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Assessment of fertility status of paddy fields in Bajo District, Luwu Regency, South Sulawesi

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Abstract

Soil fertility is the ability of soil to provide sufficient, evenly distributed and balanced nutrients to support optimal and sustainable plant growth and development. The ability of soil to provide nutrients sometimes cannot be fulfilled in the process of plant metabolism. Declining soil fertility due to intensive land use causes depletion of nutrients in the soil. The research objectives (1) to determine the status of soil fertility and limiting factors on paddy fields in Bajo District, Luwu Regency; (2) to determine the direction of management of paddy field fertility in Bajo District, Luwu Regency. The research method used was descriptive exploratory through field surveys and laboratory soil tests. Sampling of paddy field soil was determined purposively sampling each grid. The results of the analysis of the fertility status of paddy fields in Bajo District, Luwu Regency in the low category. The limiting factors, namely base saturation, P_2O_5, K_2O, and C-organic, have an important role in determining soil fertility. Efforts to manage the fertility of paddy fields are the addition of macro nutrients through phosphorus fertilisation, potassium and the addition of organic matter to reduce soil degradation, maintain soil fertility and increase optimal production.

Keywords: Paddy field; soil chemical properties; soil fertility status

Introduction

Soil fertility is an important attribute that reflects the ability of a soil to provide adequate, equitable and balanced supply of nutrients needed to support optimal and sustainable plant growth and development. When soils lose fertility, particularly as a result of intensive land use practices, there is a reduction in the availability of essential nutrients to plants. This can result in soil depletion and nutrient imbalances, which in turn can limit the soil's ability to properly support plant growth. Therefore, soil fertility management is key in maintaining the productivity and sustainability of agricultural ecosystems.

Paddy fields are specific areas for rice growth, often undergoing intensive tillage processes such as loosening, flooding, and excessive application of chemical fertilisers, sometimes not always in accordance with plant needs. The result is a build-up of residues that can be detrimental to soil fertility, threatening long-term productivity and the balance of agricultural ecosystems.

An inappropriate management system causes a decrease in land productivity so that crop production is not optimal, this shows that the soil does not function as it should due to excessive use of chemical fertilisers, burning straw, inappropriate use of pesticides, high cropping intensity, irregular irrigation resulting in changes in the physical, chemical and biological properties of the soil (Adnyana, 2015).

Evaluation of fertility status to assess and monitor soil fertility is very important to know the nutrients that become limiting factors for plants. Assessment of soil fertility status can be done through a soil test approach, where assessment using this method is relatively more accurate and faster (H. Maulana et al., 2021).

Increasing the contribution of the agricultural sector, especially in rice production, has great potential to boost income and create jobs in rural areas. Currently, rice production at the national level has not been able to fulfil domestic demand, which is reflected in rice imports from countries such as Thailand and Vietnam. By optimising agricultural technology, improving the efficiency of irrigation systems, and providing training to farmers, it can be expected that the rice farming sector can become one of the main pillars in supporting economic growth, reducing dependence on rice imports, as well as creating significant employment opportunities in rural communities. Wachid & Mintono, (2017), that the average productivity is still low compared to the optimal productivity of rice in general 7.3 to 8 ton ha-^{1}.

The purpose of the study was to determine the status of soil fertility and limiting factors as well as the direction of fertility management of paddy fields in Bajo District, Luwu Regency.

Research Method

Place and time of research

The research was conducted in Bajo sub-district, Luwu district (Figure 1). Geographically located at latitude 2^{o}3'45" SL - 3^{o}37'30" SL and 119^{o}15" EL-121^{o}45'11" EL. The research was conducted from August to December 2023. The materials used in this research are administrative maps, land use maps with a scale of 1:25,000. The tools used were soil drill, metre, abney level, stationery.

