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Assessment of tree vitality as an indicator of monitoring the health condition of community forest in agroforestry patterns

Rahmat Safe'i[1,2] ✉, *Eka Nala Puspita*[2], *Rudi Hilmanto*[2]

[1]University of Lampung, Faculty of Agriculture, Master of Forestry Study Program, Bandar Lampung, Indonesia

[2]University of Lampung, Faculty of Agriculture, Department of Forestry, Bandar Lampung, Indonesia,
e-mail: rahmat.safei@fp.unila.ac.id

Abstract

Community forest management usually applies agroforestry patterns because it is felt that they will provide more social, economic and ecological benefits. Optimal yields will be obtained if the community forest is healthy. It becomes an effort to prevent forest destruction at a low level through forest health, thereby ensuring the functions and benefits of managed community forests. One indicator of forest health is the amount of tree damage that occurs and the condition of the crown. The purpose of this report is to provide an overview of the vitality condition of agroforestry-patterned community forests and to serve as a reference for future decisions about the maintenance and development of these forests. This study was conducted in a community forest owned by members of the combined forest farmer groups Satria Rimba, Way Khilau District, Pesawaran Regency, Lampung Province, Indonesia. The method used is the Assessment of Forest Health Monitoring (FHM) method. The parameters of the vitality condition assessment consist of tree damage and crown condition. This study provides results that show there are 14 types of tree damage that attacked the trees that made up stands in community forests. The most common types of damage occurred based on the percentage of incidents, namely damaged leaves (25.29%), broken branches (24.41%) and open wounds (23.34%). assessment for damage to the tree based on the CLI value, namely in the high category (clusters 2, 3); moderate category (clusters 1, 5, 6); and low category (clusters 4, 7). Assessment of the crown condition based on the VCR value, namely in the categories of 'high' (clusters 4, 5, 6), 'moderate' (clusters 2, 7) and 'low' (clusters 1, 3).

Key words

agroforestry, community forest, crown condition, forest health, tree damage, vitality

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Introduction

Community forests have developed a lot as one of Indonesia's forest land management systems. The demand for raw wood materials continues to be pressured because natural forest products cannot be fulfilled, so this community forest is one solution to overcome these problems. In addition, community forests also provide economic, social and ecological benefits (Rochmah et al. 2021). From the point of view of economic benefits, sustainable forest management is also based on economic viability so that it provides benefits to the community and the condition of the forest is maintained (Kaliszewski and Młynarski 2020). Based on research conducted by that, almost 97% of respondents feel that the natural forest around them has benefits to their health, social and economic well-being (Mengist et al. 2022). Many international agencies related to forestry have tried to develop recommendations regarding a sustainable forest economy (Szramka and Adamowicz 2020).

Community forests are forests that are managed by land owners. Community forest is a forest that is granted rights to land or land that is managed directly by the community forest farmers on their own land and puts forward the principle of sustainable forest, which consists of various types of trees (Ansori et al. 2020). Community forests have patterns of various types of planting, that is cropping patterns monoculture, polyculture and agroforestry (Musdi et al. 2020). One of the community forests managed by agroforestry is in Kubu Batu Village, Way Khilau District, Pesawaran Regency, Lampung Province, Indonesia. Farmers manage the community forest to produce forest products, both wood and non-timber, optimally and of good quality. It aims to help improve the economy of the farming family to achieve a prosperous life. To obtain optimal results from agroforestry-patterned community forest management, the condition of that forest must be healthy. Forest health is an effort to ensure forest functions and benefits through controlling the level of forest damage (Safe'i et al. 2021).

Community forest health is monitored by the Forest Health Monitoring (FHM) method, which considers each ecological indicator's condition to assess it. The forest health indicators are used to depend on the efforts and objectives of forest management (Lestari et al. 2019). One of the indicators that can assess forest health is vitality, with tree damage and crown conditions being the measurement parameters (Safe'i et al. 2021). Assessment of vitality indicators is important in monitoring the health of community forests because healthy forest conditions are greatly influenced by tree health as a component of forest stands. The vitality indicators assessment will be measured regarding the level of tree damage and the crown condition. Tree damage will inhibit tree growth and can have a tiered effect on services, such as decreasing the quality of forest wood products that will be produced (Fuller and Quine 2016). In addition, the process of photosynthesis is very dependent on the good and bad conditions of the crown, which means that it has a strong relationship with the health of each tree as a stand-maker (Cavalli and Finger 2017).

