

Short Communication: Assessing the state and change of forest health of the proposed arboretum in Wan Abdul Rachman Grand Forest Park, Lampung, Indonesia

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²Department of Forestry, Faculty of Agriculture, Universitas Pattimura. Jl. Ir. Putuhena, Poka, Ambon 97233, Maluku, Indonesia.
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Abstract. *Safe'I R, Latumahina FS, Dewi BS, Ardiansyah F. 2021. Short Communication: Assessing the state and change of forest health of the proposed arboretum in Wan Abdul Rachman Grand Forest Park, Lampung, Indonesia. Biodiversitas 22: 2072-2077.* Forest health is the fundamental of sustainable forest management. As such, forest health needs to be continually monitored and maintained. This study assessed the state and change of forest health of the prospective arboretum in Wan Abdul Rachman Grand Forest Park (Tahura WAR), Lampung, Indonesia, aiming that the arboretum can serve for integrated conservation and education forest (Tahura War). This research used the Forest Health Monitoring (FHM) method by combining the parameters of vitality (i.e., tree damage and tree crown condition) and biodiversity (tree species diversity) across four Forest Health Monitoring plot clusters. The results showed there was a change in the state of forest health of the prospective arboretum in Tahura WAR. The first measurement showed that 50% of plot clusters had a status of bad, while 25% was moderate and 25% was good. The results of the second measurement showed that 50% of plot clusters had a status of moderate, while 25% was bad and 25% was good. This finding suggests that the prospective arboretum experienced changes toward better conditions in health status. Even so, it is still necessary to carry out regular forest health monitoring activities to determine trends.

Keywords: Arboretum, forest health, health monitoring, integrated conservation

INTRODUCTION

Forest health is a condition of a forest that can be said to be good so that it is able to carry out forest functions properly in accordance with the predetermined forest function and can ensure investment and production security, while keeping the damage or disturbance below an acceptable level to ensure the delivery of other forest functions (e.g. ecological and social) to achieve the principle of sustainable forest management (Safe'i et al. 2014, 2015). Ultimately, sustainable forest management is the goal of maintaining forest health. A healthy forest condition will preserve the forest, on the other hand, if the forest is not healthy, it will hamper the functions of the forest. Nuhamara et al. (2001) stated that healthy forests should be able to achieve the main functions mentioned previously (i.e., economic, social, and ecological).

To determine the health condition of forest, monitoring of forest health is necessary. Forest health monitoring (FHM) is a method used to monitor, assess, and report the current status, changes, and trends in the long-term health condition of forests using measurable ecological indicators (Mangold 1999). Ecological indicators are indicators that are used and can be adjusted to local ecosystem conditions, which are dynamic, adaptive, and ensure the sustainability

of forest resources (Safe'i et al. 2015, 2019). Ecological indicators that can be used in monitoring forest health include vitality, biodiversity, productivity, and site quality (Safe'i et al. 2019).

While monitoring forest health is essential to manage forest in the long run, the understanding and awareness of this issue are still lacking in Lampung Province, Indonesia (Safe'i et al. 2019). This limited awareness has resembled in Wan Abdul Rahman Grand Forest Park (*Taman Hutan Raya Wan Abdul Rahman* or Tahura WAR) in Lampung, Indonesia. This park is a state forest area designated for conservation and protection purposes (Safe'i et al. 2020). From the perspective of forest health on conservation aspect, this park should be able to preserve plant and animal species diversity, and the ecosystems, as well as the sustainable uses of such biological resources. In addition, viewed from protection function, the forest health of Tahura WAR should be able to maintain the protection of life support systems, for example, hydrological cycle.

Beside for conservation and protection functions, currently, some part of the areas in Tahura WAR is proposed as prospective arboretum for education purpose. Accordingly, the health condition of the proposed arboretum in this park, which integrates the conservation, protection and education functions should be considered. As such, to maintain a healthy forest condition, it is

necessary to know the status of and changes in forest health as a basis for decision-making by conservation forest managers. The aim of the research is to determine the status and changes of forest health of the prospective arboretum of Wan Abdul Rahman Grand Forest Park, Bandar Lampung, Indonesia.