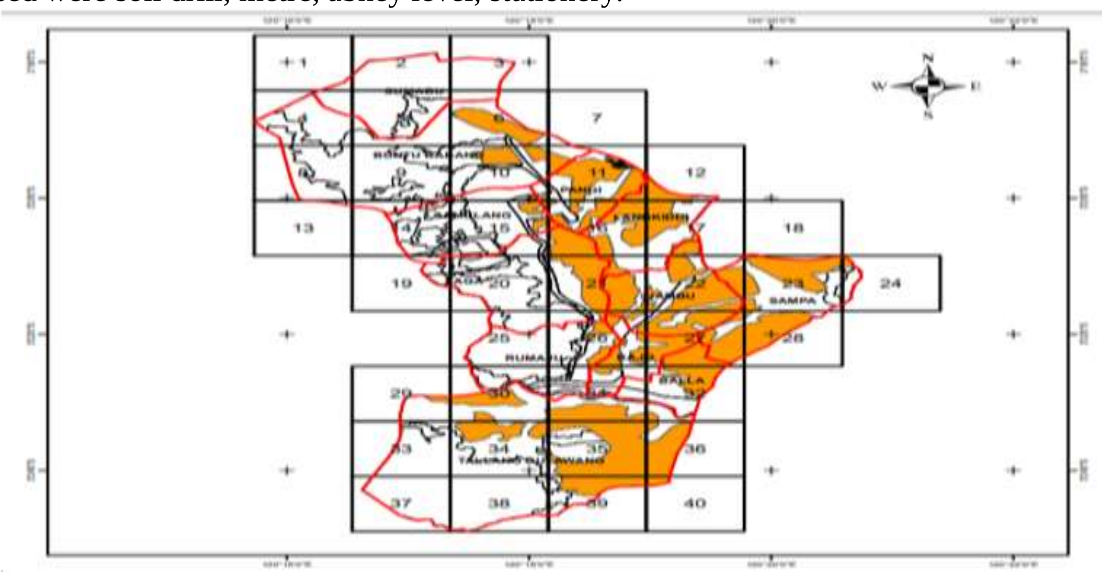

Figure 1. Grid system survey map

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Data collection

The data used in the research are secondary data related to previous studies, land use maps, and BPS data at the sub-district, district and provincial levels and reports related to the research.

Creation of working map

This research uses a land use map. Where the paddy field as the object of observation is made grid. The principle of this method is that observations are made at equal distance intervals or repeated intervals. This working map is a reference for surveys and soil sampling in the field. Grid map process with GIS software.

Field survey and sampling

The research method used was descriptive exploratory through survey. Soil sampling was carried out for each grid by purposive sampling at a depth of 0-30 cm for each grid. The selected point represents each grid.

Soil sample analysis

Laboratory test parameters are: CEC (NH4OAc), Base Saturation ((NH4OAc), C-organic (Walkley & Black), P-Total (HCl 25%-AAS), K-Total (HCl 25%-AAS), and pH H2O (Electrometry) for data interpretation and determination of soil fertility status and making soil maps. Soil fertility status is based on the Technical Guidelines for Evaluation of Soil Fertility Status (PPT, 1995).

Table 1. Combination of soil chemical properties and soil fertility status

No.	CEC	BASE SATURATION	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 with L	High
4.	H	H	≥2 M with L	Medium
5.	H	H	H > M >R	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 T without 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 T 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	M	3 H	Medium
22.	M	M	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 combinations	Low
30	VL	H, M, L	All combinations	Very Low

Sources: Bogor Soil Research Institute (1995)
Notes: H= High M=Medium L=Low

Results and Discussion

The results of the chemical properties analysis showed that the pH of H2O was in the slightly acidic to neutral range. In addition, the Soil Availability (CEC) value shows a moderate level, Base Saturation is classified as low, P2O5 content is very low to low, K2O content is very low, and organic matter (C-organic) content is in the very low to low category,

Based on the analysis of soil chemical properties, such as: CEC, KB, P2O5, K2O, and C-organic, in accordance with the Technical Guidelines for Soil Fertility Evaluation from the Soil Research Centre (PPT) in 1995, that the fertility status of paddy fields in Bajo District, Luwu Regency, is classified as low.

The cause of these low chemical properties except pH H2O is due to the very intensive management of paddy fields every year where the nutrients P, and K absorbed by plants are not balanced with phosphorus, potassium fertilisation. The lack of use of organic matter by farmers is also one of the main contributors to the low soil fertility in this region.