The damaged tree conditions indicate the vitality of trees, and tree crown conditions are factors that significantly influence tree growth. This will affect the quality and quantity of wood produced (Safe'i et al. 2020). Therefore, identifying tree damage and the crown's condition in community forests becomes the goal of this research. The aim is to provide an overview regarding the state of vitality in the community forest of Kubu Batu Village using agroforestry patterns. In addition, it is also to become the basis for making the right decisions for the maintenance and development of agroforestry community forests in the future. This is expected to support the acquisition of more optimal results from community forest management carried out by farmers.

Material and methods

The implementation of the research is in December 2020–January 2021 on community forest land belonging to members of the Association of Forest Farmers Group Satria Rimba, Kubu Batu Village, Way Khilau District, Pesawaran Regency, Lampung Province, Indonesia. The various research tools used consist of a tally sheet, labels, pins, compasses, ballpoint, meter roller (50 metres), band meter (150 centimetres), Global Positioning System (GPS), digital cameras and binoculars.

Methods used to assess tree vitality in a community forest using agroforestry patterns are the FHM method and cluster-plot observation to obtain tree vitality measurement data, as shown in Figure 1. Cluster plots are double circular plots for measuring samples of forest health data that can represent the entire existing area observed (Safe'i et al. 2021). The number of FHM plot clusters made was seven. This is to obtain representative data based on the area of existing community forest lands, 88.50 hectares, with a sampling intensity of 2.5% according to the applicable regulations, namely P.67/Menhut-II/2006 concerning Criteria and Standards for Forest Inventory in Indonesia. One of the FHM cluster plots has an area of 4,046.86 m^2, which can represent a forest area of 1 ha (Safe'i et al. 2019), as shown in Figure 1.

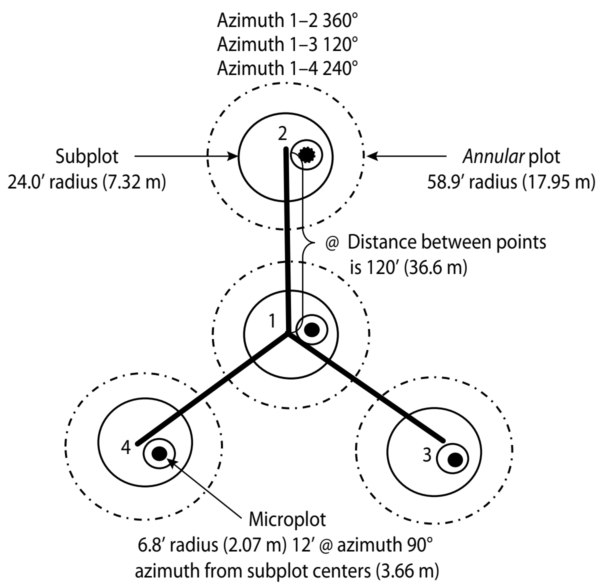

Figure 1. Design of FHM cluster plot (USDA-FS 1999)

Two parameters for assessing tree vitality consist of tree damage and crown condition. Damage to trees is measured through a damage index based on damage location, damage type and severity (Safe'i et al. 2021). Table 1 below presents the observation code used to make it easier to analyse tree damage (USDA-FS 1999).

The condition header is analysed based on the level of rank value appearances (visual crown ratio, or VCR). The value of the visual crown ratio (VCR) is the result of assessing the five parameters of crown condition. The five parameters include live crown ratio (LCR), crown density (Cden), foliage transparancy (FT), crown diameter (CD) and crown dieback (CDB) (Safe'i et al. 2015). Cluster plot Level Index (CLI) and VCR values are for each FHM cluster plot group (Anwar et al. 2022). The CLI value is obtained based on the damage index value

Table 1. Code, tree damage location, type of tree damage, and serious illness

Code	Tree Damage Location	Code	Type of Tree Damage	Code	Severity (%)
0	No damage	01	Cancer	1	10
1	Roots (exposed) and "stump"	02	Conks	2	20
2	Roots and lower bole	03	Open wounds	3	30
3	Lower bole	04	Resinosis/ gummosis	4	40
4	Lower and upper boles	05	Broken branch	5	50
5	Upper bole	06	Termite nests	6	60
6	Crown stems	11	Broken bole/roots	7	70
7	Branches	12	Brooms on roots/ bole	8	80
8	Buds and shoots	13	Broken/dead roots	9	90
9	Foliage	20	Liana (choker plant/vines in crown)		
		21	Loos of apical dominance, dead terminal		
		22	Broken/dead		
		23	Excessive branching/brooms		
		24	Damaged foliage/ shoots		
		25	Discoloration of foliage		
		26	Puru/tumor rust		
		31	Other		

Source: Safe'i et al. (2021).

