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TREE PRODUCTIVITY AS AN INDICATOR OF FOREST HEALTH AROUND THE TOURIST LOCATION OF THE WAY BELERANG SIMPUR BATHING, KALIANDA, SOUTH LAMPUNG

Produktivitas Pohon Sebagai Indikator Kesehatan Hutan di Sekitar Lokasi Wisata Pemandian Way Belerang Simpur, Kalianda, Lampung Selatan

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ABSTRACT

The Way Belerang Simpur Bath in Kalianda, South Lampung, is a protected forest and village forest rich in tropical vegetation, including timber and non-timber trees. However, with the development of tourism, it puts pressure on the tree vegetation around the location on tree growth. This study aims to determine the value of tree productivity parameters (indicators) and obtain the final value around the tourist location of the simpur eagle bath, Kalianda, South Lampung as one of the indicators of forest health assessment. The method used is the creation of FHM plot clusters which results in the determination of 4 plot around the Way Belerang Simpur Bath Tourist Location. Analysis of tree productivity parameter data (indicators) using the LBD formula (Base Field Area) = 1/4 πd². The forest health assessment is obtained from the final value of forest health conditions formulated by NKH (Forest Health Value) = NT (Weighted Value) x NS (Score Value). The results showed that the values of tree productivity parameters (indicators) for each plot cluster were 85.109 m² (cluster 1), 81.455 m² (cluster 2), 128.569 m² (cluster 3), and 12.879 m² (cluster 4) each. The final value of tree productivity is 1.00 – 1.85 in the medium category. The final tree productivity score for forest health reflects that forest areas have not been managed optimally, so tree planting is needed to maintain tree growth. Thus, the value of tree productivity parameters (indicators) is 77.003. The final value of the average tree productivity is 1.60 with medium category status. The final value of tree productivity is 1.00 – 1.85 in the medium category. The final tree productivity score for forest health reflects that forest areas have not been managed optimally, so tree planting is needed to maintain tree growth. Thus, the value of tree productivity parameters (indicators) is 77.003. The final value of the average tree productivity is 1.60 with medium category status.

Keywords: Basic Field Area; Forest Health Monitoring; Protected Forests; Tree Productivity; Way Berelang Simpur

ABSTRACT

Pemandian Way Belerang Simpur di Kalianda, Lampung Selatan, adalah hutan lindung dan hutan desa yang kaya akan vegetasi tropis, termasuk pohon kayu dan bukan kayu. Namun, dengan perkembangan wisata menimbulkan tekanan terhadap vegetasi pohon yang ada di sekitar lokasi terhadap pertumbuhan pohon. Penelitian ini bertujuan untuk mengetahui nilai parameter (indikator) produktivitas pohon dan mendapatkan nilai akhir di sekitar lokasi wisata pemandian berelang simpur, Kalianda, Lampung Selatan sebagai salah satu indikator penilaian kesehatan hutan. Metode yang digunakan adalah pengambilan sampel klaster plot FHM (*Forest Health Monitoring*) yang menghasilkan penentuan 4 klaster plot di Sekitar Lokasi Wisata Pemandian Way Belerang Simpur. Analisis data parameter (indikator) produktivitas pohon menggunakan rumus LBD (Luas Bidang Dasar) = 1/4 πd². Penilaian kesehatan hutan diperoleh dari nilai akhir kondisi kesehatan hutan yang dirumuskan oleh NKH (Nilai Kesehatan Hutan) = NT (Nilai Tertimbang) x NS (Nilai Skor). Hasil penelitian menunjukkan bahwa nilai parameter (indikator) produktivitas pohon untuk setiap klaster plot adalah 85.109 m² (klaster 1), 81.455 m² (klaster 2), 128.569 m² (klaster 3), dan 12.879 m² (klaster 4). Nilai akhir produktivitas pohon yaitu 1.00 – 1.85 kategori sedang. Skor produktivitas pohon akhir untuk kesehatan hutan mencerminkan bahwa kawasan hutan belum dikelola secara optimal sehingga memerlukan adanya penanaman pohon agar pertumbuhan pohon tetap terjaga. Dengan demikian, nilai parameter (indikator) produktivitas pohon 77.003. Adapun nilai akhir dari rata- rata produktivitas pohon yaitu 1.60 dengan status kategori sedang.

