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Soil microbial populations of several land use types in Makbon District, Sorong Regency, Indonesia

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ABSTRACT
Degradation of soil function can damage the surrounding ecosystem. Soil fertility is important to plant growth because it is the source of nutrition. One of the factors determining soil fertility is the soil's biological aspects. The study aims to identify the soil microorganism population in the area with the potential for agriculture in Makbon District. The research steps included sampling, media preparation, preparation of dilution series, isolation, and soil microorganism calculation. Based on the land usage, samples K1, M1, and M3 were mapped as primary forests; K2 was a banana farm; B1, K3, M2, and T1 were mixed farms; while T2 and T3 were for horticulture. The findings show that based on the calculation of the total bacteria using the TPC model, the biggest population was found in the mixed farms among various land usages. T2 exhibited the biggest number of bacteria ($1,2 \times 10^5$ CFU mL^{-1}) compared to other samples, followed by T1 with the total bacteria of 1.1×10^5 CFU mL^{-1} and M2 with the total bacteria of 1.0×10^5 CFU mL^{-1}. On the other hand, sample K3 displayed the biggest number of fungi colonies, 1.0×10^3 CFU mL^{-1}. The biggest number of phosphate-solubilizing bacteria colonies were found in Sample B1, which was 1.8×10^5 CFU mL^{-1}. Furthermore, the biggest number of Nitrobacter colonies was found in sample M3, which was 1.2×10^4 CFU mL^{-1}. The study is expected to provide a description and information about the ground microbe population in agroforestry and mixed farms to be considered in the next studies.

Key words: compost, waste, land potential, organic fertilizer.
Article type: Research Article.

INTRODUCTION
Optimizing agricultural land aims to meet the criteria of technical aspects of crop farming land, improving physical and chemical soil, and improving important farming infrastructure (Agoes & Novitarini 2020; Muljana 2022). Optimizing agricultural land in West Papua, especially in Makbon District, Sorong Regency, has great potential, since geographical conditions allow it for agricultural use, so that it can develop optimally if it is treated properly. However, we should know that each region has different geographical conditions. The environment in each region in West Papua is different. One of the differences caused by geographic and environmental conditions is the soil fertility level. However, there has not been comprehensive data regarding the soil fertility status in Makbon District. Potential land refers to the area not optimally used for agriculture. This is an urgent problem, considering many areas with big potential, but are not utilized well (Rahman *et al.* 2021). Optimizing the function of agricultural land is an important and interesting topic for further research. If agricultural land can be optimized, it can result in better products, which can impact the economy of the people of Makbon District. Apart from land processing, another strategy for optimizing agricultural land is to combine agricultural activities with cultivating food crops. Decreased soil function can disrupt the surrounding ecosystem (Tahat *et al.* 2020; Xia *et al.* 2020). Soil fertility influences the plant growth, because it is the source of nutrients. One of the determinants of soil fertility is the biological conditions. Soil quality can be improved by soil microorganisms, especially in the rhizosphere. According to Apriliya *et al.* (2021), Abdila *et al.* (2022) and Oktavia *et al.* (2023), this is because,

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in the soil, microorganisms have quite complex roles, including mineralization, nitrogen fixation, nitrification/denitrification, phosphate solubilization, antibiosis, siderophore production, plant growth regulation, and induction of plant resistance. Soil microorganisms maintain soil structure by stabilizing soil aggregates through the adhesion of hyphae and polysaccharides (Nannipieri *et al.* 2020). The microbial community's balance can improve fertilization efficiency, making agroecosystems more optimal. Therefore, C, N, P, S, and microbes in the soil can be used to measure nutrient dynamics (Dodd *et al*. 2000; Al-Atrash *et al.* 2023). Measuring soil organisms involves many criteria to indicate appropriate land management, including the population of soil microbes (Teke & Akowel 2023). The type of land use can influence soil biological diversity. According to Apriani *et al.* (2022), high biodiversity of microbes can be found in soils with different vegetation. Research results (Wu *et al*. 2020) show that microbial activity in the rhizosphere contributes positively to plants as a dominant factor in soil biology. Based on this description, it is important to carry out this research to determine the population of soil microorganisms on land that has potential for agriculture in Makbon District.