at the cluster level plot by dividing the Plot Level Index (PLI) value and the number of plots, while the PLI value is obtained by dividing the Tree Level Index (TLI) value by the number of trees in the plot (Ajijah et al. 2022). The formula used is as follows:

$$CLI = \frac{\sum PLI}{\sum Plot} \quad (1)$$

$$CLI = \frac{\sum TLI \text{ dalam Plot}}{\sum \text{Pohon dalam plot}} \quad (2)$$

$$TLI = [K\ 1] + [K\ 2] + [K\ 3] \quad (3)$$

Information:
CLI – Cluster plot Level Index,
PLI – Plot Level Index,
TLI – Tree Level Index,
IK 1, 2, 3 – Damage index to 1, 2, 3.

VCR values were obtained based on the results of the assessment of each crown condition parameter, namely live crown ratio (LCR), crown density (Cden), foliage transparancy (FT), crown diameter (CD) and crown dieback (CDB), with the conditions as presented in Table 2.

Table 2. Tree individual VCR values

VCR Value	Criteria
4 (High)	All header condition parameters are 3, or only 1 parameter has a value of 2, none parameter that is worth 1
3 (Currently)	More combinations of values 3 and 2 in header parameter, or all value 2, but not there is a parameter that is worth 1
2 (Low)	At least 1 parameter is worth 1, but not all parameters
1 (Very low)	All header condition parameters are 1

Source: Safe'i et al. (2021). VCR – Visual crown ratio.

Results

Assessment of tree damage

Management of forest health in a forest population incorporates the health of individual trees (Cavers 2015). Therefore, it is important to pay attention to the death of each tree because it can lead to a decrease in the population level. One of the important indicators that function as a notification system to maintain forest sustainability is the damage experienced by trees (Fuller and Quine 2016).

Based on the observations, 13 tree species were found in all cluster plots. The trees found were damaged in individual cases. Damage to trees is measured based on damage location, type of tree damage and serious illness. The species and number of trees that were damaged are presented in Table 3.

The types of damage that occurred were quite varied. Based on the observations that the tree damage was found in the roots, stems, branches, shoots and leaves.

Table 3. The species and number of damaged trees

Tree Species	Many Trees are Damaged
Avocado/Alpukat (*Persea americana*)	2
Bayur/Bayur (*Pterospermum javanicum*)	2
Pecan/Kemiri (*Aleurites moluccanus*)	3
Rubber/Karet (*Hevea brasiliensis*)	2
Jengkol/Jengkol (*Archidendron pauciflorum*)	1
Medang/Medang (*Dehaasia cuenata*)	4
Jackfruit/Nangka (*Artocarpus heterophylla*)	3
Mango/Mangga (*Mangifera indica*)	1
Noni/Mengkudu (*Morinda citrifolia*)	2
Sengon Buto/Sengon Buto (*Entorolobium cyclocarpum*)	1
Melinjo/Melinjo (*Gnetum gnemon*)	1
Wareng/Wareng (*Gmelina arborea* Roxb.)	8
Teak/Jati (*Tectona grandis*)	1
Petai/Petai (*Parkia speciosa*)	4
Total Number of Trees	35

Source: Processed data.

The characteristics of the appearance of attacks on a tree, as seen from the colour, size, shape and texture, can be a sign to identify a type of tree damage (Safe'i et al. 2020). The most common types of damage that occur are presented in Figure 2.

With the application of the FHM method, there were 259 trees in the entire FHM plot cluster, which were measured for the vitality condition of the trees. As seen from Figure 2, 14 types of damage are found on trees in community forest land with agroforestry patterns. The type of tree damage that is most likely to occur, ranging from leaf damage to broken branches to open wounds, is followed by the type of tree damage, as shown in Figure 3. Tree damage is the result of disturbance to trees caused by pathogens, insects, air pollution, natural conditions and human activities (Coulston et al. 2005). Insect pests and pathogens have a major role in causing tree damage (Bałazy 2020).

