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Evaluation of Land Suitability for Revegetation Plants at Megawati Soekarno Putri Botanical Garden Ratatotok, Minahasa Tenggara Regency

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Abstract: This study aims to: (1) Identify suitable plants for the study site; (2) Determine the suitability of the land and factors limiting the growth of revegetation plants. The study site is the post-mining reclamation land of PT. Newmont Minahasa Raya as the Megawati Soekarno Putri Botanical Garden in Ratatotok, Southeast Minahasa, North Sulawesi. The benefits gained from efforts to preserve natural resources, particularly in the concept of environmental conservation, which is important for the continuity of the ecological system and reference. This study uses a descriptive method with a survey approach and is supported by soil analysis in the laboratory. Primary data includes vegetation data, soil and water conservation measures, topography, soil depth, surface drainage, surface rocks, rock outcrops, erosion hazards, and flood/flooding hazards. Observations and soil sampling were carried out along transects. The types of plants evaluated for suitability were mahogany, teak, sengon, mango, coconut, and clove. The data were analyzed using qualitative descriptive methods. The results of the study showed that (1) there were several types of local trees that grew naturally, which were also found in secondary forests, including: Kapur wood (*Melanolepsis sp.*), *Ficus sp., Trema orientalis*, Melinjo (*Gnemo gnetum*) and Nyatoh/Nantu (*Palaqium sp*), *Cananga odorata, Koordersiodendron pinnatum, Cratoxylum sp.*; (2) The suitability of the land for mahogany, teak, sengon, mango, clove, and coconut trees each has a subclass of S1 (very suitable), subclass S2eh (somewhat suitable), subclass S2rc (somewhat suitable), and subclass S2eh/rc (moderately suitable), and subclass S3eh/rc (marginally suitable) with limiting factors of erosion hazard and root medium.

Keywords: Land suitability; MSP Ratatotok Botanical Garden; Revegetation

Introduction

Land evaluation is the process of assessing the behavior of land resources when used for specific purposes, including conducting surveys and interpretations as well as studying landforms, soil, vegetation, climate, and other aspects to determine and assist in comparing the possibilities of various land uses that can be applied to specific use options (FAO, 1976; Elsheikh et al., 2013; Hartati et al., 2018). Land evaluation provides data that will be used in land use planning by comparing the requirements of the type of land use with the characteristics or quality of the land to be used (Rayes, 2007; Hardjowigeno, 2011; Abdullah et al., 2024).

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Land use types are types of land use described in more detail because they involve specific management, inputs required, and expected outputs (Djaenudin et al., 2011; Kaunang et al., 2025). Each land quality consists of one or more land characteristics. Several land characteristics generally relate to each other regarding land quality and will affect the type of use and/or plant growth.

Land suitability evaluation describes the level of suitability of a piece of land for a particular use, which can be assessed based on environmental characteristics of climate, soil, topography, and drainage (Sitorus, 1985; Fathoni & Aji, 2015; Sitorus, 2016; Mangkunegara & Firdamayanti, 2021). The diversity of soil, topography, and climate properties can be used to select suitable commodities to be developed in a region. The selection of plant species is one of the most essential technological inputs in the revegetation of post-mining land. Revegetating post-mining land with annual plants is an effective way to restore the function of forests as carbon sinks, maintain soil carbon content, and reduce erosion and surface runoff (Patiung et al., 2011).

The area of reclaimed land from the former gold mine of PT Newmont Minahasa Raya is 443.40 ha, which includes the Megawati Soekarno Putri Ratatotok botanical garden, which covers an area of 221.5 ha (Purnomo et al., 2020; Mamengko et al., 2022). This botanical garden can function as a water catchment area to maintain the hydrological cycle and provide water for communities in lower-lying areas.