MATERIALS AND METHODS

The research was conducted in Makbon District, Sorong Regency, Indonesia. Data were collected from several potential locations for agriculture there. Soil samples were taken randomly from the research plot (Fig. 1) from 0-20 cm depth. The quantity of soil was approximately 1 kg after being composited. Next, the soil samples were analyzed at the Microbiology Laboratory of Muhammadiyah University, Sorong. The total microorganism analysis procedure initiated by isolating soil microorganisms using the pipette and petri dish method with 10^{-3} retailing. For bacterial populations, we used Nutrient Agar (NA) media; for fungal populations Potato Dextrose Agar (PDA), Pikov'skaya, and Nitrobacter ($NaNO_2$, K_2HPO_4, NaCl, $MgSO_4.7H_2O$, $FeSO_4.7H_2O$, Na_2CO_3, Bacto agar). Samples were cultured using the spread plate method and incubated at 30 °C. The microbial colonies that grew from the isolation results were counted using the Total Plate Count (TPC) method. The number of microbial colonies was calculated by directly observing the microbes in the previously incubated media. The principle of this method is that every viable cell will develop into a colony, which is an index for the number of organisms that can live in the sample. Research data were analyzed descriptively. We interpreted data on populations of fungi, soil bacteria, phosphate solubilizing bacteria, and Nitrobacter obtained from the laboratory as facts that describe soil microbial populations in the field.

RESULTS AND DISCUSSION

The soil selected as samples came from four locations representing land in Makbon District, which has the potential for agriculture. The map of the sample source location is shown in Fig. 1. Based on the study about the activity of soil microorganisms on land in Makbon District with different uses, the activity of soil microorganisms emerges as microorganisms carry out living activities in a soil mass. The activity of soil microorganisms is directly proportional to the total number of microorganisms in the soil. The higher the number of microorganisms, the more intensitive the activity of the microorganisms. Analysis of total soil microorganisms consisting of total bacteria, total fungi, P-solubilizing bacteria, and Nitrobacter from several land uses resulted in the data presented in Table 1. Based on Table 1, the calculation of total bacteria using the TPC method shows that T2 has the highest bacterial cells (1.2×10^5 CFU mL^{-1}) among the other samples, followed by T1 with total bacteria of 1.1×10^5 CFU mL^{-1} and M2 with 1.0×10^5 CFU mL^{-1}. In terms of the number of fungi, K3 exhibited the highest number of colonies = 1.0×10^3 CFU mL^{-1}. Meanwhile, the highest number of phosphate-solubilizing bacteria colonies was found in B1, with 1.8×10^5 CFU mL^{-1}, while the highest total *Nitrobacter* colonies in M3 (with 1.2×10^4 CFU mL^{-1}). Based on their usages, soil samples K1, M1, and M3 can be mapped as primary forest, K2 is a banana plantation, B1, K3, M2, and T1 are mixed gardens, while T2 and T3 are horticultural crops. Sabrina & Lubis (2019) and Rosariastuti *et al.* (2023) reported that mutualist bacteria have different compositions and numbers depending on soil conditions and the plants growing there. These bacteria can come from the *Rhizobium*, *Azotobacter*, *Pseudomonas*, *Lactobacillus*, *Bacillus*, and phosphate solubilizing bacteria groups. On the other hand, Flores-Tena *et al.* (2007) suggested that soil can contain Gram-negative pathogenic bacteria, especially those from the enteric bacterial group, while Nath Yadav *et al*. (2017) found that soil particles are bound by organic chemicals, including compounds produced by soil bacteria. Biochemicals produced by soil bacteria, such as polysaccharides, have impact soil particle binding. Mineralization of soil microorganisms in organic matter can also affect soil structure, increase the exudate number of the roots, affect soil structure, and upraise microbial populations.