Kata Kunci: *Forest Health Monitoring;* Hutan Lindung; Luas Bidang Dasar; Produktivitas Pohon; Way Belerang Simpur

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A. INTRODUCTION

Forests are important ecosystems that provide many ecological, economic, and social benefits for human life. Forest health is a major factor in determining how well it is managed over time. Indicators such as tree productivity play a key role as a reflection of the forest's ability to carry out its production functions. Tree productivity is measured through the growth of trunk diameter and trunk base area, and shows how well forest stands respond to environmental conditions and disturbances (Safe'i *et al.* 2022). High productivity values indicate ecological stability and sustainability of the function of protected forests or people's forests.

The Way Belerang Simpur Bath area in Kalianda, South Lampung, is a protected forest and village forest rich in tropical vegetation, including timber and non-timber trees. This area has high potential as a habitat for biodiversity and a buffer for coastal ecosystems (Indrasari *et al.* 2017). Local activities such as social forestry affect forest dynamics. These local conditions make monitoring forest health critical to prevent degradation due to illegal logging or climate change. In the Simpur Sulfur Way, productivity is good for efficient management, which results in stable growth and high ecological contributions such as soil nitrogen fixation (Puspita *et al.* 2021). This forest, which is part of the Register 3 Protected Forest Area of Mount Rajabasa, has two important functions as a source of sulfur hot springs and also as a habitat for local biodiversity.

The hot spring is the result of geothermal activity that occurs on the slopes of Mount Rajabasa. However, with the development of the tourism industry, the pressure on forest ecosystems also increases, which requires a smart management approach to maintain ecological and economic functions. The health of the forests in this region is often indicated by factors such as tree canopy, tree productivity, and tree damage rate. This directly affects the ability of trees to photosynthesize and produce biomass. In South Lampung, hundreds of hectares of protected forests have been restored to address degradation. This includes planting productive tree species such as teak, sengon, and durian around similar areas. This effort aims to increase tree productivity through management that involves the local community. Overall, the health of the Simpur Way Belerang forest is the main foundation for long-term tree productivity. Productivity as an indicator in protected forests was chosen because it is able to represent the physiological and ecological conditions of the stand as a whole, including tree growth, biomass accumulation, and resource utilization efficiency. This indicator is also sensitive to environmental changes so it is effective for early detection of disturbances or degradation. In addition, productivity is closely related to ecological functions such as carbon sequestration, water system regulation, and soil stability, so it is important in assessing the sustainability of forest functions both ecologically and for communities.

Productivity is the growth rate of a tree or stand in a certain period of time or currently. Tree growth is calculated as the area of the base area (LBD) (Safe'i & Rahman 2022). LBD describe the instantaneous growth rate or productivity of a tree over time. The data source for calculating LBD is by measuring the diameter of trees (Kuswandi 2017). Tree productivity refers to the growth rate of tree biomass over time and area. This shows the vitality of the tree stand and the quality of the location where it grows. The health of the forest area will have a good impact on the fulfillment of the main function. Forest health monitoring is a system to monitor the condition of forest ecosystems using *the* Forest Health Monitoring (FHM) method (Safe'i *et al.* 2019). In addition, forest health can be used as a way to manage the main functions of forests (Safe'i *et al.* 2020) and also to create sustainable forest management (Pratiwi *et al.* 2018). Therefore, this study aims to determine the value of tree productivity and obtain the final value of tree productivity around The Way Belerang Simpur Bath Tourist Location, Kalianda, South Lampung as one of the indicators of forest health assessment.

B. METHODS

This research was carried out in June 2025 located around the Way Belerang Simpur Bathing Tourist Location, Kalianda, South Lampung. The map of the research location can be seen in Figure 1.