In relation to the above information, the issues examined in this study are: what factors limit plant growth in the Megawati Soekarno Putri Ratatotok botanical garden, and whether the plants grown in the Megawati Soekarno Putri Ratatotok botanical garden are suitable. Information about the suitability of land for revegetation will significantly support the existence of the Megawati Soekarno Putri Botanical Garden as a nature conservation area for collecting plants used for research, science, education, cultivation, culture, tourism, and recreation. The objectives of this study are: (1) to identify suitable plants to be planted in the Megawati Soekarno Putri Ratatotok Botanical Garden; and (2) to determine the suitability of the land and identify the limiting factors for the growth of revegetation plants in the Megawati Soekarno Putri Ratatotok Botanical Garden.

Information on the results of research on land suitability for revegetation will greatly support the existence of the Megawati Soekarno Putri Botanical Garden as a conservation area. The development of an agro-educational tourism area with a collection of plants used for research, science, and nature education, including soil and water resources, supports cultivation, culture, tourism, and recreation.

Method

Research Location and Time

The research was conducted at the Megawati Soekarno Putri Botanical Garden, Ratatotok Selatan village, Ratatotok Satu village, Ratatotok sub-district, Southeast Minahasa Regency. Geographically, this botanical garden is located at 124°39'30" S - 124°40'28" S and 0°52'35" E - 0°53'55" E. It is about 115 km from Manado and 35 km from Ratahan, the capital of Southeast Minahasa Regency. The distance from the capital of Ratatotok sub-district is about 6.5 km. In comparison, the distance from the nearest settlement to the location of the Megawati Soekarno Putri Botanical Garden is approximately 3.4 km.

The Megawati Soekarno Putri Botanical Garden is divided by an asphalt-paved village road approximately 5–6 km long. This road is the access and circulation route for vehicles entering and exiting the botanical garden area. It is a busy route for community activities leading to mining, agriculture, and smallholder plantations. To reach the location of the Megawati Soekarno Putri Botanical Garden, you can use four-wheeled and two-wheeled land transportation.

Research Materials and Tools

The materials used in this research included plastic bags, sacks, raffia rope, writing instruments, and materials for physical soil analysis. The equipment used included *a Global Positioning System* (GPS) to determine the coordinates and altitude of the location, a clinometer to determine the slope angle, and a digital camera to document all research activities. Other equipment included measuring tape, boring equipment, machetes, and shovels.

Data Analysis

This research is descriptive research with a variable approach through field surveys. Field surveys were conducted to determine physical and environmental conditions, such as soil and water conservation measures, vegetation, adequate depth, slope inclination, surface rocks, rock outcrops, surface drainage, erosion, and flood/flooding hazards. The observation sites and physical and environmental conditions were determined using stratified random sampling, and sampling points were determined using transects/paths. Vegetation observations were carried out descriptively by recording the dominant species at the research site. The data obtained were analysed descriptively using a qualitative approach.

Result and Discussion

General Description of the Research Location

Ratatotok District has an air temperature of 22.7 °C. Water availability includes rainfall of 2,373 mm/year, a dry season lasting 3 months, and air humidity of 88%. Geographically, the Megawati Soekarno Putri botanical garden is located between 0°48' 00" - 01° 03' 00" north latitude and 124° 38' 00" - 124° 55' 00" east longitude, at an altitude of between 75 and 430 meters above sea level, with a soil depth of around 50 - > 100 cm, generally good surface drainage, no standing water/flooding except on slopes with a gradient of 0-3%, and the main erosion hazard is surface/channel erosion, with a topography ranging from flat to steep. The location map can be seen in Figure 1.

