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Dynamic of soil properties under an exotic pine (*Pinus sp.*) species growing in Bantaeng Regency

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Abstract. One of the conifer species that can thrive in Indonesia is *Pinus merkusii*. This pine is an endemic species on the island of Sumatra, particularly in Aceh, Tapanuli, and Kerinci. In addition, there were other exotic species (*Pinus sp.*) growing on the island of Sulawesi. However, it has never been reported before. Therefore, this study aims to examine and describe the soil characteristics under Rombeng Pine (*Pinus sp.*) stand in Bantaeng Regency in terms of information on the soil nutrients under the *Pinus sp.* stand. The used method included sampling soil and collecting tree tissues. The results showed that the characteristics of soil properties varied. Both physical and chemical soil characteristics varied, particularly in soil texture class, organic matter content, C%, N%, C/N ratio, P₂O₅, and Mg.

1. Introduction

Coniferous forests are forests that are located between the subtropical and arctic climates in the northern hemisphere. For example, forests in North America, Alaska, the Scandinavian Peninsula, and Russia. The plants that dominate this biome are those with coniferous features, such as spruce, birch, alder, juniper, pine, and spruce. Coniferous forests account for 29% of the total forest area in the world [1].

Pine forest is one of the coniferous forests used as timber forest products and non-timber forest products [2]. *Pinus merkusii* has enormous potential to improve the economy of the surrounding communities. Pine forest areas that can be used are wood for carpentry, firewood, tree sap, and punus seeds. Pine sap can be processed into gondorukem and turpentine. Gondorukem can be used to mix batik, soap, paper, paint, and varnish. Meanwhile, turpentine is used for paint oil, perfume mixtures, detergents, flavoring agents, protective coatings, insecticides, lubricants, medicine, plastics, rubber [3].

In Indonesia, the only pine that grows naturally is *Pinus merkusii* Jungh. et De Vriese in three places in Sumatra, namely in Aceh, Tapanuli and Kerinci [4]. *Pinus merkusii* is the only type of pine that thrives in Indonesia, and one of them grows in the Aceh, Tapanuli, and Kerinci areas, northern Sumatra [5]. Geographically, pines are spread between 2° LS - 22° N and 95° 0' BB - 120° 31' East [6]. *P. merkusii* has the potential to control landslides because it can reduce the amount of rainfall that falls to the ground with a high interception, increases slopes through long and deep roots, and can reduce the load force by groundwater through high evapotranspiration. Its pioneering nature means it has roots that grow faster and bind the soil stronger [7].

In Bonto Lojong Village, Bantaeng Regency, South Sulawesi, there are pine stands that are not known for certain (unknown species), but the local community (local community) calls it a "rombeng



pine" tree. The *Pinus sp.* was estimated around 80-90 years old. It is reinforced by the arguments of several community leaders who believe that the beginning of planting one of these coniferous trees was around the 30s during the Dutch colonial period [8].

The *Pinus sp.* stands had never been reported before following reference searches in various national and international journals. It may be due to the morphological similarities with *P. merkusii* species which can also be found growing not far from *Pinus sp.* Hence, they are both considered to be different species. However, due to the absence of information on tree species, information on the biological characteristics and place of growth has been confirmed as not yet available.

One of the parameters where a tree population grows is its edaphic nature (soil characteristics). [9] The land is a land area where it can be used for various businesses, such as agriculture, livestock, building buildings, and others. If it is interpreted more specifically, the soil is a medium for the growth of land plants originating from rock weathering mixed with the remains of organic matter and organisms (vegetation and animals) that live on it or in it, and there is also air and water in the water. Soil is a heterogeneous natural object consisting of solid, liquid, and gas components with dynamic properties and behavior. Soil science views soil from two main concepts: weathering the parent material through chemical biophysical processes and plants' habitat. Various types of soil have different sensitivity to erosion. The intensity of soil erosion or the ease with which it is eroded is a function of various soil physical, chemical, and biological properties [10].

Soil physical properties are soil properties related to the shape/condition of the original soil, which includes texture, structure, porosity, stability, color consistency, and soil temperature. Soil physical properties play a role in plant root activity, both in absorbing nutrients and water. Therefore, soil physical properties, including soil density and strength, have long been recognized as the main parameters in assessing the success of tillage techniques. In addition, the physical properties of soil are environmental elements that greatly affect the availability of water and soil air and indirectly affect the availability of plant nutrients [11].

