status. The objective of this study is to determine the soil fertility status (SFS) of paddy fields in Polewali District, Polewali Mandar Regency, West Sulawesi.

MATERIALS AND METHODS

Materials and data collection

The materials used in this study were soil samples and chemicals for laboratory analysis of soil samples. While secondary data were obtained from the BPS Polewali Mandar, and the Polman Agriculture and Food Service. The tools that were used namely soil drill, plastic bags, paper, labels, GPS (*global positioning system*), hoes, markers, stationery, and other supporting equipment used in this research.

Research methods

The method used in this research is the purposive sampling method, namely taking soil sample points randomly on each land map unit (LMU) which is then analyzed for soil fertility at the Soil Science and Environmental Conservation Laboratory, Faculty of Agriculture, Universitas Muslim Indonesia. Based on the results of overlaying the administrative map and soil type map, 4 points of soil sampling locations were determined as land map units (LMUs). Secondary data used is sourced from BPS Polewali Mandar data (2023) and the Agriculture and Food Office of Polewali Mandar Regency (2023).

The implementation of soil sampling was carried out based on the LMU. Soil samples were taken at a depth of 0-20 cm based on the number of LMUs that have been determined, then analyzed for chemical properties including total P_2O_5, total K_2O, organic C, cation exchange capacity (CEC), and base saturation (BS). Each parameter was then determined based on Table 1.

Table 1. Criteria for soil chemical properties (Ministry of Agriculture, 2011).

No	Chemical properties	Very low	Low	Medium	High	Very high
1	C-organic (%)	<1.00	1.00-2.01	2.01-3.00	3.00-5.00	>5.00
2	Nitrogen (%)	<0.10	0.10-0.20	0.21-0.50	0.51-0.75	>0.75
3	P_2O_5 HCl 25% (mg/100g)	<10	10-20	21-40	41-60	>60
4	K_2O HCl 25% (mg/100g)	<10	10-20	21-40	41-60	>60
5	CEC (me/100 g)	<5	5-16	17-24	25-40	>40
6	Base saturation (%)	<20	20-35	36-50	51-70	>70
7	pH (H_2O)	<4.5 (Very acidic)	5.6-6.5 (Acidic)	6.6-7.5 (Neutral)	7.6-8.5 (Slightly Acidic)	>8.5 (Alkaline)

Determination of soil fertility status (SFS) is carried out by combining the categories obtained from the results of chemical analysis, namely CEC and BS against the categories of chemical analysis of P, K, and C-organic content as listed in Table 2. The results of the SFS determination can then be used as a reference in determining the dose of P and K fertilizers, as well as organic matter that must be added so that all these elements which are in very low (VL), low (L), and medium (M) status change to high (H) status.

Table 2. Combination of soil chemical properties and soil fertility status.

No.	CEC	BS	P_2O_5, K_2O, C-organic	Fertility status
1.	H	H	≥2 H without L	High
2.	H	H	≥2 H with L	Medium
3.	H	H	≥2 without L	High
4.	H	H	≥2 M with L	Medium
5.	H	H	H> M >L	Medium
6.	H	H	≥2 L with H	Medium
7.	H	H	≥2 L with M	Low
8	H	M	≥2 H without L	High
9.	H	M	≥2 H with L	Medium
10.	H	M	≥2 M	Medium
11.	H	M	Other combinations	Low
12.	H	L	≥2 H without L	Medium
13.	H	L	≥2 H with L	Low
14.	H	L	Other combinations	Low
15.	M	H	≥2 H without L	Medium
16.	M	H	≥2 M without L	Medium
17.	M	H	Other combinations	Low
18.	M	M	≥2 H without L	Medium
19.	M	M	≥2 M without L	Medium
20.	M	M	Other combinations	Low
21.	M	L	3 H	Medium
22.	M	L	Other combinations	Low
23.	L	H	≥2 H without L	Medium
24.	L	H	≥2 H with L	Low
25.	L	H	≥2 M without L	Medium
26.	L	H	Other combinations	Low
27.	L	M	≥2 H without L	Medium
28.	L	M	Other combinations	Low
29	L	L	All combination	Low
30	VL	VL	All combination	Very Low

Note: Adapted from Ministry of Agriculture (2011). CEC = cation exchange capacity, BS = base saturation.

