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Effects of Anthropogenic Factors on Tree Health in Natural Forests Within Customary Forest Areas of Beungga Village, Aceh Province, Indonesia

[1]Ade Putra, [1,2]*Ichwana Ramli and [3]Dahlan

1. Master Program of Environmental Management, Graduate School, Syiah Kuala University, Banda Aceh, Indonesia
2. Department of Agricultural Engineering, Faculty of Agriculture, Syiah Kuala University, Banda Aceh, Indonesia*
3. Department of Forestry, Faculty of Agriculture Universitas Syiah Kuala University, Banda Aceh, Indonesia

*Correspondence email: ichwana.ramli@usk.ac.id

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Abstrak: Hutan alam di wilayah daratan tinggi Provinsi Aceh memiliki peran penting dalam menjaga keseimbangan ekosistem, namun tekanan aktivitas manusia (antropogenik) berpotensi menurunkan kualitas dan kesehatan pohon. Penelitian ini bertujuan untuk menilai status kesehatan pohon serta mengidentifikasi faktor antropogenik yang memengaruhinya di hutan alam kawasan hutan adat Desa Beungga, Provinsi Aceh, menggunakan metode Forest Health Monitoring (FHM) yang menilai kerusakan pohon melalui Tree Damage Level Index (TDLI) dan kondisi tajuk melalui Visual Crown Rating (VCR), serta analisis skala Likert untuk faktor antropogenik. Hasil penelitian menunjukkan kondisi kesehatan pohon relatif baik, dengan nilai rata-rata 6,7 (kategori sangat sehat). Tipe kerusakan paling dominan adalah luka terbuka pada batang pohon, sebagian besar disebabkan oleh aktivitas manusia, sementara kondisi tajuk secara umum baik, menunjukkan fungsi fisiologis pohon masih berjalan optimal. Faktor antropogenik paling berpengaruh adalah penebangan ilegal dan perambahan hutan, keduanya berkategori tinggi berdasarkan skala Likert. Secara keseluruhan, meskipun tekanan aktivitas manusia masih terjadi, kondisi kesehatan pohon di kawasan ini masih tergolong baik, namun tetap memerlukan pengelolaan dan pengawasan berkelanjutan untuk menjaga stabilitas ekosistem hutan.

Kata kunci: kesehatan pohon; faktor antropogenik; Forest Health Monitoring (FHM); hutan adat.

Abstract: Natural forests in the highland areas of Aceh Province play an important role in maintaining ecosystem balance; however, pressure from human (anthropogenic) activities has the potential to reduce tree quality and health. This study aims to assess tree health status and identify the anthropogenic factors affecting it in the natural forest of the customary forest area of Beungga Village, Aceh Province, using the Forest Health Monitoring (FHM) method, which evaluates tree damage through the Tree Damage Level Index (TDLI) and crown condition through Visual Crown Rating (VCR), along with Likert scale analysis to examine anthropogenic factors. The results show that overall tree health is relatively good, with an average value of 6.7 (very healthy category). The most dominant type of damage is open wounds on tree stems, largely caused by human activities, while crown conditions are

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generally in the good category, indicating that the physiological functions of trees remain optimal. The most influential anthropogenic factors are illegal logging and forest encroachment, both categorized as high based on the Likert scale. Overall, although pressure from human activities persists, tree health condition in this area remains relatively good, though it still requires sustainable management and monitoring to maintain forest ecosystem stability.

Keywords: tree health; anthropogenic factors; Forest Health Monitoring (FHM); customary forest

1. Introduction

Forests are complex ecosystems that sustain the balance of natural resources through ecological functions such as carbon sequestration, water cycle regulation, biodiversity conservation, and the provision of ecosystem services supporting human well-being, while also acting as critical habitat for flora and fauna and a regulator of climate stability and hydrological cycles [1], [2], [3]. Although human-forest interactions can be sustainable when properly managed, globalization and rapid population growth have intensified pressure on forest ecosystems through land conversion and unsustainable resource exploitation, inducing physiological stress in trees and reducing vegetation resilience; nevertheless, local communities continue to play a crucial role in supporting long-term forest sustainability when management practices are appropriately applied [5].

Forest management authority in Indonesia largely rests with central and regional governments, which often adopt a mono-interpretative approach overlooking local communities, increasing conflict potential and limiting adaptability to local conditions [6]. Aceh Province still retains approximately 54% forest cover, with its highland forests forming part of the Leuser Ecosystem and playing a crucial role in regional stability; however, the past decade has seen declining primary and secondary forest cover driven by land-use change for agriculture and settlement expansion, indicating high vulnerability to anthropogenic pressure [7].