Soil chemical properties are defined as the overall Physico-chemical and chemical reactions between soil constituents and between soil constituents and materials added to the soil in the form of fertilizers or other soil enhancers. The velocity factor for all forms of chemical reactions in the soil has a very wide range, ranging from very short calculated by minutes (certain absorption reactions) to extraordinary calculated by centuries (reactions related to soil formation). In general, the reactions that occur in the soil are induced by the action of certain environmental factors [12].

Data related to differences in the physical and chemical properties of soil in the land or stand is very important to determine the level of soil fertility and the potential for erosion that will occur so that it can be seen that the treatment will be carried out in minimizing this and increasing the soil fertility of land or stand.

2. Materials and methods

The tools used in this research were: 1) Soil drill was used for soil sampling; 2) Labels were used for providing information on soil samples taken; 3) Plastic Clips were used to store soil samples; 4) Writing tools were used to record observations; 5) Camera was used to document research results; 6) Dropper pipettes were used for dropping chemicals on the soil; 7) pH meter was used to determine soil pH.

The materials used in this study were water, distilled water, penitar, sulfuric acid, and indicator solutions used in the laboratory. Sampling using a composite sample system in the area where *Pinus sp.* grows. Soil samples were taken at three depths, namely 20, 40, and 60 (cm), each soil sample was 100 grams, then the soil was collected and mixed homogeneously then 200 grams were taken for laboratory analysis.

Analysis of the physical and chemical properties of the soil was carried out at the Tree Silviculture and Physiology Lab, Hasanuddin University Faculty of Forestry, Makassar. Laboratory tests were intended to determine the soil nutrients under the *Pinus sp.* stand.

The parameters observed in this study included the physical properties of the soil, which included texture analyzed using the pipette method, as well as the chemical properties of the soil, which included pH using a pH meter, Nitrogen (Kjedhal method), K with (Bray I method), C-organic (Walkley and Black method), C/N ratio by comparing the values of C% and N%, P-available with the P-Olsen analysis method. Organic matter by multiplying the value of C by 1.724. The values of Ca, Mg, K, Na and bases saturation, the Cation Exchange Capacity (CEC) used the I N NH₄OAc Extraction analysis method pH 7.

3. Results and discussion

The results of observations and analysis of the physical properties of the soil in a stand of Rombeng Pine (*Pinus sp.*) In Bantaeng Regency can be seen in table 1.

Table 1. Analysis of physical properties of soil.

Sample ID	Soil fraction			Texture class
	Sand (%)	Silt (%)	Clay (%)	
1	36	42	32	Clay loam
2	32	31	37	Clay loam
3	40	33	27	Loam
4	50	33	16	Loam
5	40	45	15	Loam
6	41	30	25	Loam

The results of the soil texture analysis showed that each soil sample from the six plots had a different percentage of sand, silt, and clay. For example, for the percentage of sand, the lowest yield was 32%, and the highest was 50%, then the lowest percentage of silt was 30%, and the highest was 45%, while for the lowest clay percentage was 15%, and the highest was 37%. For texture class, plots 1 and 2 were clay loam, and the rest were loam.

The analysis results with the clay texture class indicated that the soil condition is classified as good in releasing water into the soil in reducing the potential for erosion and surface runoff. It follows the opinion of [10], which states that sand-textured soil has a high infiltration capacity, so the soil is not sensitive to erosion. Soils dominated by sand will have many macro (large) pores, which are called more porous. Soils that are dominated by silt will have a lot of meso (medium) slightly porous pores. In contrast, those dominated by clay will have micro (small) pores or not porous [13], indicating that plots 1 and 2 have a lower infiltration capacity than locations 3-6. Based on the study conducted by [14] under pine stands in the Poso district, the texture criteria obtained were silty clay. The results of observations and analysis of soil chemical properties in Rombeng Pine (*Pinus sp.*) stands in Bantaeng Regency was showed in table 2.

Table 2. Sample variable results of criteria analysis.