Damage to leaves became the type of damage with the highest percentage, at 25.29%. The damage found on the teak (*Tectona grandis*) tree occurs due to pest or disease attacks. Damage to the leaves is found in the form of hollow leaves and discoloured leaves. Symptoms of this type of damage are marked by the condition of the

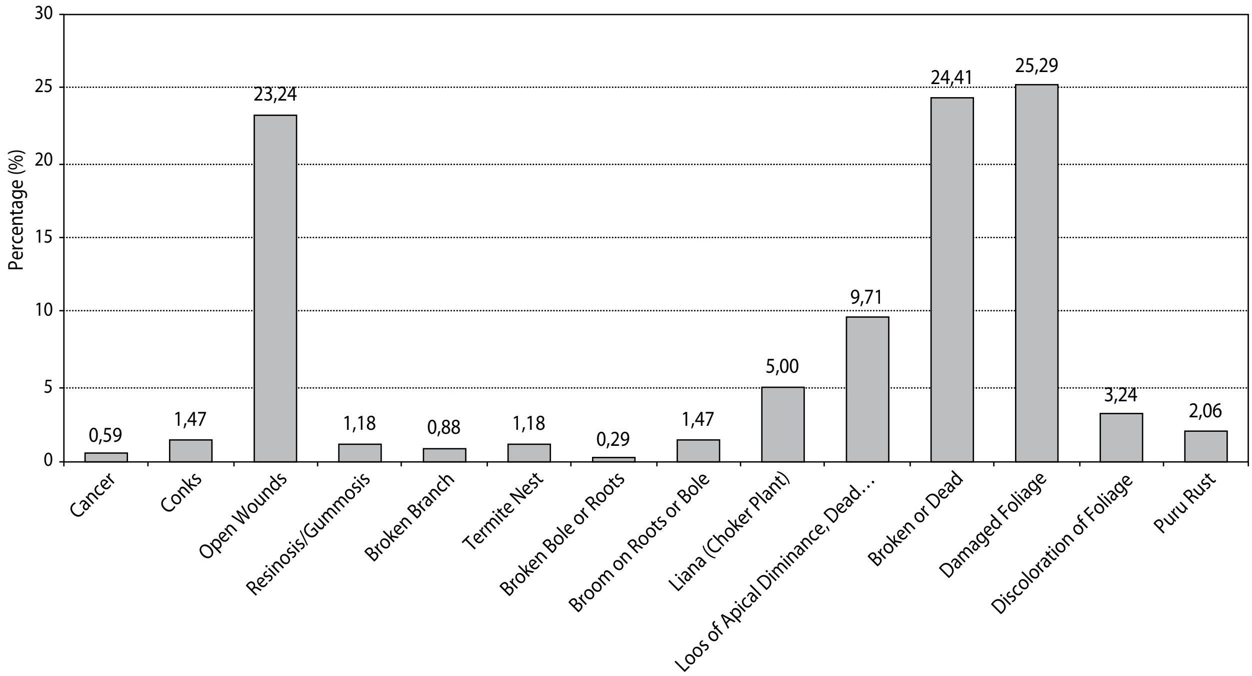

Figure 2. Graph of the percentage (%) each type of tree damage

Figure 3. Types of damage: A – damaged foliage on teak trees (*Tectona grandis*); B – broken branch on jengkol trees (*Achidendron pauciflorum*); C – open wounds on petai trees (*Parkia speciosa*)

leaves, which are no longer green, turn yellow, fall off and also have holes due to pests (Safe'i et al. 2021).

The type of damage that occupies the second category is damage to branches in the form of broken branches. Damage was found on the jengkol tree (*Achidendron pauciflorum*) with an incidence percentage of 24.41%. This type of disease is characterised by symptoms of loss of twigs and leaves, and it seems as if there is weathering of dead branches. The condition of broken branches can occur due to the condition of weak or rotten branches. Destroying fungi and pathogens that attack can cause branches to become weak and rotten (Abimanyu et al. 2019). This will cause the tree's health to decline.

Open wounds were the third worst damage found on petai trees (*Parkia speciosa*) with an incidence of 23.24%. Open wounds can be caused by the activity of the tree itself or by human intervention. Open wounds are characterised by peeling tree bark (Safe'i et al. 2020). Owing to the peeling of the tree trunk, the damage becomes the starting point for the entry of pathogens into the interior of the trunk, causing further damage to the tree and decreasing tree health.

Overall, the tree damage assessment is seen in the tree damage index that occurred. The tree damage index calculation accumulates the three tree damage assessment parameters, consisting of damage location, type of tree damage and serious illness. In more detail, the damage index value that occurs in each FHM plot cluster is shown in Table 4. Table 4 shows the CLI value for each cluster plot FHM.

At the cluster plot level, a cluster that has a higher level of tree decay is indicated by a higher CLI value (Safe'i et al. 2019). The results presented in Table 4 show that the damage to trees in the high category is found in cluster plots 2 and 3. Moderate damage is found in cluster plots 1, 5 and 6. Meanwhile, in cluster plots 4 and 7, the damage is in a low category. Therefore, the average level of tree damage in a community forest with agroforestry patterns can be in the moderate category. The level of tree damage is influenced by three parameters measuring that damage location was found, type of tree damage and the serious illness. The type and part of the tree that cause worse impacts will also cause a higher level of damage (Widodo et al. 2022). Various tree damages have also occurred due to several environmental factors that influence it (Safe'i qand Upe 2022). Tree damage can be identified as the cause to provide valuable information so that it is possible to prevent or overcome the occurrence of further damage (Randolph et al. 2021).

