Assessment of forest health status of Panca Indah Lestari Community Plantation Forest (case study in Bukit Layang Village, Bakam District, Bangka Regency, Bangka Belitung Province)

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Abstract. Currently, community plantation forests play an essential role in providing wood supply for the timber industry with due regard to sustainability. One way to achieve the sustainability aspects of forest management is by conducting monitoring forest health. This study aims to determine the value of the health status of the Panca Indah Lestari Community Plantation Forest. This community plantation forest is located in Bukit Layang Village, Bakam District, Bangka Regency, Bangka Belitung Province. The stages of this research include: determining the number of cluster-plots using sampling intensity based on the area of community plantation forest, making cluster plots based on Forest Health Monitoring (FHM) cluster-plot design, collecting data by measuring the ecological indicators of forest health (productivity and vitality) based on the FHM method, as well as data analysis and processing using the Forest Health Assessment Information System. The results showed that the health status of the Panca Indah Lestari Community Plantation Forest had a range of values ranging from 1,890 - 5,530. The average health status value of Panca Indah Lestari Community Plantation Forest is 4,210, which was included in the medium category. Thus, the value of the health status of community plantation forests illustrates that the conditions for productivity and vitality indicators are insufficient. Knowing the forest condition's status value helps managers provide recommendations in making decisions on sustainable community plantation forest management.

1. Introduction
The Panca Indah Lestari Community Plantation Forest (HTR) is one of the HTR, which is the main foundation for the surrounding community in meeting their daily needs, located in Bukit Layang Village, Bakam District, Bangka Regency. The HTR can produce products in the form of timber forest products and non-timber forest products from various types of plants. The dominant plant species in this HTR is Hevea brasiliensis, used for its wood and sap. The HTR was formed to increase farmers' income in Forest Farmer Group (KTH) Panca Indah Lestari, meet their daily needs through non-timber forest products, and conserve resources through legal access provided. Currently, HTR has an important role in filling the demand for wood supply in the timber industry as a substitute for natural forests that have suffered various damages. The goal of the HTR program is to increase...
land productivity, especially degraded forest areas, and provide opportunities for communities to work in the plantation forest sector [1]. In addition, HTR development can prevent soil erosion by filling empty and unproductive lands in productive forest areas. In the same area, the HTR has a much larger volume of wood than a natural forest when viewed in terms of timber forest products. The establishment of plantation forests is hoped to progressively transform essential land into productive regions, thereby improving the community's welfare [1].

The success rate of managing an HTR can be seen from the health condition of the forest. Productivity and vitality are indicators that can be used to decide the health condition of the woodland. Tree productivity levels can be measured using basal area parameters (LBDs). At the same time, vitality is one of the indicators measured by two parameters; they are the tree damage parameter and the tree crown condition parameter [32]. A healthy forest ecosystem is one in which the ecosystem is in good shape or has not been harmed so that the forest can carry out its functions properly [2]. Therefore, it is necessary to monitor forest health regularly or continuously using the Forest Health Monitoring (FHM) technique. FHM is a technique that can be used for intensive monitoring and assessment of ecosystem health conditions [3]. The use of the FHM method can help determine the health condition of a forest area. This method can provide management recommendations for forest managers so that the principles of forest sustainability are realized.

The quality of forest health is currently considered very important, especially in forestry, because the quality of forest health will affect the functioning of the forest [4]. Forest health refers to the endeavor to minimize forest damage to a minimum so that forest functions and benefits can be preserved [5]. Healthy forest conditions will help conserve the forest; nevertheless, if the forest is unhealthy, it will interfere with forest functions [6]. To address forest health issues that affect forest ecosystem sustainability, the FHM system should explain changes in forest conditions at certain times [7]. According to [8] this FHM approach aims to figure out the existing state of the forest, as well as any changes or future trends that may occur as a result of forest operations. Through the results of forest health conditions, especially in the Panca Indah Lestari HTR, it can be seen whether the management carried out meets the principles of sustainability or not. As a result, this study was carried out to estimate the value of the Panca Indah Lestari community plantations' health state using indicators of tree productivity and vitality.