Chemical soil properties	Sample	Results	Criteria
pH	1	5.67	Acid
	2	5.1	Acid
	3	5.67	Acid
	4	5.94	Acid
	5	5.57	Acid
	6	5.9	Acid
Organic matter (%)	1	2.85	High
	2	3.82	High

Chemical soil properties	Sample	Results	Criteria
	3	3.75	High
	4	3.99	High
	5	3.65	High
	6	3.98	High
	1	1.65	Low
	2	2.21	Moderate
C%	3	2.17	Moderate
	4	2.32	Moderate
	5	2.12	Moderate
	6	2.31	Moderate
	1	0.18	Low
	2	0.10	Low
N%	3	0.24	Moderate
	4	0.16	Low
	5	0.13	Low
	6	0.15	Low
	1	8	Low
	2	26	Moderate
C/N ratio	3	9	Low
	4	25	Moderate
	5	31	Moderate
	6	23	Moderate
	1	18.93	Moderate
	2	19.65	Moderate
CEC (cmol (+)kg-1)	3	18.54	Moderate
	4	20.71	Moderate
	5	22.8	Moderate
	6	19.84	Moderate
	1	54.33	Moderate
	2	52.33	Moderate
Bases saturation (%)	3	47.33	Moderate
	4	44.66	Moderate
	5	55.66	Moderate
	6	52.66	Moderate
	1	9.86	Very low
	2	13.34	Low
P-Olsen (ppm)	3	11.36	Low
	4	16.57	Low
	5	17.17	Low
	6	16.03	Low
	1	7.49	Moderate
	2	7.70	Moderate
Ca (cmol (+)kg-1)	3	7.15	Moderate
	4	7.35	Moderate
	5	9.79	Moderate
	6	8.91	Moderate
	1	2.86	High
	2	2.49	High
Mg (cmol (+)kg-1)	3	1.39	Moderate
	4	1.34	Moderate
	5	2.53	High
	6	1.39	Moderate
	1	0.20	Low
K (cmol (+)kg-1)	2	0.26	Low

Chemical soil properties	Sample	Results	Criteria
Na (cmol (+)kg-1)	3	0.34	Low
	4	0.34	Low
	5	0.33	Low
	6	0.31	Low
	1	0.34	Low
	2	0.24	Low
	3	0.23	Low
	4	0.32	Low
	5	0.21	Low
	6	0.25	Low

3.1. Soil pH

Based on soil analysis results with acidic conditions in each sample infusion plot, it was explained that soils with acidic conditions had difficulty absorbing nutrients by plant roots. It was revealed by [9], who stating that in general, nutrients are easily absorbed by plant roots at neutral soil pH because most nutrients can dissolve at neutral pH conditions. Rain is one of the factors that can reduce the pH value of the soil, [12] revealed that ground air has a high enough CO₂ content which can reduce the soil pH between 0.5-1. [14] stated that soil acidity occurs due to weathering processes of minerals and rocks and very fast washing. The level of soil acidity affects the solubility of soil nutrients. Increasing pH in acid soils can increase the availability of macronutrients and reduce the solubility of Al and Mn elements. If the pH is lower, the amount of Fe and Mn will dissolve in large quantities [15]. Based on research conducted by [16] in the area of former stands of *Tectona grandis*, the obtained pH conditions were also in the acid criteria, and according to the study that the low soil pH value made it difficult for plants to absorb nutrients because generally plants easily absorb nutrients at a neutral pH (pH 6 to 7).

3.2. Organic matter

When viewed from the variable organic matter content, all sampling plots are classified as high. This is because the age of the stands causes the high level of organic matter since the pine tree was planted in the 30s, which means that the tree is 90 years old or more. Hence the tree tissues had a rich organic matter content. Therefore, the availability of organic matter at each sampling point is based on trees classified as many and shady to produce high organic matter. It indicates that the soil has good criteria to reduce the potential for the soil to avoid erosion. It is in line with [9], who states that the amount of organic matter at the surface of the soil affects the soil's ability to hold water so that surface runoff can be minimized. It also indicates that the soil can be a good soil aggregate base [17].

3.3. Carbon %

The organic matter content in the form of C-Organic in the soil must be maintained at no less than 2 percent. The organic matter content in the soil does not decrease with time due to the mineralization decomposition process [18]. However, the government has revised the previous regulation with a new regulation, namely Regulation of The Ministry of Agriculture No.70/Regulation of The Ministry of Agriculture/SR.140/10/2011 concerning organic fertilizers, biological fertilizers, and soil repairers Organic content of at least 6%. Meanwhile, based on the analysis results, it shows that in all the research plots, the C% value does not reach the standard, where plot one is low. Plot 2-6 is classified as moderate with the C% value, and none of it reaches 3%. Therefore, it can be said that C-organic is a factor that limits plant growth. Because in this lower layer, there are plant roots that will absorb nutrients but do not find the benefit of organic C because it is in a low state. The research results by [16] on the former stand area of *Tectona grandis* received a low C-Organic content. At the same time, according to [9], the effect of organic matter on soil physical and chemical properties was enormous, including as a granulator. The nutrients N, P, S, microelements increase the ability of the soil to hold

water, retain the ability of the soil to hold nutrients, and serve as a source of energy for microorganisms.