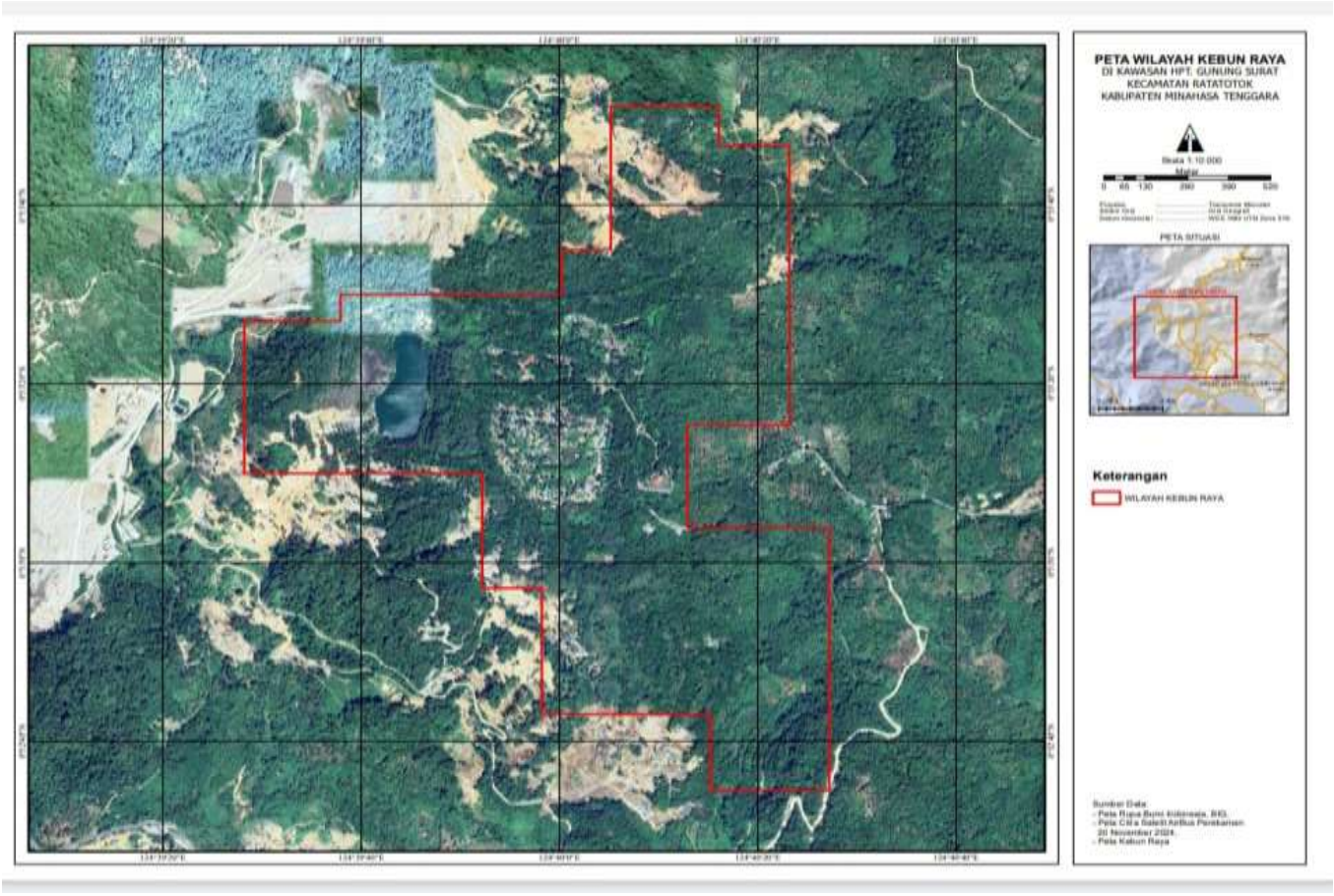

Figure 1. Map of the Megawati Soekarno Putri Ratatotok Botanical Garden Area

Vegetation in the MSP Botanical Garden Area

According to Purnomo et al. (2012) and Purnomo et al. (2018), the dominant tree species in the revegetation area include gamal (*Gliricidia sepium*) and lamtoro (*Leucaena leucocephala*). Gamal (*Gliricidia sepium*) is a type of rehabilitation plant because of its multifunctional properties, including shade, erosion control, livestock feed, and firewood. In addition, this plant can bind nitrogen from the atmosphere, release high-quality organic matter, facilitate nutrient circulation, and store water reserves (Stagnari et al., 2017; Purnomo et al., 2018). Lamtoro (*Leucaena leucocephala)* can cause several problems, including becoming *invasive,* outcompeting native species, or carrying diseases that can attack native plant species (Primack, 2006; Utomo et al., 2007; Sunaryo et al., 2012; Hidayat, 2014).