2. Method

This research was conducted in 4 (four) cluster plots in Community Plantation Forest (HTR), Bukit Layang Village, Bakam District, Bangka Regency. This research was conducted in March 2021, located in the People's Plantation Forest, Bukit Layang Village, Bakam District, Bangka Regency. The location of the research is shown in figure 1.
Forest health measurements were carried out using the FHM method using two indicators, namely productivity and vitality. FHM is a forest monitoring technique to analyze forest stands’ current and future condition and provide recommendations for improving management [2]. This technique can provide management recommendations for forest managers so that the principles of forest sustainability can be realized. Forest health can be measured to guarantee that forest functions and benefits are maintained [2].

The determination of forest health measurement plots in HTR using techniques purposive sampling. According to [33], purposive sampling is a sampling technique using certain considerations. Considerations in determining the sample for measuring the health condition of HTR by taking into account the ownership of the land owned by the (KTH). Thus, the number of plot clusters made is four plot clusters.

Making cluster plots or measuring plots is carried out to take several objects representing the entire observed area. The cluster-plot design is based on technical references Forest Health Monitoring (FHM) [34], as presented in figure 2.
Figure 2. Forest Health Monitoring (FHM) plot cluster design.

Processing and analysis of data from the measurement of HTR health indicators at tree productivity levels can be explained by using tree growth rate parameters measured through LBDs measurement parameters. Productivity is done by measuring the tree growth volume of the tree at this time. Tree growth measurements were carried out on trees in the subplot. The calculation formula of the LBDs is as follows (equation 1).

\[ \text{LBDs} = \frac{1}{4} \pi \times d^2 \]  

Information:
- LBDs = individual tree basal area (m\(^2\))
- \(d\) = trunk diameter (1.3 meters from the base of the tree)
- \(\pi\) = constant (3.14)

Tree damage and crown conditions are used to determine vitality indicators. The trees of damage conditions were created using the cluster plot-level tree damage index value (Cluster plot Level Index-CLI) [35]. The crown condition is obtained from the merger of 5 (five) parameters of the crown condition [35], this comprises the LCR (Live Crown Ratio), Cden (the maximum number of rays that can reach the forest floor before being obstructed by the tree canopy) (Crown Density), FT (Foliage Transparency), CDW (Crown Diameter Width), CD90\(^0\) (Crown Diameter at 90\(^0\)), and CDB (dieback). The visual crown ratio (VCR) value will be determined after the five factors have been assessed. The data obtained were used to determine the health status of the forest as measured by FHM [9]. The following equation 2 is the formula for computing the ultimate value of forest health:

\[ \text{NKH} = \sum (\text{NT} \times \text{NS}) \]  

The sum of the weighted value (NT) and the score value (NS) is used to calculate the forest health assessment based on the final score (NKH).

3. Results and discussion

The Panca Indah Lestari Community Plantation Forest (HTR) was formed by farmers in Bukit Layang
Village to optimally increase the use of production forest land, increasing community economic income from timber or non-timber products. The destination of the HTR program is to increase land productivity, especially degraded forest areas, and provide opportunities for communities to do business in the plantation forest sector [10]. Several studies have shown how the role of community plantations in increasing farmers’ income [11, 12]. In addition, HTR can also increase the export of timber and non-timber forest products.

This HTR was built by applying a polyculture system, where the plants were dominated by rubber (*Hevea brasiliensis*). One of the important ecological aspects of polyculture planting is increasing the diversity of flora and fauna, maintaining soil fertility, controlling natural pests, and sustaining land productivity [13]. Rubber is used as the main crop because it is a fast-growing plant. The product of this type of rubber can be wood and not wood in the form of sap. Apart from rubber, there are other plants, such as *Durio zibethinus*, *Artocarpus heterophyllus*, *Schima wallichii*, *Parkia speciosa*, *Campospermum auriculatum*, *Swietenia macrophylla*, *Ficus variegata*, and *Falcataria moluccana*.