MATERIALS AND METHODS

Study period and area

This research was conducted from May 2017 to May 2018 at the prospective arboretum in Wan Abdul Rachman Grand Forest Park (Taman Hutan Raya Wan Abdul Rahman or Tahura WAR), Bandar Lampung City, Lampung, Indonesia, with a geographic location between $05^{\circ}23'47,03''$ - $05^{\circ}30'34,86''$ S and between $105^{\circ}02'42,01$ - $105^{\circ}13'42,09''$ E. This park was stipulated through the Decree of the Minister of Forestry Number 408/Kpts-II/1993 dated 10 August 1993 with an area of 22,245.50 ha (UPTD KPHK Tahura WAR 2020).

Research procedure

The assessment at the prospective arboretum in Tahura WAR was based on two parameters. The first parameter was to determine the forest health status and the second parameter was to determine the forest health changes. The parameters used the Forest Health Monitoring (FHM) method (Mangold 1999) with indicators of vitality (i.e. tree

damage and tree crown condition) and biodiversity (tree species diversity) (Indriani et al. 2020; Safe'i et al. 2018). The measuring plot used was in the form of an Forest Health Monitoring plot cluster (Figure 1), made permanently on four plots for conservation and education purposes.

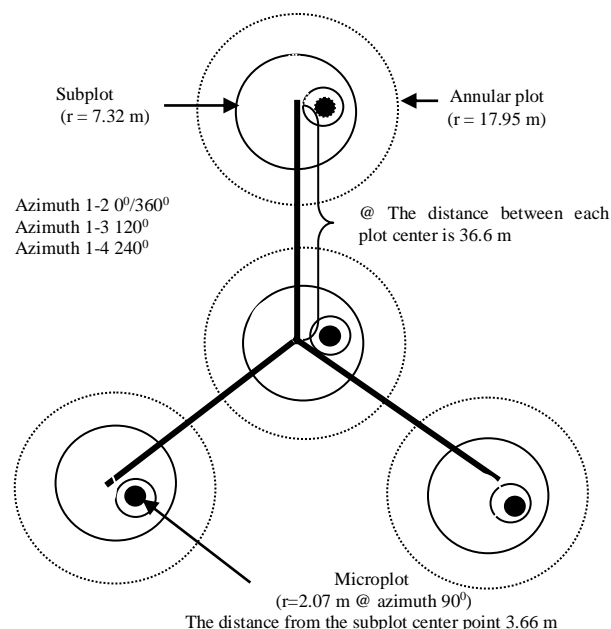


Figure 2. Diagram of plot cluster design based on Forest Health Monitoring (FHM) method (Source: Mangold 1999)