RESULTS AND DISCUSSION

Soil chemical analysis

Data from soil chemical analysis based on parameters measured in each land map unit (LMU) are presented in Table 3. The data in Table 3 shows that the criteria for soil chemical content for CEC parameters, C-organic content, P content, and K content are classified as very low (VL) to low (L), and nitrogen content in the soil is classified as medium (M). While the base saturation parameter (BS) varies greatly from low (L), medium (M) and high (H).

Soil fertility status

Soil fertility status (SFS) is determined through a combination of soil chemical parameters between CEC, BS, P_2O_5, K_2O, and organic C content status as listed in Table 2. Data on soil fertility status in four land map units (LMUs) representing the Polewali District area are presented in Table 4.

Table 3. Soil chemical analysis in each soil map unit in Polewali district.

LMU	pH (H_2O)	N (%)	CEC (cmol (+)/kg)	BS (%)	P_2O_5 (ppm)	K_2O (ppm)	C-org (%)
LMU-1	6.19	0.20 (L)	10.54 (L)	48.86 (M)	5.17 (VL)	3.00 (VL)	1.05 (L)
LMU-2	6.20	0.20 (L)	15.50 (L)	65.23 (H)	5.15 (VL)	6.06 (VL)	1.72 (L)
LMU-3	6.25	0.35 (M)	20.40 (M)	69.71 (H)	5.21 (VL)	9.83 (VL)	1.74 (L)
LMU-4	6.37	0.42 (M)	18.00 (M)	26.94 (L)	5.15 (VL)	2.81 (VL)	1.19 (L)

Note: VL = Very low, L = Low, M = Medium, H = High, LMU = land map unit.

Table 4. Soil fertility status based on a combination of chemical parameters in each LMU.

LMU	CEC	BS	P_2O_5	K_2O	C-org	Combination	SFS
LMU-1	L	M	VL	VL	L	Another comb.(28)	Low
LMU-2	L	H	VL	VL	L	Another comb.(26)	Low
LMU-3	M	H	VL	VL	L	Another comb.(17)	Low
LMU-4	M	L	VL	VL	L	Another comb.(22)	Low

The data shows that based on the results of the analysis of the combination of chemical parameters at all LMUs, the SFS in the Polewali District area is classified as low (L). At LMU-1 it can be seen that the combination of CEC and BS is L-M and when combined with the values of P_2O_5, K_2O, and C-organic, the soil fertility status is classified as low (combination no 28 in Table 2). LMU-2 shows that the combination of CEC and BS is L-H, and when combined with P_2O_5, K_2O, and C-organic values, the soil fertility status is low (combination no 26 in Table 2). LMU-3 shows that the combination of CEC and BS is M-H, and when combined with P_2O_5, K_2O, and C-organic values, the soil fertility status is classified as low (combination no 17 in Table 2). Meanwhile, LMU-4 shows that the combination of CEC and BS is M-L, and when combined with the values of P_2O_5, K_2O, and C-organic, the soil fertility status is classified as low (combination no. 22 in Table 2).

Rice productivity in Polewali Mandar Regency

Data on rice productivity for the years 2020, 2021, and 2022 in Polewali Mandar Regency is presented in Table 5. The data shows that rice productivity in Polewali Mandar Regency has decreased over the past three years. The data also shows that although there was an increase in the planting area in 2022 compared to 2020, productivity in 2022 continued to decline.

Table 5. Harvested area and rice production in Polewali Mandar Regency.

Year	Harvested area (ha)	Production (ton)	Productivity (ton ha^{-1})
2020	32,973	195,644	6.45
2021	28,958	164,538	5.68
2022	34,624	199,665	5.76
Amount	96,555	559,847	17.89
Average productivity			5.79

Note: Adapted from Central Agency of Statistics (BPS) Polewali Mandar (2023).

Rice productivity in Polewali District

Data on rice productivity for the last three years (period 2020, 2021, 2022) in Polewali District is presented in Table 6. This data shows that rice productivity in Polewali District has decreased over the last 3 years, and although there was an increase in the harvested area in 2022 compared to 2021 and 2020, productivity still decreased.

Table 6. Harvested area and rice production in Polewali District.