While SP-36 and KCl fertilisers are effective sources of phosphorus and potassium, their availability in the market is very limited and they are expensive. This has discouraged farmers from using them extensively in their farming practices.

Table 2. Assessment of soil fertility status of paddy fields

No.	Grid	pH	CEC	Base Saturation	P_2O_5	K_2O	C-organic	Fertility Status
1	6	6,57 (N)	21,72 (M)	28,13 (L)	5,16 (VL)	0,87 (VL)	0,83 (VR)	Low
2	10	6,58 (N)	21,73 (M)	27,84 (L)	5,18 (VL)	0,85 (VL)	0,85 (VL)	Low
3	11	6,56 (N)	21,69 (M)	27,75 (L)	5,19 (VL)	1,40 (VL)	0,83 (VL)	Low
4	12	6,59 (N)	22,7 (M)	26,34 (L)	5,17 (VL)	1,42 (VL)	0,84 VL)	Low
5	15	6,57 (N)	21,68 (M)	28,0 (L)	5,16 (VL)	1,37 (VL)	0,87 (VL)	Low
6	16	6,58 (N)	21,69 (M)	28,08 (L)	5,18 (VL)	1,35 (VL)	0,83 (VL)	Low
7	17	6,57 (N)	21,62 (M)	27,80 (L)	5,17 (VL)	2,27 (VL)	0,84 (VL)	Low
8	21	6,57 (SA)	21,72 (M)	28,13 (L)	5,16 (VL)	1,52 (VL)	0,85 (VL)	Low
9	22	5,98 (SA)	19,94 (M)	29,84 (L)	9,65 (VL)	0,69 (VL)	0,58 (VL)	Low
10	23	5,81 (SA)	21,42 (M)	24,79 (L)	8,66 (VL)	0,60 (VL)	0,84 (VL)	Low
11	24	5,84 (SA)	21,44 (M)	24,44 (L)	8,67 (VL)	0,63 (VL)	0,86 (VL)	Low
12	26	5,96 (SA)	19,95 (M)	29,97 (L)	9,64 (VL)	0,73 (VL)	0,56 (VL)	Low
13	27	5,98 (SA)	19,94 (M)	29,84 (L)	9,65 (VL)	0,71 (VL)	0,58 (VL)	Low
14	28	5,81 (SA)	21,42 (M)	24,79 (L)	8,65 (VL)	1.00 (VL)	0,84 (VL)	Low
15	29	6,67 (N)	21,86 (M)	22,87 (L)	10,17 (L)	0,65 (VL)	1,06 (L)	Low
16	30	6,65 (N)	21,87 (M)	22,68 (L)	10,19 (L)	0,63 (VL)	1,05 (L)	Low
17	31	6,66 (N)	20,87 (M)	23,86 (L)	10,18 (L)	3,97 (VL)	1,04 (L)	Low
18	32	5,79 (SA)	27,94 (H)	21,30 (L)	7,28 (VL)	1,65 (VL)	0,77 (VL)	Low
19	34	6,13 (SA)	20,52 (M)	26,36 (L)	10,17 (L)	1,23 (VL)	1,55 (L)	Low
20	35	6,1 (SA)	20,51 (M)	26,28 (L)	10,18 (L)	1,21 (VL)	1,56 (L)	Low
21	36	6,35 (SA)	20,02 (M)	21,48 (L)	11,18 (L)	1,98 (VL)	1,56 (L)	Low
22	39	6,14 (SA)	20,51 (M)	23,89 (L)	10,16 (L)	1,22 (VL)	1,54 (L)	Low
23	40	6,35 (SA)	20,04 (M)	21,41 (L)	11,17 (L)	1,99 (VL)	1,55 (L)	Low

Notes:
N = Neutral, SA = Slightly Acidic, M = Medium, H = High, VL = Very Low, L = Low

Soil reaction (pH)

Soil reaction indicates the level of acidity or alkalinity of the soil. Soil pH soil reaction plays an important role in determining whether or not nutrients are easily absorbed by plants. Nutrients can generally be absorbed well by plants at neutral pH. Likewise, soil microorganisms and fungi can develop well at pH above 5.5 if less, their activity will be inhibited (Gunawan et al., 2019). The results of pH analysis in the research area are slightly acidic to neutral. This is in line with (Syachroni, 2019), that generally has a pH close to neutral.