3.4. Nitrogen %

Nitrogen is the main nutrient for plant growth, which is generally indispensable for the formation or growth of vegetative parts of plants, such as leaves, stems, and roots [18]. Based on the analysis results, the N% content is classified as moderate in plot three. Other plots are classified as low, resulting in not giving a maximum contribution to nutrient absorption into the soil, in line with research conducted by [16] in the former *Tectona grandis* stand, which gets an average N% content the low category. At the same time, Element N acts as a constituent of all protein, chlorophyll, and nucleic acids and plays an important role in forming coenzymes [13].

3.5. C/N ratio

The C/N ratio functions to regulate whether organic material is fast or difficult to disintegrate. Organic matter can be in the form of fine and coarse. Factors that affect the destruction of organic matter include temperature, humidity, soil air conditioning, soil processing, pH, and types of organic matter [19]. In sampling plots 1 and 3, the C/N value is classified as low, while the others are classified as moderate. A value less than 11 means that the organic matter is very decaying in the soil. Please add materials containing organic matter, such as compost or livestock manure. Moderate values above 15 mean that the organic matter has not been decomposed, so it takes time to support plant growth.

3.6. Cation exchange capacity

Cation exchange capacity (CEC) is a soil chemical characteristic that is closely related to soil fertility. Soils with high CEC can absorb and provide nutrients better than soils with low CEC. Because these elements are in the soil seepage complex, these nutrient elements are not easily lost or washed by water. Soil CEC describes soil cations such as Ca, Mg, Na, and K that can be exchanged and absorbed by plant roots [19]. All the sampling plots, the CEC value criteria were all classified as moderate. Each at the soil sampling point had a moderate CEC value. Suspects that its ability to absorb nutrients is not as good as CEC with high criteria, almost the same as the research conducted by [16] on the *Ex-Tectona Grandis Stand Area*, which received moderate to high CEC values. [9] explains that soils with high CEC can absorb and provide nutrients better than soils with low / medium CEC. The low soil CEC in these locations is directly and indirectly influenced by the acidic soil reaction. The low cation exchange capacity is due to the cations in the soil having been exchanged or replaced by other ions in the soil solution.

3.7. Base saturation

Base saturation is the percentage of base cations that can be exchanged in a number of exchangeable cations in the soil. Base saturation is determined to estimate the level of base ion absorption in a complex [20]. In each sampling plot, the criteria for the base saturation value are classified as moderate, unlike the research conducted by [16] on the Former Stand of *Tectona grandis* area, which obtained base saturation values that varied from very low to very high. Base saturation shows the ratio between the number of base cations with the number of all cations (alkaline and acidic cations) present in the soil seepage complex. Base saturation is closely related to soil pH, where soils with low pH have low base saturation, while soils with high pH have high base saturation as well [19].

3.8. P_2O_5

P_2O_5 is K_2O and P_2O_5 extracted with 25% HCl, which indicates that K and P are absorbed in the soil, which will potentially provide K and P for plants [21]. Still, in each research plot, the P-Olsen value obtained is low even in plot one is classified as very low, indicating that the K and P available for plants is minimal.

3.9. Calcium (Ca)

Calcium (Ca) cation is calcium in the soil uptake complex, and this value will affect the value of CEC and bases saturation of the soil [19]. Based on the results of the analysis carried out, it was found that the Ca value in the medium category in all research plots indicated that the Ca content in all research plots was still insufficient in increasing soil fertility at the research location.

3.10. Magnesium (Mg)

Like the Ca cation, the Mg cation is also a cation in the soil absorption complex, and this value will affect the CEC value and base saturation [19], which also affects soil fertility in an area. Based on the analysis, there are three plots with high Mg criteria, namely plots 1, 2, and 5, while plots 3, 4, and 6 are classified as moderate.

3.11. Potassium (K)

Potassium is the third nutrient after N and P, which plants need in large quantities. It plays an important role in photosynthesis, the formation of carbohydrates and proteins [19]. Meanwhile, based on the results of the analysis carried out, the K content obtained in all research plots was classified as low, indicating that the photosynthetic process, carbohydrate, and protein formation in all research plots were slow due to research conducted by [16] in the area of the former *Tectona grandis* stand which get an average K content in the low category. The role of the nutrient potassium for plant metabolism is very large. Also, the nutrient potassium serves to strengthen the stems. If the quality of the plant stems is not good because of low potassium in the soil and the plant, the plant will be susceptible to attack by pests and diseases through the plant. In addition, potassium functions to activate enzymes, regulate the absorption of other elements and root growth [9]

3.12. Sodium (Na)

The Na content in each research plot is classified as low so that the potential for erosion due to Na content is minimal because excess Na in the soil will cause the soil to be dispersed so that it is easily eroded [22]. In addition, sodium is a micronutrient absorbed by plants in the form of Na, the normal level of sodium in the soil is 0.03 me 100-1 [23].