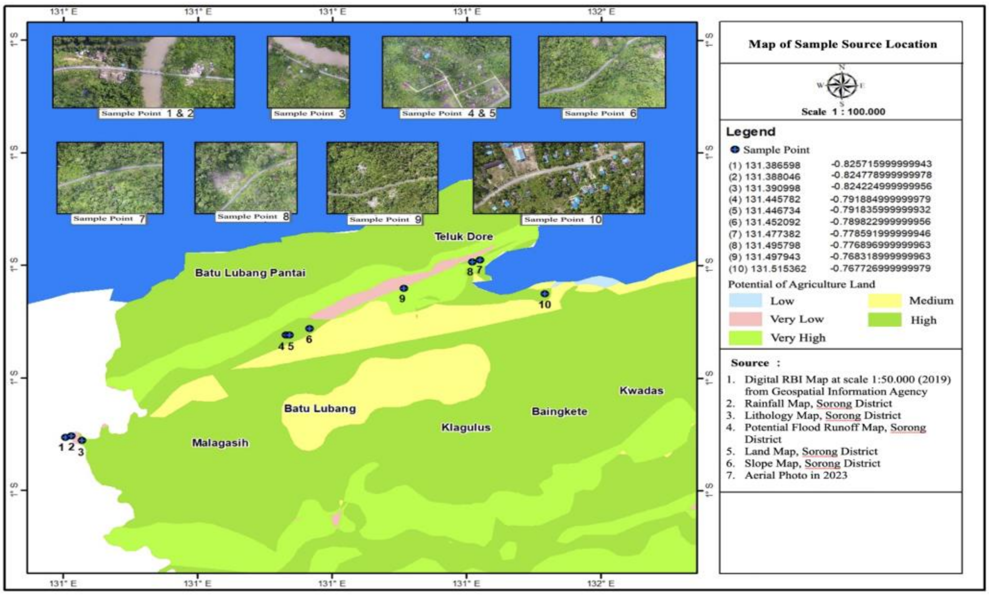

Fig. 1. Map of sample source location.

Table 1. Total soil microorganisms.

No	Samples	Total bacteria	Total fungi	P solubilizing bacteria	Nitrobacter
		CFU mL^{-1}			
1	B1	1.3×10^4	1.2×10^2	1.8×10^5	1.5×10^2
2	K1	1.9×10^4	6.0×10^2	1.1×10^5	8.8×10^3
3	K2	2.0×10^4	4.4×10^2	4.1×10^4	4.5×10^3
4	K3	1.5×10^4	1.0×10^3	3.1×10^4	6.1×10^3
5	M1	2.8×10^4	4.1×10^2	7.9×10^3	2.1×10^2
6	M2	1.0×10^5	1.7×10^2	4.5×10^4	9.5×10^3
7	M3	3.8×10^4	6.6×10^2	2.9×10^4	1.2×10^4
8	T1	1.1×10^5	1.4×10^2	2.9×10^4	1.6×10^2
9	T2	1.2×10^5	2.3×10^2	5.9×10^4	1.7×10^2
10	T3	2.9×10^4	1.8×10^2	5.0×10^4	1.9×10^2

Based on data presented in Fig. 2, the highest total population of bacteria was found in lands for horticulture, mixed farms, and primary forests. The land for one season plant promotes the diversity of vegetation, and the bacterial population boosts the result of the conventional land management technology performed by the Makbon communities, which improves the structure, texture, and aeration of land, triggering the growth of soil microorganisms. According to Sabrina & Lubis (2019), Susilawati *et al*. (2016) and Rosalina & Sukmawati (2022), soil management also influences the growth of population of bacteria in a seasoned plant. Soil management will improve the structure, texture, and aeration of land. Different quantity of bacteria in a land shows their activities in the soil. The more active the microorganisms, the higher their role in biochemical processes in the soil, so that the use of inorganic fertilizer can be reduced (Solihin & Fitriatin 2017; Octaprama *et al.* 2020). Microorganisms in the soil play multiple roles, such as providing nutrients, breaking down organic matter, promoting plant growth, and controlling plant pests and diseases. The number of microorganism populations in a soil can indicate the soil's fertility, since a large population of microorganisms indicates the presence of sufficient organic matter, sufficient water availability, proper temperature, and soil ecological conditions. In addition, soil turning and destruction of organic materials create zones of intensive microbial activity in the till layer (Permana *et al.* 2017). Based on the data in Fig. 4, the largest fungal population was found in mixed garden land (K3; 1.0×10^3). The largest fungal population on this type of land is believed to be caused by the treatment and management of plant residues by people in Batu Lubang Village. Differences in vegetation and temperature can influence soil properties due to variations in vegetation on land that can change soil properties, and there is a complex reciprocal relationship between the types. Alterations in properties due to changes in the type of vegetation covering the soil directly affect the distribution of soil organic matter and the activity of soil microorganisms (Irfan 2014).

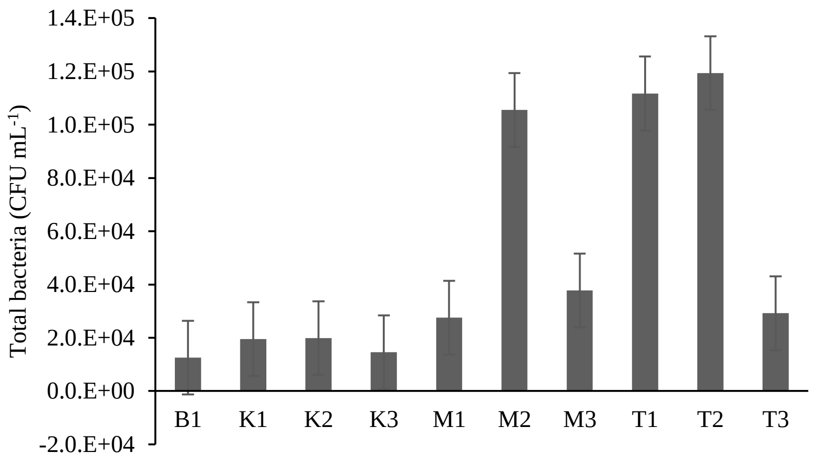

Fig. 2. Total bacteria at each sampling location.