Tools and Materials

The tools used in this study are tally sheets, pita diameter, 50m meters, cameras, calculators, rulers, GPS (global positioning system), ATK (office stationery), plastics, rubber strap, PVC pipe. Establishing cluster plots as sites for data collection in this monitoring.

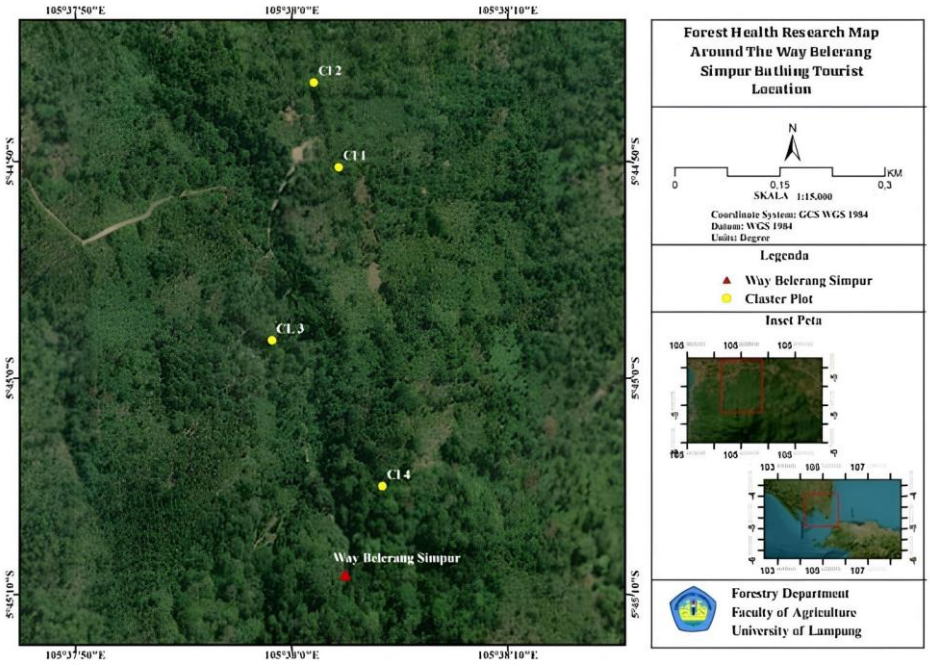

Figure 1. Map of the research location

Data Collection Techniques

The object of this research is the creation of 4 plot clusters of forest health FHM plots at the location of this study by determining justification. The justification is determined based on protected forest areas and community forests, the determination of the LPHD (Village Forest Management Board) manages the protected forest and locations in tourism while the community manages the community forest and locations around tourism. Then an assessment will be carried out of the final value of forest health obtained from the final value of forest health conditions around the Way Belerang Simpur Bathing Location, Kalianda, South Lampung. The following is the assignment and creation of the plot cluster can be seen in Figure 2.