Cation Exchange Capacity

Cation exchange capacity is the number of cations absorbed and exchanged by the soil and is expressed in units of cmol (+) / kg. besides clay, organic matter is a material that can contribute to soil CEC, because the negative charge of organic matter can attract positively charged cations (Syachroni, 2019).

Cation exchange capacity (CEC) is one of the soil parameters that measures the ability of soil to hold and release cation ions. CEC describes how much cations such as calcium (Ca2+), magnesium (Mg2+), potassium (K+), and other ions can be stored by the soil and made available to plants (Singh et al., 2019).

Soil cation exchange capacity is influenced by the nature and characteristics of the soil itself which include soil reaction or pH, soil texture or amount of clay, type of clay minerals, organic matter, and liming and fertilisation (Hakim et al., 1986), Nofelman et al., 2012), (Nursanti, 2018).

The results of CEC analysis at the research location showed 19.94 - 27.94 cmol(+) kg-1 (medium to high). According to Hardjowigeno and Widiatmaka (2020), that the CEC criteria for wetland rice plants greater than or equal to medium is very suitable.

Soils that have a high CEC tend to be more fertile because they can provide more nutrient ions for plants. In contrast, soils with low CEC may have problems storing nutrients because the cations are more easily leached by rain or irrigation water.

Base Saturation

Base saturation is the ratio between the amount of exchangeable base cations and the CEC of the soil expressed in per cent. The results of the analysis of KB at 14 observation points The results of the analysis of base saturation (KB) of soil in rainfed rice fields have values ranging from 21.35 - 29.84% with low criteria.

The low base saturation (KB) is thought to be due to the low pH value of the soil in the research location. This is in accordance with the statement (Astungkara et al., 2014) that low base saturation is due to the presence of acidic cations (H+ and Al3+) which replace base cations in the cation sorption complex by liberating Ca2+ and Mg2+ cations into the soil solution which are then leached because they are carried by water flow. Although the pH analysis results are slightly acidic to neutral.

Phosphorus Content

Phosphorus is one of the macro nutrients that is very important for plants. Macro nutrients are nutrients that are required by plants in large quantities. Phosphorus has a crucial role in plant growth because it is involved in many biochemical processes, including the synthesis of DNA, RNA, and cell energy through the ATP (adenosine triphosphate) molecule (Rosmarkam & Yuwono, 2023), (Kusumawati, 2021).

The results of the analysis of soil phosphorus content at the research site with very low to low criteria. The low phosphorus content is due to the fact that paddy fields are very intensive agricultural land that is managed throughout the season so that phosphorus is absorbed by plants, not balanced by SP-36 fertiliser and organic matter as a source of P. In addition, farmers rarely use SP-36 fertiliser because it is difficult to obtain and the price is expensive because SP-36 fertiliser is not subsidised by the government.

The application of organic fertilisers and inorganic fertilisers containing phosphorus can increase soil phosphorus content and improve soil fertility. Organic fertilisers, such as compost or manure, can provide phosphorus gradually as they are slowly decomposed by soil microorganisms. Inorganic fertilisers, such as chemical-based phosphorus fertilisers, can provide additional phosphorus quickly. According to (Zainuddin & Kesumaningwati, 2021), soil conditions with low to very low phosphorus (P) content can have a negative impact on plant growth. Phosphorus is one of the essential nutrients that is important for root development, flower formation, and seed formation. Phosphorus-deficient plants can exhibit slow growth, small leaves, and low fruit or seed production. (Sulakhuddin et al., 2020), that elemental phosphorus (P) in soil usually comes from several main sources, including the decomposition of organic matter and the disintegration of phosphorus-containing minerals. One of the main minerals containing phosphorus is apatite.

Potassium content

Potassium nutrient is an essential macronutrient for plants, which means it absolutely must be present and needed by plants in large quantities and cannot be replaced by other elements. This nutrient is mobile in plants both in plant tissues and in xylem and phloem and immobile in soil. This element is absorbed by plants in the form of K+ cations (Rosmarkam & Yuwono, 2023; Kusumawati, 2021).