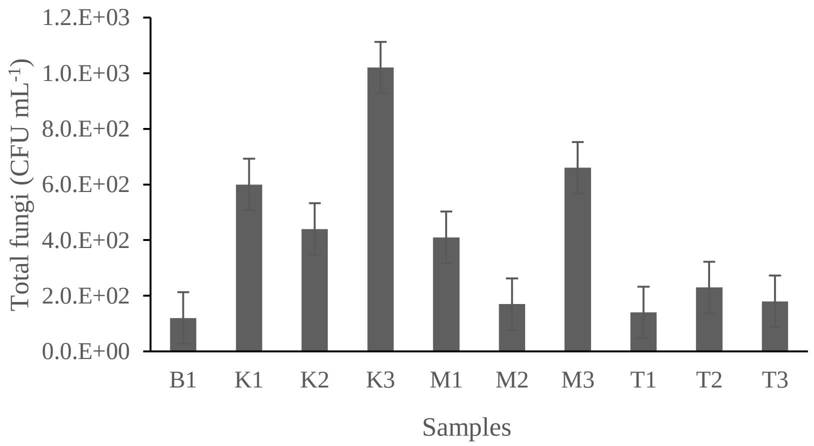

Fig. 4. Total fungi at each sampling location.

Based on research by Mukrin *et al.* 2019), the largest fungal population is found in mixed land, which is 811 × 10^3 CFU mL^{-1}. The organic matter in each type of soil is different. This depends on several factors, including the type of vegetation in the area, the population of soil microorganisms, the soil drainage, rainfall, temperature, and soil management. This is also in accordance with Al-Masoodi *et al.* (2023) and Rosariastuti *et al.* (2023) that among all the land uses studied, fungi and actinomycetes dominate mixed gardens. The characteristics of phosphate solubilizing bacteria are that they have Gram-negative bacteria, can dissolve phosphate (P), and on Pikovskaya media, they can form a clear zone around the colony, indicating the presence of phosphate dissolution. Phosphate (P) solubilizing bacteria in the soil can release P from Fe, Al, Ca, and Mg bonds (Raharjo *et al.* 2007; Djuuna *et al*. 2022; Rosalina & Febriadi 2023). Phosphate-solubilizing bacteria are nonpathogenic and can stimulate plant growth. Phosphate solubilizing bacteria can produce vitamins and phytohormones to accelerate root growth and increase nutrient uptake (Maulana & Irmawatie 2020). Based on the data in Fig. 6, the population of phosphate-solubilizing bacteria is more commonly found in mixed gardens. The microbial population in mixed garden agricultural soil is high because the organic C content of this soil is higher, which is a source of energy and nutrition for microbial growth, especially heterotrophic microbes. Based on some authors (Utami *et al.* 2020; Tarigan 2023), the population of phosphate-solubilizing bacteria and phosphatase activity are higher in soil with intercropped vegetation compared to monoculture systems. Based on the data in Fig. 8, the population of nitrobacter bacteria is more commonly found in primary forest land. This is probably because forest soil has higher organic matter, which encourages the development of chemoautotrophic microbes, including nitrifying bacteria. Hence, the potential population number tends to be higher than soil, which is poor in organic matter. According to Bargali *et al.* 2019), different chemical properties of waste will cause differences in the level of waste decomposition so that the level of inhibition of nitrification will also differ between wastes. This difference in the level of inhibition will affect the nitrification potential value through the activity of nitrifying bacteria and the activity of heterotrophic microbes. Additionally, according to Vieira & Nahas (2005), soil type seems to determine the composition of microbial populations in the soil.