This HTR was formed in 2017, but planting has been carried out since 2015. Planting is done using different spacing depending on the landowner, namely 4x4 m, 4x5 m, 5x5 m, and 5x6 m. Spacing plays an important role in plant cultivation because the right spacing will minimize the possibility of competition for water, nutrients, and light among individual plants [13]. The spacing is intended so that plants in the HTR, especially rubber, have large diameter tree growth and grow perpendicularly where the tree diameter can be used to determine the value of the LBDs area of a tree. Apart from that, according to [14], the spacing which is regulated in such a way can not only reduce pest attacks and reduce disease progression as well as be unprofitable for the development of pathogens to avoid damage caused by pests and diseases.

The health of the forest can be used to measure the level of productivity and vitality of a tree. A system for monitoring the health of forest ecosystems is known as forest health monitoring using the technique FHM [8]. The principles of forest sustainability can be realized because this system can provide recommendations for appropriate forest management for the future. Information on the health condition of forest ecosystems in several countries has become a goal in sustainable forest management [15]. According to [32], one of the factors that can support the principle of sustainable forest management and can be used to control forest function is the forest health condition. Forest health monitoring is an activity that can report and assess the current health status of forests using measurable ecological indicators [16], where the indicators used to measure the health of these community plantations are productivity and vitality.

Productivity indicators are indicators determined by two factors, namely tree diameter, and height. The level of productivity is some considered because the high and low productivity in the forest reflects the success of forest management [16]. The growth of LBDs, calculated like tree growth, can be utilized to calculate productivity [17]. The diameter of each tree trunk is used to compute the LBDs. A cross-section of the breast height diameter is used to create LBDs (1.3 m from ground level) [18]. The more the number of trees or the denser the stands, the greater the LBDs value; conversely, the lower the density, the smaller the LBDs value [19].

Vitality is a forest health measure that considers two factors: tree damage and crown state. Forest health identification based on vitality indicators [20] is required to work with tree damage parameters to determine the location of the harm, the type of damage, and the degree of the damage. Humans, animals, and the environment can all contribute to the damage that happens. According to [21] disease, pest infestations, weeds, fire, weather, and animals can all cause harm. This damage causes a decrease in tree health. This is, as stated by [32], that to some extent, it can affect the health of the forest. Identification of damage signs and symptoms is important information that takes into account forest conditions and indicators that could lead to deviations from predicted conditions [22].

Measurement of forest health indicator parameters is carried out on the cluster plot in the subplot. The results of field measurements show that tree productivity levels can be explained by using LBDs parameters and tree vitality using tree damage parameters (CLI) and crown condition (VCR). The results of table 1 show the assessment of the two indicators on each cluster plot.
Table 1. LBDs, VCR, and CLI values in each cluster plot.

| Plot Clusters | LBDs (m$^2$) | VCR  | CLI  |
|---------------|--------------|------|------|
| 1             | 1,816        | 2,714| 5,078|
| 2             | 0.660        | 2,380| 4,051|
| 3             | 0.850        | 3,007| 3,647|
| 4             | 0.702        | 3,215| 2,834|
| Average       | 1,007        | 2,829| 3,903|

In table 2, the score values for the LBDs, VCR, and CLI parameters for each cluster plot. The score is calculated by transforming each parameter's value from the forest health indicators. The greater the score, the more important an indicator parameter is.

Table 2. The value of the LBDs, VCR, and CLI indicator scores on the health of community plantation forests.