3.13. Plot-based heatmap analysis

The results of the heatmap analysis are based on the plot forming 2 clusters, namely the first cluster consisting of plots 6, 4, and 5 and the second cluster consisting of plots 1, 3, and 2 with the same Al, N%, Na, C%, Texture, Mg and pH variables. Then it looks different in the variables Ca, C / N ratio, P-Olsen, CEC, and bases saturation can be seen in figure 1.

3.14. Soil depth-based heatmap analysis

The results of the heatmap analysis based on the depth formed 2 clusters, namely the first cluster consisting of a depth of 0-20 and 20-40 (cm) and the second cluster consisting of a depth of 40-60 cm with variables Na, N%, K, Al, %C, Mg which the same, then looked different on the variables pH, Ca, C / N Ratio, Texture, P-Olsen, CEC, and bases saturation can be seen in figure 2.

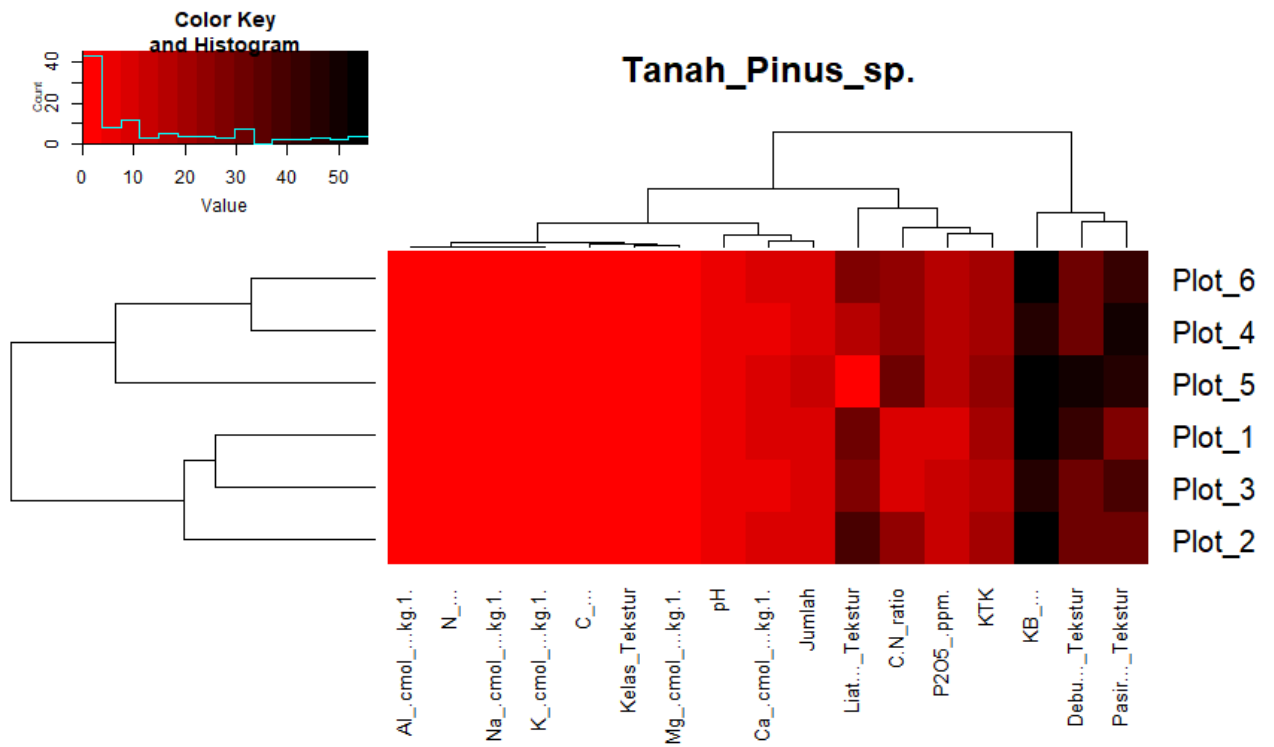


Figure 1. Heatmap analysis based on plots.