Year	Harvested area (ha)	Production (ton)	Productivity (ton ha^{-1})
2020	2,241	14,565	6.49
2021	2,198	14,243	6.47
2022	2,334	14,422	6.17
Amount	6,773	43,230	19.13
Average productivity			6.37

Note: Adapted from Polewali Mandar Regency Agriculture and Food Service (2022).

Comparison of recommendations and application of fertilizer doses by farmers

Data on recommended fertilizer doses recommended by the Agency for the Assessment of Agricultural Technology (AAAT) with fertilizer doses applied by farmers are presented in Table 7.

The data shows that there is a difference between the doses recommended by AAAT West Sulawesi and those applied by farmers in Polewali District. The decision of farmers to apply higher doses of fertilizer than those recommended by AAAT is based on the experience of farmers and on the consideration that the dose of fertilizer used previously according to AAAT recommendations has been used for more than twenty years so it is estimated that soil fertility has decreased. The results show an influence on decreasing rice productivity in Polewali District. This also can be seen in the comparison between rice productivity at the Polewali Mandar Regency and the Polewali District (Table 5 and Table 6).

Table 7. Comparison of recommendations and application of fertilizer doses by farmers in Polewali District.

Type of fertilizer	Recommendation (kg ha^{-1})	Productivity (ton ha^{-1})	Application by farmer (kg ha^{-1})	Productivity (ton ha^{-1})
Urea	250	6.45	300	6.49
TSP	75	5.68	150	6.47
KCl	75	5.76	150	6.17

Source: Adapted from Polewali Mandar Regency Agriculture and Food Service (2022).

Soil fertility status

The results of chemical analysis on the tested parameters related to soil fertility status at all LMUs in the study site (Table 3) show that the criteria are classified as very low (VL) to high (H).

The C-organic content in all LMUs was classified as low. Low C-organic content is an indicator of limiting factors for soil fertility. C-organic values ranged from 1.05% to 1.74%

(L). The low C-organic content is caused by the low production of organic matter remaining in the soil due to the farmers' habit of transporting out rice straw during harvest for livestock food needs. In addition, there is also a bad habit of farmers burning the straw before tillage to prepare the next planting land. This is despite the fact that the amount of straw produced in rice cultivation is high, reaching up to 7 tons ha^{-1} (Danapriatna et al., 2020). The components of rice straw are mainly cellulose, hemicellulose, lignin, and a little protein which makes the C/N value high so that it can increase the C-organic content of the soil. Land use at the research site is rice monoculture without crop rotation every season. According to Zhang et al. (2021), organic additions absolutely must be given because soil organic matter plays an important role in creating soil fertility.

Soil reaction (pH) is one of the limiting factors of soil fertility. The soil at the rice research location at a depth of 0-20 cm can be categorized as slightly acidic with a pH value of 6.23. Low pH values cause high solubility of Al, Fe, and Mn elements so that they become toxic to plants. If the pH value is maintained in the range of 6 to 7, the possibility of Al, Fe, and Mn poisoning can be prevented (Rachmawati, 2017). Improving soil quality can also be done by adding ameliorant materials in the form of biomass and rice husks through increasing pH, soil nutrients (N, P, K, S), CEC, cations, and base saturation (Toyip et al., 2024).

Another parameter related to the assessment of soil fertility status is base saturation (BS). The BS value at each LMU varies from low (L) to high (H). The ability of the soil to release ions depends on the degree of BS. Soil is very fertile when it has a base saturation of more than 80%. (Sumarniasih et al., 2021), the high value of BS at the research location shows that the ion exchange complex is dominated by basic cations, cation uptake provides information on available nutrients so that it can cause pH in the neutral range. The relationship between BS and soil pH is generally positive, namely the higher the pH, the higher the soil BS and vice versa.

Cation exchange capacity (CEC) is also an important chemical characteristic of soil related to soil fertility, the value of CEC is also closely related to the value of base saturation. The results of the study (Table 3) show that at the four LMUs the soil CEC value is very low to low. The low CEC is strongly influenced by the low organic matter content. Organic matter is humus that acts as a soil colloid, so the lower the organic matter, the lower the CEC value (Hayati et al., 2020). In addition to organic matter content, soil CEC value is also influenced by soil pH (Nursanti, 2018), and soil texture (Nurmegawati, 2019).