Table 1. Vegetation Types, Land Use, and Soil Conservation Measures at Megawati Soekarno Putri Ratatotok Botanical Garden, Southeast Minahasa Regency

Vegetation Type	Land Use	Soil and Water Conservation Measures
Mahogany	Reclaimed Land	Bench/stair terraces
Shrubs, Mango, Mahogany, Limestone wood, Rambutan, Clove	Non-Reclaimed Land	Vegetative
Teak, Sengon, Mahogany, Mango.	Reclaimed Land	Bench/stair terrace

Vegetation Type	Land Use	Soil and Water Conservation Measures
Mahogany, Teak, Sengon, and Glyricidia.	Reclaimed Land	Bench/stair terrace
Mahogany, Teak, Glyricidia.	Reclaimed Land	Bench/stair terrace
Mahogany, Teak, Glyricidia.	Reclaimed Land	Bench/stair terrace
Glyricidia, Shrubs Scrub, Coconut, Limestone wood, Mahogany, Banana, Sweet potato, Cinnamon	Non-reclaimed land	Vegetative
Coconut, Clove, Banana, Sugar Palm, Bamboo, Pineapple, Cassava, Taro/Bete, Chilli, Glyricidia and grasses.	Mixed Gardens	Terrace farming
Mahogany, Nantu, Mango, Bamboo, Areca Nut.	Reclaimed Land	Bench/stair terrace
Cananga odorata, Melanolepis sp, Palaqium sp, Koordersiodendron pinnatum, Ficus sp., Cratoxylum sp, Trema orientalis, Dracontomelon dao, Mallotus sp, Myrtaceae sp, Evodia sp, Myristica sp, Pometia sp, Anthocephalus cadamba, Gnetum sp., Lithocarpus sp., Acalypha sp.	Secondary Forest	Vegetative

On the other hand, the presence of shrubs will protect and increase the growth of seedlings, which is a process of regeneration (Bawa et al., 2021; Prameswari & Sudarmono, 2011). This can be seen in the Mahogany (*Swietenia mahagoni)* stands planted in 1997 and the Teak (*Tectona grandis)* stands planted in 2000, which have been able to regenerate, as indicated by the presence of naturally growing saplings at the bottom of these stands. The same can be seen in the kapur wood (*Melanolepsis sp.*).

Several local trees grew naturally in the Megawati Soekarno Putri botanical garden and were identified in the secondary forest. These local tree species include kapur wood (*Melanolepsis sp),* parao wood (*Spathodea campanulata), Knema sp, Ficus sp, Casuarina sp,* melinjo (*Gnemo gnetum), cemara, Canarium sp,* and *Trema orientalis.*

Land Suitability

Based on field observations and supported by laboratory analysis data, the results of matching land characteristics and plant growth requirements, the land suitability assessment shows variations in land suitability for Mahogany, Teak, Sengon, Mango, Clove, and Coconut trees. The assessment results show that Mahogany, Teak, Sengon, Mango, Clove, and Coconut plants consist of subclass S1 (highly suitable), subclass S2 (somewhat appropriate), and subclass S3 (marginally suitable). The actual and potential land suitability assessment results are presented in Tables 2 and 3.

Table 2. Assessment of Actual Land Suitability for Mahogany, Teak, Mango, Clove, and Coconut in KR-MSP Ratatotok, Southeast Minahasa Regency

Mahogany			Teak			Sengon		
Subclass	Class	Limiting Factor	Subclass	Class	Limiting Factors	Subclass	Class	Limiting Factors
Bachelor	Highly Suitable	None	S1	Very Suitable	None	Bachelor's	Highly Suitable	None
S2eh	Somewhat Suitable	Danger Erosion	S2eh	Somewhat Suitable	Danger Erosion	S2eh	Somewhat Suitable	Erosion hazard
S2rc	Somewhat Suitable	Media Rooting	S2rc	Somewhat Suitable	Media Rooting	S2rc	Somewhat Suitable	Media Rooting
S2eh/rc	Somewhat Suitable	Hazard Erosion and Media Rooting	S2eh/rc	Somewhat Suitable	Hazard Erosion and Media Rooting	S2eh/rc	Somewhat Suitable	The Dangers of rosion and Media Rooting
S32h/rc	Marginal	Hazards Erosion and Media Rooting	S32h/rc	Marginal	Hazard Erosion and Media Rooting	S32h/rc	Marginal	Erosion Hazards and Media Rooting
Mango			Clove			Coconut		
Subclass	Class	Limiting Factor	Subclass	Class	Limiting Factors	Subclass	Class	Limiting Factors