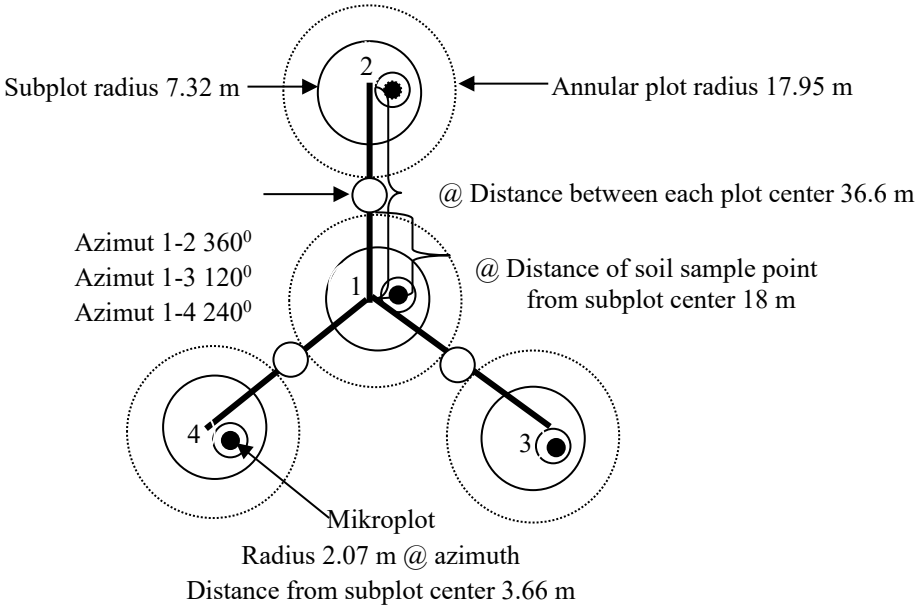

Figure 2. Forest health monitoring plot cluster design

Data Analysis

Data is collected in the field by measuring productivity indicators. The parameter used in this study is tree growth measured through diameter. The diameter of the rod was measured at a height of 1.3 meters above the ground (Safe'i *et al.* 2015). Measurements are carried out at the pole, and tree stages. Tree growth refers to the increase in the number and

size of trees, including diameter and height, contained in a stand (Safe'i & Tsani 2016). Therefore, the growth of tree diameter can be used as the basis for calculating the growth of the base area (LBD) of trees. The following is the formula for LBD:

$$LBD = 1/4\ \pi d^2$$

where, LBD is an individual tree base area (m^2), d is a trunk diameter (1.3 meters from the base of the tree), and π is a constancy (3.14).

Weighted value determination using the value obtained using the Analytic Networking Process (ANP). The steps to obtain a weighted value with the ANP technique are as follows: (1) perform a paired comparison on each indicator. At this stage, the weighted value of the indicator on the achievement of the goal is obtained, (3) comparing the indicators that have mutual dependencies and (4) multiplying the weighted value of the indicator obtained in stage one and the weighted value of the indicator obtained in stage three. The results obtained are the final weighted values for each indicator. The determination of the indicator score value is obtained through the transformation of the value of each parameter of the ecological indicator of forest health.

The score is given in the range of 1–10 (the higher the score, the higher the parameter value of the ecological indicator so that it can indicate the higher the level of health). Forest health assessments are obtained from the final value of forest health conditions based on parameter measurements of each ecological indicator; With categories consisting of three classes, namely good, medium, and bad. The classification is calculated based on the forest health threshold value of the constructed plot cluster. The forest health threshold value is obtained based on the highest value and the lowest value of the final value of forest health at the measurement location because each forest ecosystem has specific (distinctive) characteristics. To get the final value of forest health consisting of the diameter and height of the tree, you can use the following formula:

$$NKH = \sum(NT \times NS)$$

where, NKH is a final value of forest health conditions, NT is the weighted value of the parameter of the productivity indikator, and NS is parameter score value of productivity indikator.

C. RESULTS AND DISCUSSION

Based on the results of field observations of the condition of the forest ecosystem in the area around the Way Belerang Simpur Bathing Tourist Location, Kalianda, South Lampung, it is known that efforts to manage and utilize the area have not been fully balanced. Tourism activities that continue to grow put pressure on forest vegetation, both through increasing the intensity of visits and less controlled use of space.The various types of plants around the tourist site include Durian (*Durio zibethinus*), Avocado (*Persea americana*), Damar (*Agathis dammara*), Mango (*Mangifera indica*), Longan (*Dimocarpus*), Kersen (*Muntingia calabura*). The planting of these trees aims to be a source of balance of the forest ecosystem around the Way Belerang Simpur Bathing Tourist Location.

The benefits of forests that can be directly felt by the community are increased land productivity, sources of income, and industrial raw materials (Safe'i *et al.* 2021). Forest health managed by communities and village forest management institutions is a key factor in achieving sustainable forest management. LBD are used to assess the productivity potential of a cluster of plots in a particular area. The greater the value of LBD, the higher the potential for forest growth and productivity in that region (Safe'i *et al.* 2024). The results of LBD in each plot cluster at the research around the Way Belerang Simpur Bathing Tourist Location, Kalianda are presented in Table 1.