| Skor | LBDs  | VCR  | CLI  |
|------|-------|------|------|
| 1    | 0.660 | 0.775| 2,380| 5,078| 4,854|
| 2    | 0.776 | 0.890| 2,464| 2,547| 2,463| 4,853| 4,629|
| 3    | 0.891 | 1.006| 2,547| 2,630| 2,547| 2,630| 4,628| 4,405|
| 4    | 1.007 | 1.121| 2,631| 2,713| 2,631| 2,713| 4,404| 4,180|
| 5    | 1.122 | 1.237| 2,714| 2,797| 2,714| 2,797| 4,179| 3,956|
| 6    | 1.238 | 1.353| 2,798| 2,880| 2,798| 2,880| 3,955| 3,732|
| 7    | 1.354 | 1.468| 2,881| 2,964| 2,881| 2,964| 3,731| 3,507|
| 8    | 1.469 | 1.584| 2,965| 3,047| 2,965| 3,047| 3,506| 3,283|
| 9    | 1.585 | 1.699| 3,048| 3,131| 3,048| 3,131| 3,282| 3,058|
| 10   | 1.700 | 1.816| 3,132| 3,215| 3,132| 3,215| 3,057| 2,834|

As for the results of table 1, it can be seen that the productivity value at the research location is in the bad category at the location of cluster plots 2, 3, and 4, as well as the good category in cluster plot 1. In cluster plot 1 has the highest LBDs value of 1,816 m$^2$, while cluster plot 2 has the lowest LBDs value of 0.660 m$^2$. Plot 1 clusters have much higher productivity compared to plot clusters 2, 3, and 4 because they have larger tree diameters and heights due to differences in planting years. In cluster plot 1, it was planted in 2015, while cluster plots 2, 3, and 4 were planted in 2017 and 2018. This proves that with the increasing age of the trees, the height and diameter of the trees will also increase, which can increase the productivity value of the forest stands. In addition, the LBDs value is also influenced by the number of trees that grow in that location [23]. The growth of a tree can be estimated as the growth of the tree's LBDs [2]. The higher the productivity value of a forest, the better it is for its health. This suggests that LBDs can be used to explain productivity [36]. Based on tables 1 and 2, it can be seen that the average productivity condition in the research location has a value of 1,007, which is at a score of 4 (medium). This could be because the research location is in a production forest with different planting years but has a good quality growing place to support tree growth in the research location.

Vitality was measured using tree damage parameters and crown conditions. The cluster plot-level tree damage values (CLI) of the four plot clusters can be used to assess tree damage conditions by first computing the damage index for each tree, then calculating the damage at the plot level, and finally at the plot cluster level. Meanwhile, the assessment of canopy condition can be identified through an assessment of the five crown parameters that must be assessed. The canopy appearance rating (VCR) was obtained. Table 1 shows the results of the assessment of tree damage conditions
and canopy appearance on each cluster plot. The results of table 1 show that the vitality value for tree damage parameters at the research location is in a bad category at the cluster plot 1 location, the medium category at clusters 2 and 3, as well as good categories in cluster plot 4. Tables 1 and 2 show that the average state of tree damage in the research location is 3.903, which is a 6 on a scale of 1 to 6 (medium). Cluster plot 1 has the highest damage value of 5.078, while cluster plot 4 has the lowest damage value of 2.834. Cluster plot 1 has much more serious damage than cluster plots 2, 3, and 4 due to the large intensity of the attacks that occur.

Damage to trees is a symptom that can be observed due to disruption of plant growth, namely changes in plant shape, size, color, and texture [21]. The types of damage that occurred in the Panca Indah Lestari HTR were open wounds, cancer, broken branches, dieback, discolored leaves, leaf damage, and termite nests. The most common damages were open wounds and termite nests. Open wounds are caused by human activity in taking rubber sap so that it cuts the tree trunk and leaves a wound. At the same time, termite nests do not only occur in one tree but can spread from one tree to another through trunks, branches, twigs on the forest floor and also from lianas found on the tree [24].