Bachelor	Highly Suitable	None	S1	Very Suitable	None	Bachelor's	Highly Suitable	None
S2eh	Somewhat Suitable	Erosion hazard	S2eh	Somewhat Suitable	Erosion Hazard	S2eh	Somewhat Suitable	Erosion Hazard
S2rc	Somewhat Suitable	Media Rooting	S2rc	Somewhat Suitable	Media Rooting	S2rc	Somewhat Suitable	Media Rooting
S2eh/rc	Somewhat Suitable	Hazard Erosion and Media Rooting	S2eh/rc	Somewhat Suitable	Hazard Erosion and Media Rooting	S2eh/rc	Somewhat Suitable	Erosion Hazards and Media Rooting
S32h/rc	Marginal Suitable	Hazard Erosion and Media Rooting	S3h/rc	Marginal	Hazard Erosion and Media Rooting	S32h/rc	Marginal	Erosion Hazards and Media Rooting

Note: rc = rooting medium limiting factor, eh = erosion hazard limiting factor.

Table 3. Suitability of Potential Land for Mahogany, Teak, Sengon, Mango, Clove, and Coconut Trees in KR-MSP Ratatotok, Southeast Minahasa Regency

Mahogany					Teak			Sengon
Subclass	Class	Limiting Factor	Subclass	Class	Limiting Factors	Subclass	Class	Limiting Factors
Bachelor	Highly Suitable	None	Bachelor's Degree	Highly Suitable	Not	S1	Very Suitable	None
S2rc	Somewhat Suitable	Medium Rooting	S2rc	Somewhat Suitable	Media Rooting	S2rc	Somewhat Suitable	Media Rooting
S2eh/rc	Somewhat Suitable	Hazard Erosion and Media Rooting	S2eh/rc	Somewhat Suitable	Hazard Erosion and Media Rooting	S2eh/rc	Somewhat Suitable	Erosion Hazards and Media Rooting
Mango					Clove			Coconut
Subclass	Class	Limiting Factor	Subclass	Class	Limiting Factors	Subclass	Class	Limiting Factors
Bachelor	Highly Suitable	None	S1	Very Suitable	None	Bachelor's	Highly Suitable	None
S2rc	Somewhat Suitable	Medium Rooting	S2rc	Somewhat Suitable	Media Rooting	S2rc	Somewhat Suitable	Rooting medium
S32h/rc	Marginally Suitable	Hazard Erosion and Media Rooting	S2eh/rc	Somewhat Suitable	Hazard Erosion and Media Rooting	S32h/rc	Marginal	Erosion Hazards and Media Rooting

Note: rc = rooting medium limiting factor, eh = erosion hazard limiting factor.

Limiting Factors for Land Suitability in the MSP Botanical Garden Area

The evaluation results show several limiting factors for Mahogany, Teak, Sengon, Mango, Clove, and Coconut trees in the Megawati Soekarno Putri Botanical Garden area, including erosion hazard and rooting media. The main limiting factor for erosion hazard is slope gradient. The topography can be seen in Figure 2.

The post-mining reclamation area is dominated by slopes with a gradient of 25-40% (steep) covering an area of 146.23 ha, followed by slopes with a gradient of 15-25% (slightly steep) covering an area of 115.16 ha, slopes with a gradient of > 40% (steep) covering an area of 97.21 ha, slopes of 8–15% (gentle) covering an area of 58.08 ha, a slope gradient of 0–3% (flat to slightly flat) covering an area of 17.54 ha, and a slope gradient of 3–8% (slightly sloping) covering an area of 3.43 ha (Soputan et al., 2018; Soputan et al., 2024). On slopes that are somewhat sloping to steep, there is the potential for surface runoff and reduced water infiltration into the soil, erosion, and loss of nutrients during the rainy season.