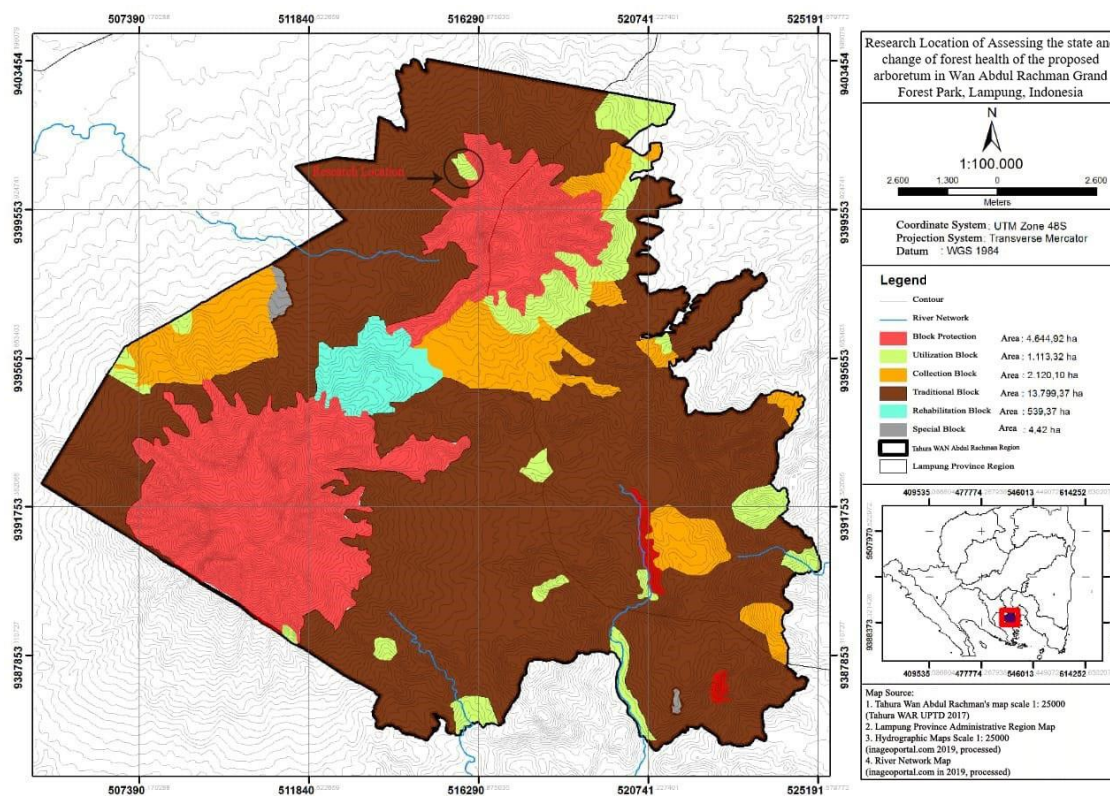


Figure 1. Research location map in in Wan Abdul Rachman Grand Forest Park (Tahura WAR), Bandar Lampung City, Indonesia

The vitality indicator in term of tree damage was based on the value of the cluster level index (CLI) which was calculated with the formula:

$$CLI = \frac{\sum PLI}{\sum Plot}$$

Where:

1. $PLI = \frac{\sum TLI \text{ in the plot}}{\sum \text{ trees in the plot}}$
2. $TLI = [IK1] + [IK2] + [IK3]$
3. $IK = x \text{ location} \times y \text{ damage type} \times z \text{ severity}$

Note: x , y , z are weighting values that vary depending on the relative impact of each component on tree growth and resilience.

The vitality indicator in terms of tree crown condition was calculated based on the value of the visual crown ratio (VCR). VCR values were obtained based on the live crown ratio (LCR), crown density (Cden), crown transparency (FT), crown diameter (CDW and CD 90⁰), and dieback (CDB).

The value of biodiversity indicator (tree species diversity) was based on the Shannon-Wiener index (Kasim and Hamid 2015), with the formula:

$$H' = \sum_{i=1}^s \left[\left(\frac{n_i}{N} \right) \ln \left(\frac{n_i}{N} \right) \right]$$

Where:

- H' : Shannon-Wiener diversity index
- s : Number of species
- \ln : Natural logarithm
- n_i : Number of individuals of type i
- N : Total of all individuals

The result of $H' \leq 1$ indicates that species diversity is low, if $1 < H' \leq 3$ species diversity is classified as moderate, and if $H' > 3$ indicates high diversity (Hendrayana et al. 2019).

The assessment of status and changes in forest health at the arboretum in Tahura WAR for integrating conservation and education used the Forest Health Assessment Information System. Forest health assessment was obtained based on the results of the final forest health score which was the sum of the weight values multiplied by the score for each forest health indicator (parameter). The formula for the final value of forest health was calculated as follows (Safe'i 2020):

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

Where:

- NKH: The final value of forest health
- NT : Weighted values of the parameters of each indicator
- NS : Parameter score value for each indicator

The weighted values used in this study referred to Safe'i et al. (2019), namely vitality (0.10) and biodiversity (0.48). The score was obtained by transforming the value of each parameter from the ecological indicators of forest health.

RESULTS AND DISCUSSION

The CLI, VCR, and H' values (Woodall et al. 2011) were obtained for each Forest Health Monitoring plot cluster at the prospective arboretum in Tahura WAR. Based on the 1st and 2nd measurements, the status of and changes in forest health using such parameters at the studied area can be determined.

The Cluster Level Index (CLI) values in the 1st and 2nd measurements and their changes at each Forest Health Monitoring plot cluster in the Tahura WAR are presented in Table 1. The condition of tree damage shown in the CLI is an indicator parameter of whether the tree stand is healthy or unhealthy. The assessment of the changes of tree damage conditions was based on the difference between the CLI values in the 1st and 2nd measurements. Three plots had positive changes with the largest change occurred at Plot 2 with 0.42, while one cluster (i.e., Plot 1) had negative change with -0.03 (Table 1).