The Phosphorus (P) content of the soil at the study site is very low. Very low P content indicates a lack of organic matter content and poor soil minerals containing P because the source of P in the soil comes from P-containing minerals such as apatite minerals, and decomposition of organic matter. In paddy fields that do not apply organic fertilizers and only apply inorganic fertilizers containing P continuously, the available P content in the soil becomes low to very low. This is due to the large amount of P that is absorbed/fixed by Al-dd in the soil. Phosphorus (P) in the soil is mostly absorbed by clay minerals, Al, and Fe, as well as by allophane in Andosol soils. In soils that have a low pH, the solubility of Al and Fe ions is relatively high so that they can fix P in the soil which causes poor plant growth (Jayadi et al., 2023). Furthermore, it is stated that low P content is also caused by P losses that occur through leaching and erosion. Leaching is the main mechanism of P loss from the soil, including in paddy fields.

Potassium (K) at the study site was also very low. The nature of K that is easily lost from the soil causes its efficiency to be low as well as the element N. Potassium is at a very low status. The low K element in the soil is due to the K used by plants being only a small portion in this case in paddy fields. The cause of high and low potassium in the soil is influenced by parent material, soil pH, and soil CEC. K ions are classified as mobile elements that are easily lost from the soil through leaching because K is not held firmly by the soil's colloidal surface. The nature of K that is easily lost from the soil causes its low efficiency (Agoesdy et al., 2019).

The N content of the soil is classified as low (L) to medium (M). Nitrogen forms important organic molecules such as amino acids, proteins, enzymes, nucleic acids, and chlorophyll. The N-total content ranges from 0.20 - 0.42% and is included in the medium category. Soil N-total is low because much of the N is lost by harvesting and there is no return of harvested residue to the field. Harvest losses depend on the harvesting method. This loss is large if the straw is also transported out. Nitrogen has been absorbed by plants for growth. N-total content in the range of 0.20% to 0.42% is less than ideal for rice plants (Sumarniasih et al., 2021)

The results of the analysis of the determination of soil fertility status (SFS) show that the entire LMU in Polewali District is classified as low SFS (Table 4). The data in Table 4 shows that low soil fertility status greatly affects the level of rice productivity. The effect of low SFS can be seen in rice productivity both at the district level of 6.3 tons ha^{-1} as well as at the regency level with a productivity range of 5.8 tons ha^{-1}. This achievement was actually still above the achievement of rice productivity at the national level which only reached 5.2-5.3 tons ha^{-1} (BPS, 2023; Herdiyanti et al., 2021).

An overview of the chemical content of soil, especially P and K elements, and soil fertility status in Polewali District as seen in Table 3 and Table 4, can be used as a reference in the provision of additional P fertilizer and K fertilizer to change the soil fertility status from low (L) or medium (M) to high (H) status so that the availability of nutrients is sufficient and ideal in supporting optimal plant growth.

The data in Table 5 and Table 6 show that the longer the rice field is planted with rice, the lower the soil fertility level, which results in a decrease in rice productivity from year to year. One of the solutions taken by farmers to increase production is to increase the dose used beyond the recommended dose of AAAT West Sulawesi as shown in Table 7. There are differences in rice productivity achieved at the District level compared to the Regency area as listed in Table 5 and Table 6. This is due to differences in the dose or dose of fertilizer used by farmers in Polewali District compared to farmers in other districts in Polewali Mandar Regency.

Soil management recommendations

Soil management is based on indicators related to SFS. Indicators that are significantly correlated with SFS and have low values are C-organic, P content, K content, and CEC. C-organic, phosphorus, and potassium play a very important role in soil quality and plant growth. The focus of soil management is to improve low soil indicator values.

Recommended soil fertility improvement efforts include the use of organic matter. The addition of organic matter that contains a lot of P and K elements such as chicken manure, goat or cow manure can increase the availability of P in the soil because organic acids resulting from the decomposition of organic matter have the ability to bind cations such as Al and Fe through chelation bonds so that phosphorus (P) can be available (Anshori et al., 2021). The selection of organic fertilizers is highly recommended to maintain nutrient stability, prevent nutrient imbalances due to excess chemical fertilizers, and create sustainable agriculture. Organic matter can also be obtained from crop litter left over from harvest and applied when resting the soil after harvest. Organic matter is very easy and affordable to be applied by farmers, namely by putting litter to cover the soil and leaving it for a while until the soil is reused (Syamsiyah et al., 2018).