Anthropogenic activities, including illegal logging, forest encroachment, and land-use conversion, are among the primary drivers of forest degradation

in Indonesia [8], directly impairing tree health through physical damage and physiological stress that increase susceptibility to pests and disease. Declining tree health is therefore a key indicator of forest ecosystem quality and ecological risk, closely linked to forest productivity and long-term sustainability of ecological functions [9].

Studies examining the effects of anthropogenic factors on tree health in Aceh Province remain relatively limited. Previous research, such as Darmadi et al. (2018), which investigated anthropogenic damage in the Cot Girek forest ecosystem, primarily focused on identifying forest degradation caused by human activities, including logging, land-use conversion, infrastructure development, and other disturbances affecting forest structure and ecological functions. However, the study did not quantitatively examine the relationship between anthropogenic activities and tree health using standardized forest health indicators, particularly in customary forests [10]. This study addresses this gap by integrating the assessment of anthropogenic disturbance intensity with the *Forest Health Monitoring* (FHM) approach to analyze its relationship with tree health based on the *Tree Damage Level Index* (TDLI) and *Visual Crown Rating* (VCR). The findings are expected to provide a scientific basis for more effective and sustainable management and conservation of customary forests in Aceh Province.

This study aims to assess tree health status and identify the anthropogenic factors influencing tree health in natural forests within customary forest areas in Aceh Province, providing an evidence-based foundation for sustainable forest management and conservation policy.

2. Research Method

This study was conducted in January 2026 in a natural forest within a customary forest area in Beungga Village, Tangse District, Aceh Province, covering approximately 565 hectares with a population of around 417 residents. Instruments and materials used for field data collection included a measuring tape, phi-band, 50-meter tape measure, compass, GPS device, clinometer, camera, fisheye lens, voice recorder, tally sheets, magic cards, and

questionnaires. This study employed a mixed-methods approach, combining quantitative methods to assess tree health with qualitative methods to identify influencing anthropogenic factors, drawing on a vegetation population (all trees within the study area) and a social population (local communities surrounding the forest), as illustrated in Figure 1.

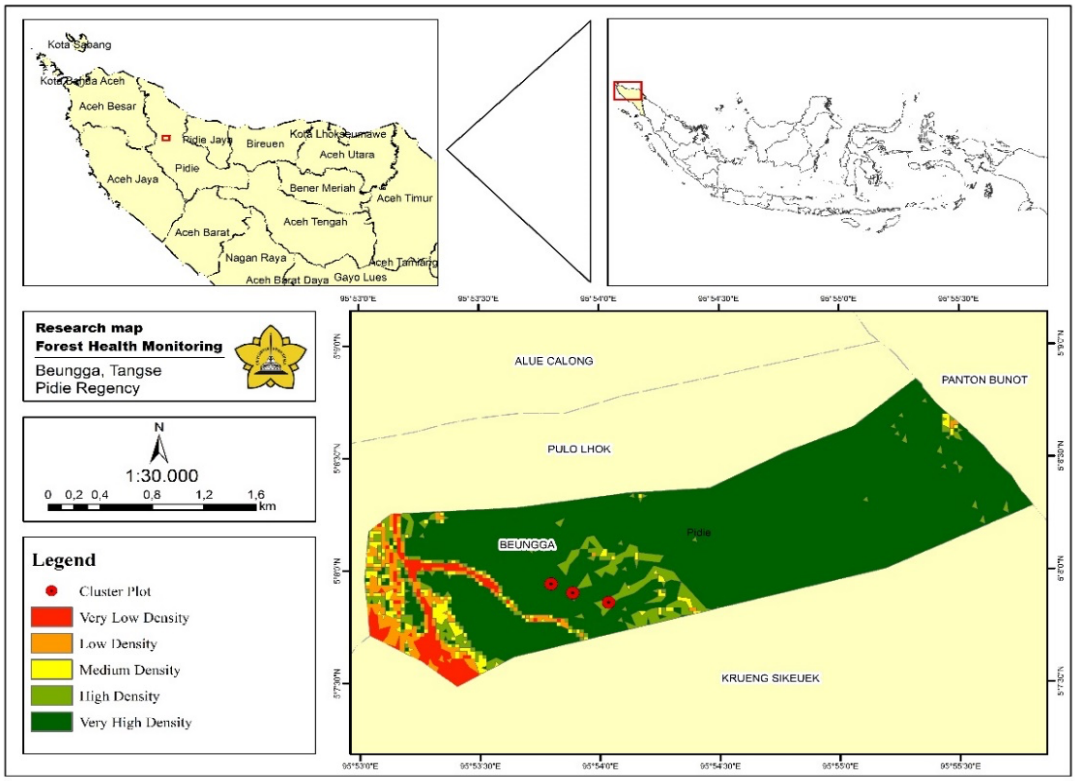


Figure 1. Study location

Vegetation data were collected using a purposive sampling approach with a random start based on vegetation-density classes, namely very dense, dense, and moderately dense; areas with low and very low density were excluded from sampling [11]. The number of Forest Health Monitoring (FHM) cluster plots was determined using a sampling intensity of 0.2% of the total study area, following the Regulation of the Minister of Forestry of the Republic of Indonesia No. P.67/Menhut-II/2006, resulting in three cluster plots of approximately 1 ha each, consisting of four circular subplots, distributed across the three vegetation-density classes to ensure representative tree health assessment. In addition, respondents were selected using purposive and