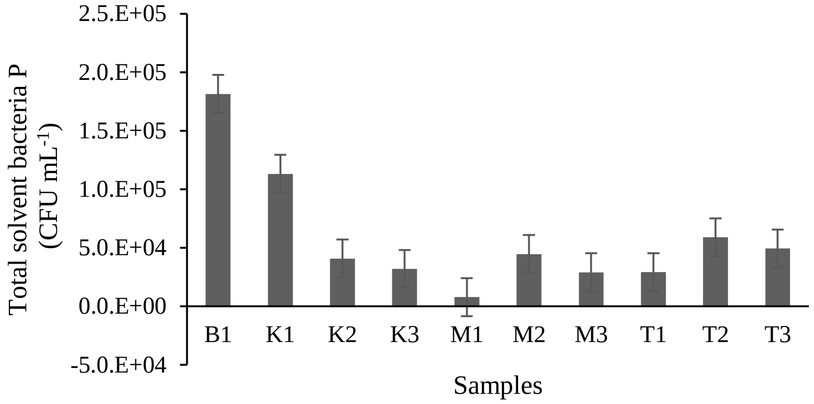

Fig. 6. Total P-solubilizing bacteria at each sampling location.

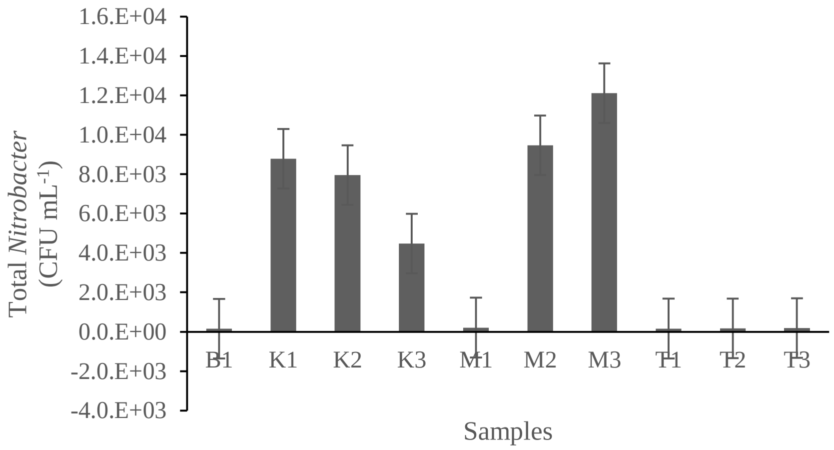

Fig. 8. Total *Nitrobacter* at each sample location.

Adding organic matter to the soil can boost the N, P, and K contents (Sukmawati *et al.* 2022). In adding organic materials into the soil, we should pay attention to the ratio of levels of the element C to the nutrients such as N, P, K and so on, since an unbalanced ratio can promote immobilization, which reduces the amount of N, P, K, and other important nutrients in the soil by microorganism activity (Soleimani *et al*. 2019). The biggest population is generally found on land used for mixed gardens. Land for mixed gardens is covered with annual vegetation of one type or a mixture, either in a random or regular pattern, as a border for the moor. Land use for mixed gardens provides organic material throughout the year from leaves, twigs, and branches that have fallen on the ground surface, which then die to become waste. Trees provide organic material from dead roots, dead root caps, root exudation, and root respiration in the underground part. According to Saragih et al. (2015), Kurniawan *et al*. (2019), Kusumawati & Prayogo (2019) and Sui *et al*. (2019), land processing systems make a significant difference in the total population of soil microbes. Using land for cultivating seasonal crops can enrich vegetation diversity. In addition, processing agricultural systems such as inorganic and organic fertilization stimulates the growth of soil microbes. The results of this observation are supported by Coleman & Whitman (2005), Mhete *et al.* (2020) and Ramírez *et al.* (2020) who stated that microbes with high biodiversity are found in soils with different vegetation. This aligns with Kurnia & Azis (2017) that land used intensively for annual crops tends to have more soil microbes than others.

CONCLUSION

The findings show that based on the calculation of the total bacteria using the TPC model, the biggest population was found in the mixed farms among various land usages. T2 exhibited the biggest number of bacteria (1.2×10^5 CFU mL^{-1}) compared to other samples, followed by T1 with the total bacteria of 1.1×10^5 CFU mL^{-1} and M2 with 1.0×10^5 CFU mL^{-1}. On the other hand, K3 displayed the highest number of fungi colonies (1.0×10^3 CFU mL^{-1}). The highest phosphate-solubilizing bacteria colonies were found in B1 (1.8×10^5 CFU mL^{-1}). Furthermore, the highest number of *Nitrobacter* colonies was found in M3, which (1.2×10^4 CFU mL^{-1}). The study is expected to provide a description and information about the ground microbe population in agroforestry and mixed farms to be considered in the next studies.

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