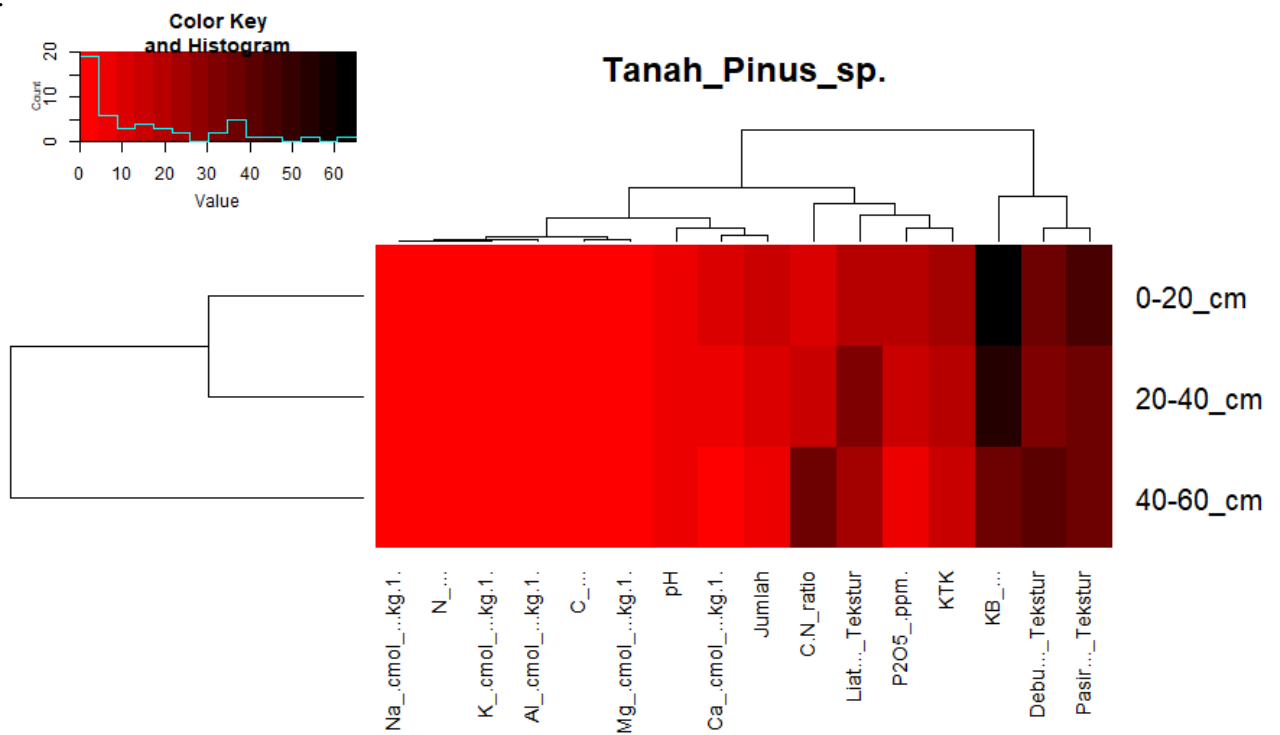


Figure 2. Heatmap analysis based on soil depth.

4. Conclusions

The results of the analysis of the physical and chemical properties of the soil from 6 samples from different sampling plots under Rombeng Pine (*Pinus sp.*) stand show the texture class of clayey clay in plots 1 and 2, clay in plot 3-6, acid soil pH conditions, organic matter content high, low and medium C%, low N% on plots 1, 2, 4, 5 and 6, moderate on plot 3. C/N ratio is low in plots 1 and 3 others classified as moderate, CEC value, base saturation, moderate Ca, K and Na, P-Olsen in plot 1 is very low. The rest is low and high Mg in plots 1, 2, and 5. Plots 3, 4, and 6 are classified as moderate. The values obtained from each variable indicate that the soil fertility under the Rombeng Pine (*Pinus sp.*) stands cannot be categorized as good and sensitive to erosion, especially the slopes classified as very steep.

Particular treatment is needed for the soil on Rombeng pine (*Pinus sp.*) stands by applying lime powder to neutralize acidic soil pH and increasing Ca levels and Bases saturation, adding organic matter to avoid erosion and increasing soil nutrient content in the topsoil, fertilization to increase soil fertility in increasing the availability of nutrients in the soil also helps plants to thrive and nourish plants, in this case, pine stands and further research in analyzing the biological properties of the soil.

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