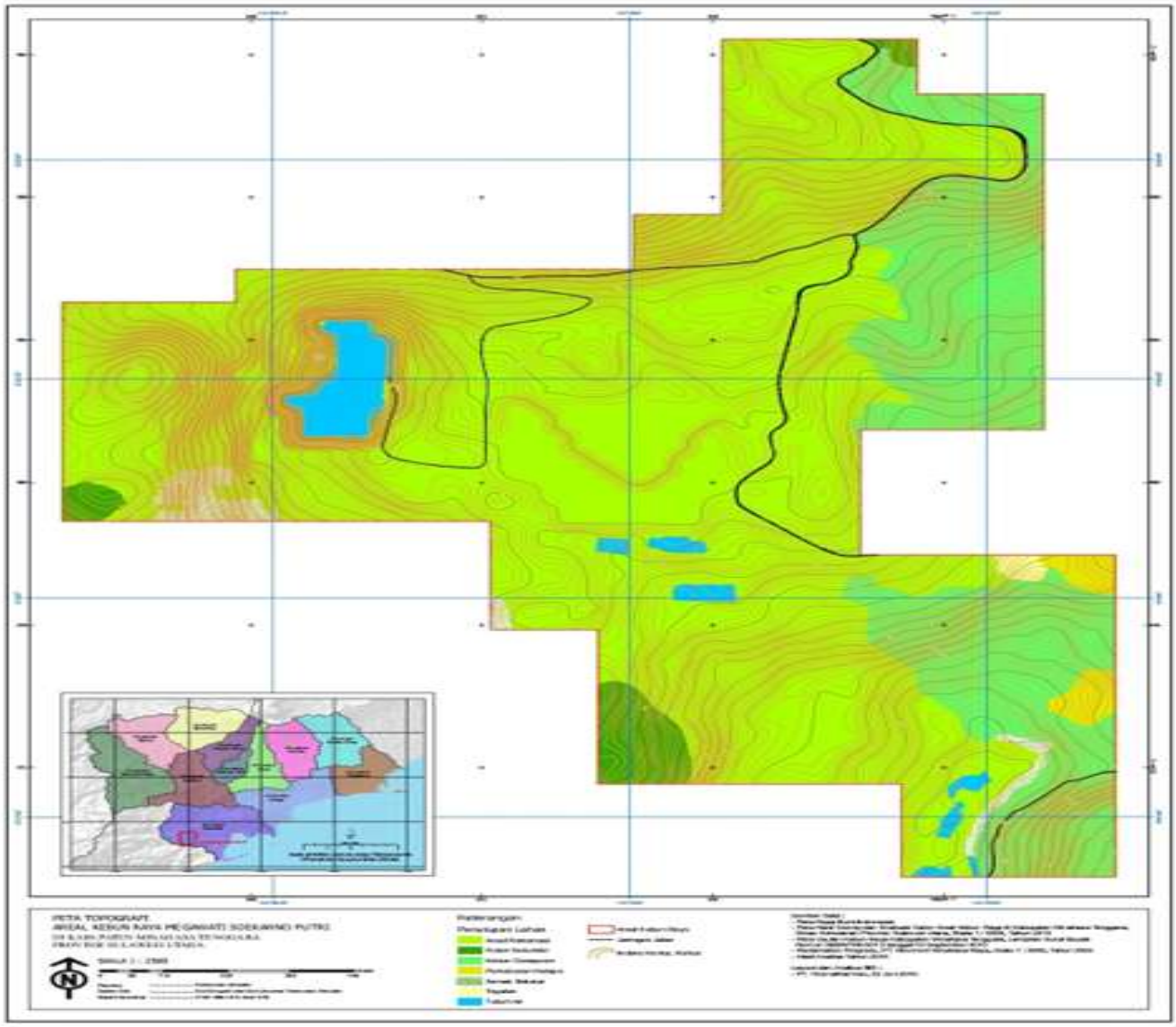

Figure 2. Topographic map of the Megawati Soekarno Putri Botanical Garden in Ratatotok