The level of damage according to the different CLI values for each cluster results in different health values, meaning that tree damage plays an important role in improving forest health (Safe'i et al. 2021). If there is a lot of damage with a value above the serious illness threshold, it will ultimately affect forest health conditions (Safe'i et al. 2022). It is necessary to take maintenance action to overcome tree damage, such as pruning or eradicating pests and diseases that have attacked trees. To be more effective, the causes of the damage need to be adjusted. Therefore, to maintain good forest health conditions, good management needs to be carried out with proper and good maintenance activities (Safe'i et al. 2021).

Table 4. The CLI value for each cluster plot FHM

Cluster plot FHM	CLI	Category
1	2.84	moderate
2	3.32	high
3	3.60	high
4	2.22	low
5	2.93	moderate
6	2.71	moderate
7	2.64	low

Source: Processed data; CLI: Cluster plot level index.

Assessment of crown condition

In monitoring forest health, an assessment of the condition of the crown is important to determine the state of its vitality (Safe'i et al. 2022). Paying attention to canopy condition is important because vitality is expressed in a tree's ability to regenerate damaged crowns as a tree's growth potential (Czapski et al. 2015).The crown is the location for gathering leaves that play an important role in the photosynthesis process to support tree growth. The results of the assessment of the crown condition obtained the value of the crown appearance rating (VCR), which is the accumulated calculation of the five measurement parameters of the crown condition assessment. The VCR value for each cluster plot is presented in more detail in Table 5.

The more the VCR rating value shows, the better the crown condition. The results shown in Table 5 show that forest stands with good crown conditions based on the high VCR category value are in clusters 4, 5 and 6. Clusters 2 and 7 are in the moderate category, while crown conditions with low categories are in clusters 1 and 3. The five parameters for assessing the condition of the tree crown will determine the value of the VCR obtained.

Table 5. The VCR values for each of cluster plot FHM

Cluster plot FHM	VCR	Category
1	2.84	low
2	3.14	moderate
3	2.77	low
4	3.36	high
5	3.37	high
6	3.32	high
7	3.21	moderate

Source: Processed data. VCR – Visual crown ratio.

This issue is consistent with the findings of Puspita et al. (2021) research, which found that conditions have a strong and significant relationship with forest health conditions. VCR high value indicates a normal crown condition. A normal crown condition is characterised by a good physical condition of the crown (Zarnoch et al. 2004). For example, a high VCR value is due to the large diameter crown, which makes the crown wide and dense so that the density is high. This shows that trees have a large number of leaves available for photosynthesis. The high density of the tree crown indicates a dense crown cover. This supports the photosynthesis process to help provide the needed nutrients. Meanwhile, bad crown condition shows that the crown has high transparency due to poor foliage caused by damage from pests, diseases or environmental factors such as drought and poor competition between plants.

The high crown conditions make the forest much healthier. This issue is consistent with the findings of Puspita et al. (2021) research, which found that conditions have a strong and significant relationship with forest health conditions. Good crown conditions make the tree able to carry out its functions optimally, which means the physiological tree is in a healthy condition so that tree growth will also be optimal. Farmers need to increase their attention to the condition of forest vitality to improve the process of tree growth in community forest lands for more optimal benefits. This is following the desired sustainable forest management because the goal is to efficiently utilise the typological capacity of the forest and its formation into highly productive and biologically sustainable stands (Yuriy et al. 2021).

Conclusion

Assessment of tree vitality in agroforestry-patterned community forest lands using 7 FHM plot clusters revealed 259 damaged trees. Damage occurs to the roots, stems, branches, shoots and leaves. There were 14 different types of damage found attacking the tree in the community forest. The most common types of damage occurred based on the percentage of incidents, namely damaged leaves (25.29%), broken branches (24.41%) and open wounds (23.34%). According to the CLI value, tree damage was categorised into three classes. The level of damage was high category (cluster plots 2, 3); moderate category (cluster plots 1, 5 and 6); and low category (cluster plots 4, 7). Assessment of the crown condition based on the VCR value, namely in the categories: high (cluster plots 4, 5 and 6); moderate (cluster plots 2, 7); and low (cluster plots 1, 3). Overall, the results of the tree vitality assessment through tree damage and crown condition showed that the forest was in good health.

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