Based on Table 1, the CLI values tended to increase, meaning that the level of tree damage at the prospective arboretum in Tahura WAR was increasing. Several factors causing such conditions including the forest disturbance as the impact of forest management carried out by the surrounding community. In addition to community activities, tree damage can also occur due to environmental conditions that do not support the growth of plants (Wulff et al. 2013). Tree damage triggers plants to be susceptible to pests and diseases.

Ecological factors and various human activities can damage tree conditions which greatly influence the stands at the prospective arboretum in Tahura WAR. Adverse interactions between plants and the environment, either the biotic and abiotic variables, can cause disturbance and become the leading cause of stand damage (Simanjorang and Safe'i 2018). Biotic factors, including pest attacks, diseases, or other living creatures, can cause damages and dieback besides the abiotic factors, such as natural disasters. Damage to a tree affects physiological functions of trees, decreases the rate of tree growth, and leads to tree's death.

Table 1. The Cluster Level Index (CLI) value at each Forest Health Monitoring plot cluster and its change in the 1st and 2nd measurements

FHM Plot Cluster	1 st CLI measurement	2 nd CLI measurement	Change
1	4.60	4.57	-0.03
2	4.80	5.22	0.42
3	6.60	6.81	0.21
4	4.50	4.52	0.02

Apart from the changes in tree damage in the form of CLI, the condition of tree canopy measured as Visual Crown Ratio (VCR) was also used to assess forest health of the proposed arboretum in Tahura WAR. The VCR values in the 1st and 2nd measurements resemble the changes in forest health of each Forest Health Monitoring plot cluster (Table 2). Table 2 shows that there were mixed results in the change of canopy condition in which two plots had positive values (i.e., Plot 3 and Plot 4) while two plots had negative values (i.e., Plot 1 and Plot 2). Nonetheless, the values of positive changes were higher than those of negative changes (Table 2). This finding suggests that in general the condition of the tree crowns at the prospective arboretum in Tahura WAR is quite good.

Changes in VCR value can be caused by various factors, including the maintenance of plants carried out by the community. Plant maintenance through fertilization can improve the crown's quality through the growth of fresh leaves that make up the tree crown. The VCR value obtained cannot be separated from the five parameters of the corresponding tree header condition assessment (Safe'i et al. 2019). The live headline ratio can describe the length proportion of headings to tree height. Density includes the number of plant organs that form a title meaning the amount of sunlight blocked from entering the forest floor. So the header density shows the percentage of the total light that the tree received (Fierke et al. 2011).

Forest health management incorporates the health of individual trees within the population across the forest (Cavers 2015). As such, the death of particular tree becomes an important matter of concern as it will result in deterioration in the population level. Nuhamara et al. (2001) described that tree damage can result in declining growth rates, low heading conditions, biomass loss, and deflections that impact the overall forest health. The damage suffered by trees is essential indicator that can serve as an early warning system to provide information about the sustainability of the forest (Fuller dan Quine 2016). Therefore, tree maintenance activities at the prospective arboretum of Tahura WAR is essential, such as pruning and eradicating termite pests from the damaged tree. Trimming can also optimize the interception of light and redirect the growth and development of branches and shoots in the right direction.

Dense canopy in a tree can mean that the tree has a heading cover with lush foliage, implying that there is plenty of resources for photosynthesis that supports tree growth (Asriyanti et al. 2015). In contrast, a low density of canopy may indicate disturbances that might be caused by disease, insects, or environmental factors. The heading's diameter can display the tree heading's actual length (Wu et al. 2013). Dense and wide tree headers can affect the stem diameter growth. When the header growth overlaps, it causes the absorption of sunlight to be obstructed so that the photosynthesis process can be interrupted and hamper optimal plant growth (Cavers dan Cottrell 2015).

The diversity of tree species at the proposed arboretum in Tahura WAR is presented in Table 3. The change in tree species diversity was based on the difference of the H'

values between the 1st and 2nd measurements. The highest diversity was obtained at Plot 1 with 3.21 while the lowest diversity was at Plot 2 with 1.11. The largest change in species diversity occurred at Plot 3 with 0.23. This finding suggests that most of the plots at the proposed arboretum in Tahura WAR had moderate diversity index (i.e., $1 < H' \leq 3$) except for Plot 1 which can be categorized as high ($H' > 3$).