The limiting factors for root media are soil depth and soil texture. In post-mining reclamation areas, soil depth is < 50 cm, except in mixed gardens and secondary forests, where soil depth is > 100 cm. Soil solum indicates the depth to which plant roots can reach and utilise available water and nutrients (Pan & Pan, 2012; Akinci et al., 2013; Hartati et al., 2018). The soil solum also indicates the degree of weathering of a soil's parent material. Soils with a deep solum indicate an advanced degree of weathering of the parent material. Land characteristics determine the potential of the land for plant growth (Pioh, 2014).

An interesting fact is that clear deposits of weathered rock are found at a depth of 50-60 cm. In addition, exposed rocks are present on the surface, except in mixed gardens and secondary forests. These rocks are remnants of mining excavations and are used as reinforcement for terrace walls/steps. Revegetation plants are visible in specific locations as they grow and develop among the rocks.

In relation to post-mining land reclamation/revegetation, soil texture affects the growing medium for plants and their availability of nutrients and water. Fine-textured soil can retain water and provide nutrients. Coarse-textured soil is easy to cultivate but less able to provide water for plants, while the opposite is true for clay-textured soil (Hermawan, 2011; Rahim et al., 2016).

The soil in the Megawati Soekarno Putri botanical garden area is dominated by dust fractions, followed by sand and clay fractions (Soputan et al., 2018). Dust and sand fractions are higher in the topsoil than in the layer directly below it. The clay fraction is different. The distribution of the clay fraction tends to increase with the depth of the soil solum. The same thing also occurs in secondary forest and mixed gardens, where the

distribution of clay increases in line with soil depth. This indicates clay leaching from the upper to the lower layer, so the soil texture tends to be dominated by loam and dusty loam.

Soil and water conservation measures, such as the construction of terraces on moderately sloping to steep slopes, are wise actions. Pioh (2014) explains that the suitability of actual land can be improved towards the suitability of potential land through a mitigation approach in land rehabilitation. PT has done this. Newmont Minahasa Raya at the beginning of post-mining reclamation work. The creation of terraces followed by revegetation can serve a dual purpose: on the one hand, it prevents erosion during the rainy season, and on the other hand, plant debris such as leaves and twigs that fall on the soil surface is a source of organic matter. Organic components such as humic acid and fulvic acid act as a cementation of clay particles by forming clay-metal-humus complexes. In addition, organic matter affects soil nutrient supply (N, P, K) and reduces the concentration of heavy metals that can poison plants. These conditions reflect the natural conditions highly conducive to the formation of trees in the Megawati Soekarno Putri Ratatotok Botanical Garden in Southeast Minahasa Regency.

The results of this study are a valuable reference for crop cultivation that can be developed in botanical gardens to promote environmental sustainability and preservation. Another factor is that it serves as the basis for research into the land's potential for maintaining the biological cycle of the environment. In addition, it leads to an agro-educational tourism area for education and tourism.

Conclusion

In the Megawati Soekarno Putri botanical garden area, several types of local trees were found growing naturally, which are also found in secondary forests, including: Kapur wood (*Melanolepsis sp.*), *Ficus sp., Trema orientalis*, Melinjo (*Gnemo gnetum*), Nyatoh/Nantu (*Palaqium sp.*), *Cananga odorata, Koordersiodendron pinnatum, and Cratoxylum sp.* The suitability of the land for mahogany, teak, sengon, mango, clove, and coconut trees is classified as subclass S1 (very suitable), subclass S2eh (somewhat appropriate), subclass S2rc (somewhat appropriate), and subclass S2eh/rc (moderately suitable), and subclass S3eh/rc (marginally suitable) with limiting factors of erosion hazard and root medium.

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Author Contributions
D.D.P.: Developing ideas, analyzing, writing, overseeing data collection reviewing, responding to reviewers' comments; H.F.P.: overseeing data collection, analyzing data reviewing scripts, and writing; M.K.: analyzing data, reviewing scripts, and writing.

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Conflicts of Interest
The authors declare no conflict of interest.

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