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snowball sampling techniques, with the sample size determined using the Slovin formula (15% margin of error), resulting in a total of 40 respondents.

Tree health was assessed using the FHM method through a cluster plot design, based on tree damage and crown condition. Tree damage was evaluated according to the location, type, and severity of damage, quantified using the Damage Index (DI) and Tree Damage Level Index (TDLI):

$$IK1 = Xi \times Yi \times Zi$$

where IK is the Damage Index, i is the weighting value of the i-th parameter, and X, Y, and Z represent the weights assigned to damage location, type, and severity threshold, respectively.

$$TDLI = IK1 + IK2 + IK3$$

Crown condition was assessed using the Visual Crown Rating (VCR) method based on live crown ratio, crown density, crown transparency, crown diameter, and dieback [10]. The final tree health value was obtained by combining TDLI and VCR:

$$\text{Final Tree Health Value} = TDLI + VCR$$

Information:
TDLI = Tree Damage Level Index
VCR = Visual Crown Rating

Anthropogenic data were collected through field observations, in-depth interviews using Likert-scale questionnaires, and documentation to identify activities such as illegal logging, forest encroachment, and forest resource utilization. The questionnaire, consisting of 20 statements representing anthropogenic disturbance indicators, was tested through a pilot study involving 27 respondents prior to the main survey to evaluate its validity and reliability. Validity was assessed using the Pearson Product Moment correlation in IBM SPSS Statistics version 25, with items considered valid when the calculated correlation coefficient exceeded the critical value (rtable = 0.381) at $p < 0.05$; 17 of the 20 items met this criterion and were retained for subsequent analysis. Reliability was evaluated using Cronbach's Alpha, yielding a value of 0.819, indicating good internal consistency ($\alpha > 0.70$). Responses were scored

using a five-point Likert scale (1 = strongly disagree, 5 = strongly agree), with the score for each anthropogenic indicator obtained by summing the valid items and calculating the mean, which was then classified into five categories (very low to very high) based on predetermined interval ranges [12][13]. Two formulas were used to derive the final Likert-scale scores:

Interval formula : I = T/Pn
Percentage index formula : Total Score/Y x 100

where T is the total number of respondents selecting a given option, Pn is the Likert scale score category, I is the interval range, and Y is the highest possible score. Average scores were interpreted using the assessment categories in Table 1, based on the interval ranges [14].

Table 1. Assessment categories based on score interval ranges

No	Score Range	Category
1	5 – 9	Very Low
2	10 – 13	Low
3	14 – 17	Moderate
4	18 – 21	High
5	22 – 25	Very High

Tree health and anthropogenic data were analyzed descriptively, using the damage index and health-level classification for tree health, and the Likert scale for anthropogenic factors, then compared across study clusters.

3. Results and Discussion

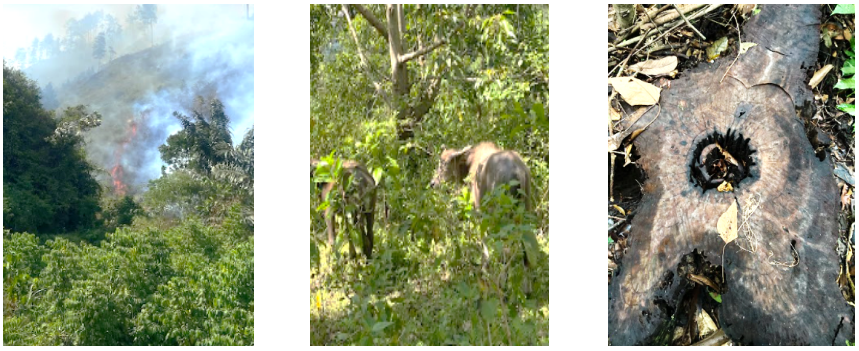
a. Identification of Questionnaire Results and Factors Influencing Tree Health

The forest encroachment factor in Beungga Village was classified as high, indicating that land-clearing activities continue to affect tree health. Nevertheless, positive community perceptions of forest functions, combined with customary-based management practices, appear to help mitigate the extent of damage. Shifting cultivation was classified as moderate (14.75), reflecting comparatively lower pressure than other anthropogenic factors. In addition, nearly all respondents (99%) reported never having observed forest

fires, suggesting that the impact of slash-and-burn practices on tree health in the Beungga customary forest remains relatively well controlled [15].