Table 1. The value of LBD (Base Field Area) in each plot cluster

Cluster Plot	Average LBD (m^2)
Cluster 1	85.10
Cluster 2	81.45
Cluster 3	128.56
Cluster 4	12.87

The score value of tree growth parameters is based on the average LBD value of trees per hectare in each plot cluster Table 2.

Table 2. Score value of each plot cluster

Number	Range LBD
1	12.87 – 24.44
2	24.44 – 36.01
3	36.01 – 47.58
4	47.58 – 59.15
5	59.15 – 70.72
6	70.72 – 82.29
7	82.29 – 93.86
8	93.86 – 105.43
9	105.43 – 116.99
10	117.00 – 128.56

The scoring is given in the range of 1-10, starts from the smallest to the largest. The higher the score, the better the health condition of the community's forests. The assessment of tree growth conditions is based on the average value of LBD (Safe'i *et al.* 2024). A scale of 1-10 indicates the different levels for each value based on previously obtained cluster measurements of the plot. Threshold values for forest health status based on the parameter score values of LBD can be presented in Table 3.

Table 3. Threshold values

Criteria for Tree Productivity Conditions	Threshold Values	
Bad	0.32	0.95
Medium	0.96	1.50
Good	1.60	2.24

The value of the final condition of tree productivity in forest health in each cluster of plots can be seen in Table 4.

Table 4. Tree productivity final value

Cluster Plot	NKH	Category
Cluster 1	2.24	Good
Cluster 2	1.32	Medium
Cluster 3	2.70	Good
Cluster 4	0.33	Bad
Average	**1.60**	**Medium**

The results of research on four clusters of plots at the Simpur Way Belerang, Kalianda, South Lampung Tourism Site show that forest management by managers and the surrounding community needs to be optimally directed to achieve sustainable goals, especially in increasing the use of non-timber forest products (NTFPs) such as leaves, fruits, and rattan. This is to be able to meet the needs of life with the principle of forest conservation. Therefore, the condition of the tree stand must be well maintained. One way is to know the condition of the tree's productivity level. The level of productivity is something that must be considered because the high and low productivity in the forest is a mirror of the success of forest management. The value of LBD due to changes in tree diameter can reduce or increase overall forest productivity. The measurement of tree volume is based on the measurement of the growth parameters of the tree or stand. In this study, the volume of trees was measured using the volume of tree stands. Monitoring forest health through productivity assessments can help understand tree development and growth. In the data obtained in the field, based on Table 1, the LBD value of each plot cluster obtained a value that shows the difference in each of the plot clusters. This generally shows how well trees can grow in the tropical forests of South Lampung.

The high value of LBD as in Cluster 3, indicates dense and strong trees as evidenced by the average results of the final value of forest health in the table. Cluster 4 showed lower growth. The low productivity value is caused by the low number of productive trees and unfavorable growth conditions. This condition shows that the stand structure is relatively unbalanced with the number of trees that are able to support the ecosystem function. Cluster 1 has a base area that is

rated good for tree productivity. Finally, cluster 2 also has a wide area and is included in the good category. The difference between the LBD Cluster 1 and Cluster 2 values is caused by several other environmental conditions such as soil quality, water availability, light intensity, microclimate, pest and disease disturbances, human activities that affect the growth rate of trees. This low biomass productivity has the potential for smaller carbon dioxide uptake and reduces the contribution of trees to the ecosystem balance in this area (Hardjana & Suastati 2014). This shows that the older the tree, the higher the tree growth. The magnitude of the growth rate will correlate with forest health. The difference in the value of LBD is due to the tree's growth rate, which is high and the diameter of the tree is higher, thus triggering higher growth and vice versa (Ansori *et al.* 2020). Productivity indicators will be the basis for assessing forest health in addition to indicators of biodiversity, vitality and site quality.