The addition of organic materials that contain a lot of nitrogen (N) is very helpful in improving soil fertility. The leguminous plant group (legumes) given to the soil can increase the availability of N in the soil (Dewi et al., 2018). Planting Azolla which is an aquatic plant that is symbiotic with *Anabaena azollae* which is able to tether N in the air. Azolla can be given in fresh form or the form of compost or compost in an effort to increase the growth and dry grain of rice (Syamsiyah et al., 2018).

In addition to adding organic matter to the soil, it is also recommended to apply PGPR. The effect of PGPR on plant growth occurs through various mechanisms (Putrie, 2016). These mechanisms include phosphate solubilization, growth hormone IAA (Indole Acetic Acid), ammonia, siderophores, enzyme activities that can degrade cell walls such as cellulase, chitinase, and protease, produce HCN, and as a biocontrol against diseases around plant roots. According to Numba et al. (2023), one of the technologies that can be used to further improve the effect of manure is the application of plant growth-promoting rhizobacteria (PGPR). The application of PGPR and organic fertilizer can increase the growth of plant numbers in acid sulfate soil with a saturated soil cultivation system (Sodiq et al., 2024) In addition, PGPR also affects the solubility of P nutrients and N uptake in the soil (Utami et al., 2018; De Lima & Yoris, 2019).

Low soil organic matter content is one of the main problems that cause low productivity of paddy fields. The low status of soil fertility (Table 2) greatly affects the level of rice productivity. The data in Table 3 and Table 4 show that the longer the land is planted with rice, the lower the soil fertility level, which results in a decrease in rice productivity from year to year. One of the solutions taken by farmers to increase production is to increase the dose used beyond the dose recommended by AAAT (Table 5). The difference in rice productivity achieved at the district level compared to the regency level is due to the different doses used by farmers in Polewali District compared to farmers in other districts in Polewali Mandar Regency.

One effort to increase rice productivity is by fertilizing. Fertilizing using inorganic fertilizers such as Urea and TSP provides nutrients to plants relatively quickly, but has the potential to reduce the soil pH to a lower level which will affect the availability of other nutrients for plants (Mahbub et al., 2023). The data in Table 2 shows that the soil pH tends to decrease so that it is slightly acidic. This condition is also indicated by the low organic-C content of the soil, so to improve the physical, chemical, and biological properties of the soil, efforts are needed to increase the organic matter content of the soil through the use of organic fertilizer. Using organic fertilizer can minimize land damage caused by excessive use of inorganic fertilizer. Mahbub et al. (2023) states that the role of organic materials is as a supplier of nutrients and improving soil properties which can maintain the availability of nutrients in the soil. Organic fertilizer can come from plant remains or animal waste. Providing organic fertilizer can not only add nutrients to the soil but can also improve damaged soil structure. According to Siswanto (2018) the use of organic fertilizer can increase the efficiency of using inorganic fertilizer. Rotation of rice plants with annual crops and others on paddy fields can help improve the soil and add materials to soil organic.

To maintain and increase soil fertility, it is necessary to add organic fertilizer. Organic fertilizer is the process of breaking down organic materials or decomposing complex compounds into simpler compounds with the help of microorganisms. There are various types of organic fertilizers such as manure, green manure, and compost. Several studies show that organic fertilizer can increase soil fertility by increasing flocculation capacity, increasing nutrient availability, and increasing soil microbial activity. Increasing the adequate availability of macronutrients N, P, K, and plant micronutrients can influence rice growth and yield.

CONCLUSION

Soil Fertility Status in Polewali District is low. Only the base saturation parameter in LMU-2 and LMU-3 is classified as high (H). Apart from that, all parameters are only classified as very low (VL), low (L) to medium (M) in all LMUs. Low organic C content (L) and very low (VL) P and K content are the main limiting factors for soil fertility status, so it is necessary to evaluate recommended fertilizer doses applied by farmers. Recommended land management to increase soil fertility is the addition of organic material which can increase total N and organic C in the soil as well as the application of manure. Good management of rice fields can maintain soil fertility and sustainable rice productivity.

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