Potassium compounds are the result of mineral weathering in the soil found in varying amounts depending on the type of parent material forming the soil. High K-total content can also be influenced by very important K sources including manure, residual K fertiliser use, and irrigation water.

The results of potassium analysis of all observation points were 0.21 to 3.97 mg 100 g^{-1} with very low criteria. The low content of potassium in the soil because it is lifted with the harvest every harvest season without being balanced by giving back through KCl fertilisation, besides the price is considered expensive for farmers, it is also difficult to obtain in the market. This is in line with (Suseno et al., 2018), the low soil K-total content in a location can be influenced by several factors, one of which is the availability of potassium (K) sources in the soil. Potassium is one of the macronutrients that is important for plant growth. If the K source is reduced in the soil, then the soil K-total content can be low. Prabowo & Subantoro (2010) stated that low cation exchange capacity tends to have limitations in releasing potassium (K) ions, which can eventually result in low to very low levels of total K content in the soil.

The research location is a technically irrigated paddy field that is always frequently inundated. While Al Mu'min et al. ((2016), the low K2O is predicted due to leaching of paddy fields that are often inundated.

C-Organic content

C-organic is one of the main constituents of organic matter in soil, such as plant, plant and animal remains of various levels of decomposition. C-organic plays a role in providing a good growing medium that plants need. C-organic can determine the physical, chemical and biological properties of soil.

Based on the analysis of C-organic content at the research location from very low to low. This is because the management of paddy fields is very intense without being balanced by giving back organic matter. According to Abera & Wolde-Meskel, (2013), that agricultural practices in paddy fields are generally dominated by the intensive use of chemical fertilisers, causing the level of soil organic carbon storage to be very low. This is in accordance with the research of Heryadi et al. (2020), which states that rice paddy farming systems that rely entirely on chemical fertilisers and synthetic pesticides tend to have low levels of C-organic storage due to the lack of use of natural organic matter in these agricultural practices.

Low C-organic content in the soil caused by agricultural intensification in paddy fields can also result from the lack of soil restoration practices, where the lack of cover cropping or use of organic fertilisers results in the degradation of soil structure and loss of organic nutrients. Therefore, holistic soil restoration measures, such as the application of crop rotation and the use of compost, are necessary to improve soil fertility and support agricultural sustainability (Lantoi et al., 2016).

Low C-organic content in soils is caused by intensive agricultural practices in paddy fields, where there is often repeated soil processing for planting activities, and harvest residues are often carried out of the cropping area. To overcome this, efforts are needed to re-enrich the soil by adding organic matter to improve ecosystem balance and soil quality (R. A. S. Maulana et al., 2021).

Soil fertility status.

Soil fertility includes the capacity of the soil to provide essential nutrients to plants in adequate amounts, with a balanced distribution and in a form that is easily accessible, to ensure plant growth reaches optimal levels and provides maximum production Yulius et al. (1997). Meanwhile, Sulakhuddin et al. (2020), soil fertility includes soil conditions in which factors such as water, air, and nutrients are in adequate balance and available according to plant needs. This balance includes physical, chemical, and biological aspects of the soil.