Changes in the value of H' can be caused by several factors, both from community activities and the management of Tahura WAR. The maintenance of forest stands by thinning by the community can reduce the value of tree species diversity in Tahura WAR. Incorrect thinning techniques can affect the value of tree species diversity, and this can be caused by a lack of knowledge in implementation. In most cases, communities use thinning methods to reduce competition between trees in obtaining nutrients and space to grow (Derose and Long 2014).

Apart from thinning, weeding was also done by the community which might impact the growth and survival of seedlings. Weeding is the activity to reduce and control weed occurrence to keep the cultivated crops under the economic or ecological threshold (Nandini et al. 2016). There will be competition between weeds and crops for light, soil moisture, and nutrients when there is no weeding. Weeding activities are essential to provide space for growth (Krisnawati et al. 2011). However, inappropriate weeding techniques will result in the disturbance of forest trees and forest floor vegetation, disrupting their growth.

Therefore, to maintain and increase the diversity of tree species (H') and to balance the forest ecosystem, silvicultural practices need to be implemented precisely and correctly (Boadi et al. 2017). In addition, it is necessary to carry out conservation efforts in the form of protection combined with restoration by enrichment planting at all study locations because the occurrence of some species is not evenly distributed (Isroni et al. 2019).

Table 2. The Visual Crown Ration (VCR) at each Forest Health Monitoring (FHM) plot cluster and its change in the 1st and 2nd measurements

FHM Plot Cluster	1 st VCR measurement	2 nd VCR measurement	Change
1	3.00	2.65	-0.35
2	3.00	2.75	-0.25
3	2.00	2.95	0.95
4	2.00	2.74	0.74

Table 3. The diversity index at each Forest Health Monitoring plot cluster and its change in the 1st and 2nd measurements

FHM Plot Cluster	1st H' measurement	2nd H' measurement	Change
1	3.21	3.21	0.00
2	1.11	1.09	-0.02
3	1.22	1.45	0.23
4	1.58	1.41	-0.17

Table 4. The final value of forest health status at each Forest Health Monitoring (FHM) plot cluster and its change in the 1st and 2nd measurements

FHM Plot Cluster	Final value for forest health (1st measurement)	Status	Final value for forest health (2nd measurement)	Status	Change
1	4.00	Moderate	5.13	Good	1.03
2	3.00	Bad	3.21	Bad	0.09
3	2.00	Bad	4.05	Moderate	1.86
4	6.00	Good	3.34	Moderate	-2.66

The final assessment of forest health at the prospective arboretum in Tahura WAR was done by summing the weighted value of the stand damage parameters (i.e., CLI and VCR) and the biodiversity parameter. The weighted value was based on the forest health indicator parameter as prescribed by Cale et al. (2014). Based on Table 4, the results of the first measurement show that 50% of the plots had a status of bad, while 25% was good and 25% was moderate. The second measurement results show that 50% of the plots had a status of moderate, while 25% was good and 25% was bad.

Changes in the final values of forest health occurred at each Forest Health Monitoring plot cluster in Tahura WAR. The most significant changes occurred in Plot 3 and Plot 4 with an increase of 1.86 and a decrease (or negative) of 2.66, respectively (Table 4). The plots that changed status were Plots 1, 3 and 4, while Plot 2 did not change. Plot 1 experienced a change in status from "moderate" to "good", Plot 3 experienced a change in status from "bad" to "moderate", and Plot 4 experienced a change in status from "good" to "moderate".

The result of the combined parameters of forest health at the proposed arboretum in Tahura WAR shows that there was a change in forest health. The change can be caused by change in the value of each parameter due to the change in forest condition. In general, the change can be caused by the activities conducted by the surrounding, the management authority of Tahura WAR, and environmental factors. Also, there is possible for the interactions of such causes which make impacts on the health of Tahura WAR (Porter-Bolland et al. 2012). Therefore, if the activities and management are done correctly, then the forest's health condition will improve and vice versa.

In summary, the study assessed the status of forest health of the prospective arboretum in Tahura WAR which found the first measurement indicated that 50% of plot clusters had a status of bad, while 25% was good and 25% was moderate. Nonetheless, there was a change that 50% of plot clusters had a moderate status, while 25% was good and 25% was bad in the second measurement. This finding suggests that the prospective arboretum experienced changes toward better conditions in health status. Even so, it is still necessary to carry out regular forest health monitoring activities to determine trends. The results of this study can be used as the baseline information for the management and conservation of Tahura WAR.

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