Observation and measurement of the crown condition parameters are depicted through the appearance of the tree canopy. In table 1, it is known that the canopy condition parameter values are in the bad category in plot cluster 2, the medium category in plot cluster 1, and the good category in plot clusters 3 and 4. Tables 1 and 2 show that the average state of the tree canopy in the research location is 2.829, which is a 6 on a scale of 1 to 6 (medium). The VCR value produced is inextricably linked to the five criteria for evaluating tree canopy conditions, all of which are interconnected. The canopy ratio is the proportion of tree height to crown length [22]. A dense and wide crown indicates the good growth experienced by the tree, whereas if the crown is small and rarely shows less growth on the tree. This indicates that the crown size can be used as a description of the health experienced by the tree. The tighter the canopy of a tree, the less sunlight can enter and penetrate the forest floor. The canopy cover of a tree with lush leaves has a high density, indicating that the tree's need for photosynthesis to maintain tree development is met [25]. Pest and disease attacks, as well as environmental factors, cause sparse and thin canopy. In addition, the spacing between trees that is too close can cause a tree canopy to be sparse and thin. Tree crowns that are thick and wide can affect the growth of stem diameter [26]. This shows a link between productivity and vitality indicators that determine the health of community plantations.

The Panca Indah Lestari Community Plantation Forest has the aim of being a wood supplier to industry in replacing the role of natural forest. Harvested wood can increase farmers' income, so the wood that is sold must be of good quality. Thus the continuity of wood products must be maintained; one way is by knowing the conditions of productivity indicators [9] and vitality indicators. Through productivity indicators, tree growth rates can be seen based on LBDs. The value of LBDs in community plantation forests will always change as the trees grow. According to [9] changes in LBDs resulting from changes in tree diameter can reduce or increase the level of overall forest productivity. This makes it very important to measure diameter in the management of a forest [27]. The productivity of a forest stand is related to tree vitality in the form of tree damage and crown condition. Lower growth rates, poor canopy conditions, biomass loss, and, most importantly, a negative influence on forest health will all come from tree damage [9].

The data obtained from productivity indicators in the form of LBDs and vitality in the form of tree damage and canopy conditions are then processed into forest health values on HTR Panca Indah Lestari using web-GIS forest health namely the Forest Health Monitoring Information System (SIPUT). Calculate the value of forest health by calculating the final value. Multiply the weighted value of each ecological index of community forest health by the parameter score of each ecological index of community forest health to calculate the final value of forest health. It is known that the threshold value for community plantation forest health can be seen in table 3. Meanwhile, the forest health value for each cluster plot in HTR Panca Indah Lestari can be seen in
The values of productivity and vitality indicators will be the basis for determining the final value of the health of the Panca Indah Lestari HTR forest, in addition to indicators of biodiversity and site quality. Through the final forest health value, the status of a forest's health condition can be determined. This value is obtained as a result of reducing the maximum value against the minimum value and then divided by three (categories used) [15]. The three categories of forest health conditions are divided into bad, medium, and good categories. Each plot cluster will have a different category depending on the ecological indicator value of each Panca Indah Lestari HTR area.

The results in table 4 show that the four plot clusters studied have various forest health values and categories. Plot clusters 1, 3, and 4 have respective values of 4.86, 4.56, and 5.53 in the good forest health category, and cluster 2 has a score of 1.89 in the bad category. The determination of the forest health category is based on the threshold values listed in table 3. So it can be concluded that the health condition status of the Panca Indah Lestari Community Plantation Forest as a whole has a value range of 3.103 - 4.316, which is included in the medium category. The value of the health status of the Panca Indah Lestari Community Plantation Forest is 4.210. The medium category owned by HTR is caused by cluster plot 2, which has poor forest health values. This poor health was caused by the high level of damage that had occurred and the canopy, which was still thin and sparse on almost all the trees in plot 2.

The forest health category in this HTR shows that intensive treatment is still needed to improve forest health conditions [28] on the HTR in the form of proper maintenance. Forest plant maintenance techniques are an important factor for forest productivity [29]. Forest productivity can be considered the rate of biomass production produced by an area of forest stands in a certain period [30]. Forest maintenance commonly carried out by farmers consists of fertilizing, pendangiran, re-planting, pruning branches, weeding, thinning, and controlling pests and diseases. Forest plant maintenance techniques are very important for the growth of forest plants, in addition to reducing competition for nutrient uptake in the soil, as well as providing space for the entry of light that plants need for their growth [31]. This technique can also minimize the damage caused by pests and diseases, such as cleaning weeds and lianas as well as pests that interfere with plants. Other than that, proper spacing and stand density allow trees to grow well so that they have a large diameter and height, affecting the productivity value of stands. This also affects the density and width of tree crown growth and reduces the intensity of tree damage that can spread from one tree to another.