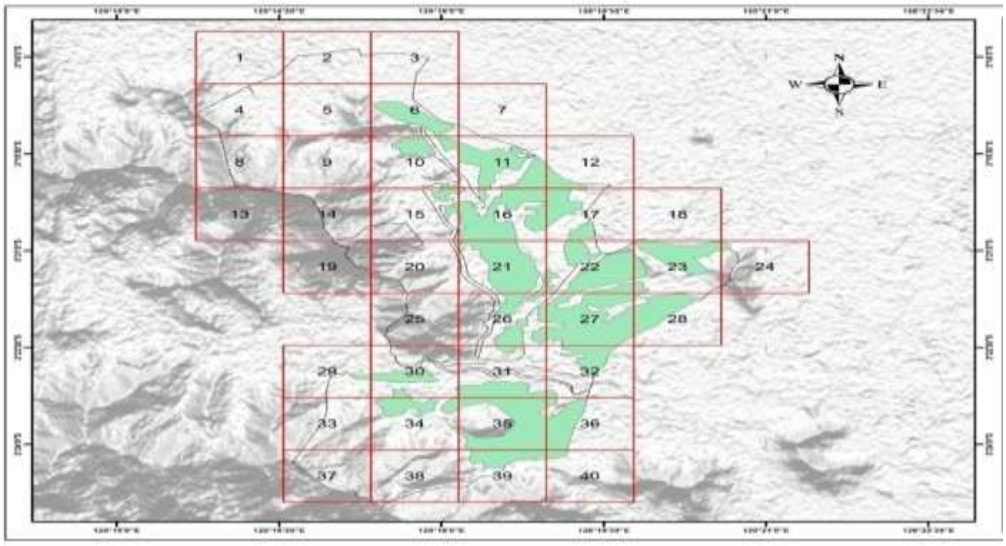

Figure 2. Soil fertility assessment map

Based on the results of the assessment of soil fertility in combination with indicators of soil characteristics at the research site, based on soil characteristics (Soil Research Centre 1995), followed by spatial analysis, the soil fertility status of rice fields is low.

Determination of soil fertility status based on the technical guidelines for soil fertility evaluation of the Soil Research Centre, Bogor (PPT, 1995) in Table 1, shows the assessment of the fertility status of paddy fields in Bajo District, Luwu Regency with low fertility status.

The low fertility status at the research location is generally caused by limiting factors such as low soil base saturation, very low to low P2O5 content, very low K_2O and very low to low soil C-organic. This is due to the very intensive management of paddy fields that causes nutrients in the soil in addition to being lifted along with the harvest and leached due to inundation. Therefore, fertilisation of P_2O_5, K_2O and the addition of organic materials were carried out. According to Sari et al. (2022) the low level of soil fertility in irrigated rice fields due to continuous planting which causes the nutrient content in the soil to decrease. Usually the soil that is continuously watered will cause nutrient factors to decrease due to leaching and flow with irrigation water, such as cations K-d, Ca-d, Mg-d, and Na-d which are susceptible to leaching in paddy fields with low levels due to flowing with water. In line with the research of R. A. S. Maulana et al. (2021), mandatory management is carried out by burying crop residues into the soil, increasing organic matter and increasing the use of NPK compound fertilisers to maximise land productivity. Soil organic matter determines the interaction between biotic and abiotic components in the ecosystem.

Organic matter in the soil functions to improve soil physical properties, improve chemical properties and improve soil microbiology The high content of organic matter will facilitate land processing, because the soil structure becomes crumblier, the growth of micro organisms is better, and root growth is optimal. But according to (R. A. S. Maulana et al., 2021), organic matter fertilisation alone does not necessarily guarantee the optimisation of land productivity. The addition of NPK compound fertiliser can support maximum land productivity. By adding NPK fertiliser to the soil, so that the essential macro nutrients needed by plants in growth so as to maximise the productivity of plants on the land. In line with the research of Yuniarti et al. (2020), that the application of organic fertilisers, nutrients Nitrogen (N), Phosphorus (P), and Potassium (K) can affect several aspects of soil quality and plant growth, including rice plants.

Organic matter in the soil functions to improve soil physical properties, improve chemical properties and improve soil microbiology The high content of organic matter will facilitate land processing, because the soil structure becomes crumblier, the growth of micro organisms is better, and root growth is optimal. According to Winazira et al. (2021), the provision of organic matter in the soil is very important to maintain or improve soil fertility status. Organic matter provides various important benefits for soil and plants.

Conclusion

The fertility status of paddy fields in Bajo District, Luwu Regency is low with limiting factors of Base Saturation, P_2O5, K_2O and C-organic.

Efforts to manage the fertility of paddy fields are the addition of macro nutrients through phosphorus, potassium fertilisation and the addition of organic matter to increase optimal production and reduce soil degradation.

To optimally increase rice production in Bajo sub-district, it is necessary to add organic matter, and apply SP-36 and KCl fertilisers in accordance with soil needs based on soil analysis.

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