On the other hand, the high LBD value in Cluster 3 indicates better health of forest ecosystems than Cluster 1, Cluster 2 and Cluster 3. The presence of this dense vegetation is essential for maintaining environmental balance, preventing soil erosion, and supporting the hydrological cycle in forest ecosystems (Pinatih *et al.* 2015). With a larger diameter, the trees in Cluster 3 have a better photosynthesis capacity, which has a positive impact on their ability to absorb CO2 and support the overall stability of the ecosystem. This good growth is also influenced by more supportive environmental factors, such as more fertile soil and more adequate water availability in the location. Therefore, the value of LBD can be a significant indicator for assessing tree productivity (Safe'i & Upe 2022). Meanwhile, cluster 4 with a value of 0.15 (poor) was caused by a low soil pH factor with the resulting soil pH value at the growth of the tree, which is 6.57; 6.67; 7.33; 6.83 due to the accumulation of sulphur from heat sources on the slopes of Simpur, which inhibited nutrient absorption and suppressed LBD to 0.15, similar to the discovery of tree damage caused by biotic and abiotic factors. Very low values in a cluster are also caused by undeveloped trees or severe damage to stands resulting in very low production. Therefore, forest ecosystems must be properly maintained according to management rules (Haikal 2020).

To find out the value of forest health status, this is obtained from the scoring results obtained. Category values are obtained from the difference in maximum and minimum values which are divided into three classes to determine the health conditions of the forest. The four plot clusters represent different conditions based on the size and age of the trees. Cluster 1 (2.24) and Cluster 3 (2.70) are in the good category, characterized by fertile soils, high species growth, and density and canopy cover that support productivity, with the additional influence of microenvironmental. At the plot level, the combination of species character and microenvironmental conditions (humidity, lighting) often has an effect on high productivity. Furthermore, the final value of tree productivity was obtained a value of 1.60 (medium) which reflects the spatial imbalance in the Way Belerang Simpur Bathing area which is influenced by hilly soil pH and microclimatic variations. Some of the causes are suboptimal management of forest areas, such as pest/disease attacks that cause damage to trees and selective logging that disrupts the structure of the stand. Steps to address this problem starting with regular maintenance processes, such as pruning leaves and organic pest control, will support plant health.

To increase average productivity, intensive silviculture is needed, including replanting superior seedlings in poorer clusters to reduce tree damage (Permadi *et al.* 2017). To be more effective, it is also necessary to integrate agroforestry with protective crops. Regular monitoring using indicators of productivity, vitality, and site quality will help detect declines early. Agroforestry needs to be implemented because it is able to combine forestry crops with agricultural crops in one land, thereby increasing productivity without damaging the function of the forest. This system helps maintain soil fertility, reduce erosion, and increase biodiversity through the presence of protective plants. Overall, the medium category at the final value of tree productivity shows good potential but is prone to degradation if not handled properly. Integrated efforts, such as sustainable forest management, are needed to maintain the health of forest ecosystems from pest/disease attacks and human activities.

D. CONCLUSION

The conclusions of the study showed that the productivity of trees at the research site varied between clusters. Cluster 3 has the highest productivity (128,56 m²), while cluster 4 has the lowest (12.87 m²). Clusters 1 and 2 are at a moderate level with relatively similar values. This difference shows that there is a variation in growth conditions in each cluster. Then the final result of tree productivity on forest health received a value of 1.60 (medium) which reflects that the management of forest areas is not optimal, because selective logging interferes with the structure of the stand. Overall, the medium category at the final value of tree productivity shows good potential but is susceptible to damage if not handled properly.

Integrated efforts, such as sustainable forest management, are needed to maintain the health of forest ecosystems from pest/disease attacks and human activities. Therefore, forest managers and the community around the Simpur Way Belerang Mandi Tourism Location, Kalianda, South Lampung need to make efforts to replant tree species, namely durian and teak to increase tree productivity.

AUTHOR'S DECLARATION

- Conflicts of Interest: None.
- We here by confirm that all the Figures and Tables in the manuscript are ours.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- No potentially identified images or data are present in the manuscript.

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