Maintenance needs to be done, especially for cluster plots with the category of poor forest health. Maintenance techniques that are often performed on HTR Panca Indah Lestari are re-planting, pruning, and weeding. Farmers are re-planting erratically; every time they see a dead plant (aged 1-2

Table 3. Forest health threshold values in Panca Indah Lestari Community Plantation Forest.

| No. | Category | Class       |
|-----|----------|-------------|
| 1   | Bad      | 1,890 - 3,102 |
| 2   | Medium   | 3,103 - 4,316 |
| 3   | Good     | 4,317 - 5,530 |

Table 4. The final value of forest health in Panca Indah Lestari Community Plantation Forest.

| Cluster | Forest Health Value | Category |
|---------|---------------------|----------|
| 1       | 4.86                | Good     |
| 2       | 1.89                | Bad      |
| 3       | 4.56                | Good     |
| 4       | 5.53                | Good     |
years), it will be re-planted immediately. Branch pruning is done by the farmer when the tree is 1-2 meters high, and the canopy starts to widen so that the tree crowns do not collide with each other. At the same time, weeding is only done by farmers occasionally when new plants are planted, even though weeding is very important to provide room for growth [37]. However, in HTR management, it is highly recommended that farmers be fertilized. Fertilization can make the tree more fertile so that the tree's diameter and height increase, for example, NPK fertilizer. This is like the statement [33] that the application of NPK fertilizer to the soil can have a good effect on soil nutrient content and can have a good effect on plants because the macronutrients contained in NP and K elements are needed for plant growth and development. The application of fertilizers can increase productivity, which affects the final value of the health of community plantation forests.

Plant maintenance treatment is not only carried out on plot clusters with poor forest health categories, but plot clusters with good categories cannot be separated from maintenance treatment to increase productivity and reduce tree damage. In addition, in terms of plant management, it is necessary to pay attention to its sustainability aspects from planting to harvesting. Good management will positively impact the health of community plantations, especially the impact of increasing productivity and maintaining tree quality without any damage. The greater the productivity of a stand will support the function of the forest in terms of production. Forest health affects the forest's ability to produce timber. The good health of the people's plantation forests will make farmers profit from selling wood because the level of productivity can be higher. Guaranteed quality wood can be produced from healthy community plantations because of the minimal damage to trees. Treatment so that managed community plantations remain healthy and sustainable can also be carried out by periodically monitoring forest health because it is more effective and efficient.

4. Conclusion
The value of productivity in community plantation forests is high based on the diameter of the tree trunks measured, as for the types of damage that occurred in the Panca Indah Lestari HTR, namely open wounds, cancer, broken branches, dead shoots (dieback), discolored leaves, leaf damage, and termite nests. The final value of forest health as measured by productivity and vitality indices in each cluster plot was 4.86, 1.89, 4.56, and 5.53, respectively. The worth of the current state of forest health in the Panca Indah Lestari Community Plantation Forest in Bukit Layang Village, Bakam District, Bangka Regency for each cluster plot, namely cluster plots 1, 3, and 4 in good forest health conditions, and cluster plot 2 in bad conditions. The results showed that the health status of the HTR Panca Indah Lestari has a range of values of 3.103 - 4.316, which falls into the medium category. The health status value of the Panca Indah Lestari Community Plantation Forest is 4.210. The value of the current state of forest conditions in the Panca Indah Lestari Community Plantation Forest is a factor to evaluate and a recommendation for future management. This decision was made so that the management of the Panca Indah Lestari Community Plantation Forest in the future can increase the value of stand productivity based on LBDs parameters sustainably. In addition, plant maintenance can be carried out, such as fertilization to help tree growth and eradicate termite nest pests so that tree trunk damage can be avoided.

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