Table 2. Average Scores of Anthropogenic Factors Affecting Tree Health (Likert Scale)

No	Variable	Average Score	Criteria
1	Forest encroachment (X1)	17.80	High
2	Shifting cultivation (X2)	14.75	Moderate
3	Uncontrolled grazing (X3)	17.65	High
4	Illegal logging (X4)	18.18	High



(a) (b) (c)

Figure 2. Anthropogenic activities in the natural forest of the customary forest area in Beungga Village: (a) Land burning activities in the forest, (b) Livestock Activities within Forest Areas, (c) Illegal logging activities.

Uncontrolled grazing was classified as high (17.65) and is associated with potential soil compaction and inhibited tree regeneration (Table 2). Similarly, illegal logging in Beungga Village was classified as high (18.18) and represents one of the primary factors contributing to the decline in tree health (Figure 2), largely driven by economic necessity and persisting despite the presence of customary social controls, underscoring the need for strengthened monitoring and community empowerment [16].

b. Tree Health Levels in Natural Forests

Across the three cluster plots in the Beungga customary forest, a total of 74 trees were recorded, dominated by pine, kemiri (candlenut), and melinjo. Open wounds were the dominant type of damage, accounting for 33% (47 of 144 damage points) of total recorded damage across all clusters (Table 3), generally resulting from both anthropogenic factors, such as logging and tool use during forest management, and natural factors, including strong winds and destructive organisms; such wounds may serve as entry points for pathogens

that reduce tree health [17]. The presence of lianas and leaf damage further contributes to declining tree vitality through resource competition and physiological disturbance. Overall, damage in Beungga Village remains dominated by mild to moderate physical disturbances, which could intensify into more severe damage without proper management.

Table 3. Number of tree damage points in the natural forest of the customary forest area in Beungga Village

No	Tree Species Name	Damage Code																Total
		1	2	3	4	5	6	11	12	13	20	21	22	23	24	25	31	
1	Ara	1		1	1													3
2	Balik Angin										1							1
3	Belimbing wuluh		1	2		1					1	1						6
4	Beringin	1		3		1					1		1					7
5	Damar	1		2														3
6	Durian			1		3	1	1	2	1			2	1	1	1		14
7	Jambu Bol		1	1											1			3
8	Jati Putih																	0
9	Karsen			1														1
10	Kayu Manis			3		1							1		1			6
11	Kemiri	2		7	1	1	2		3		3	2	1	3	3	1		29
12	Mancang			2												1		3
13	Melinjo	3	1	8							2	1	2			3		20
14	Pagar anak										1							1
15	Pala			2			1					2						5
16	Pinus	1	1	12	3	2	1				2	2	3		1			28
17	Seumantok	1				1							1					3
18	Sukun	1		2		1						1			1			6
19	Tampu												1		1	2		4
20	Tingkem					1												1
Total		**11**	**4**	**47**	**5**	**12**	**5**	**1**	**5**	**1**	**11**	**9**	**12**	**4**	**9**	**8**	**0**	**144**
Persentase (%)		**8**	**3**	**33**	**3**	**8**	**3**	**1**	**3**	**1**	**8**	**6**	**8**	**3**	**6**	**6**	**0**	**100**

Note: Code 1 = cancer, code 2 = heart rot, code 3 = open wound, code 4 = exudation (resinosis or gummosis), code 5 = split stem, code 6 = termite nest, code 11 = broken stem < 0.91 m, code 12 = broom on roots or stem, code 13 = injured or dead roots, code 20 = liana, code 21 = dieback, code 22 = broken or dead branch, code 23 = broom on branch or crown, code 24 = foliage and shoot damage, code 25 = discolored leaves.

Based on Figure 3, the most dominant damage occurred in the crown stem area (30 damage points), followed by the lower stem and foliage (24 and 22 points, respectively), while the least damage was found in the lower and upper stem sections (5 points), indicating that tree damage in the area occurs primarily in the crown region. The most dominant severity level fell within the 20–29% range (approximately 42 damage points), classified as moderate damage, while the low severity class (0–9%) was least frequently observed (Figure 4), suggesting that most trees experience moderate-level disturbance with potential effects on overall stand health. This distribution reflects considerable ecological pressure, though not yet at severe levels, based on

indicators of damage location, type, and severity used to comprehensively describe forest health condition [18].

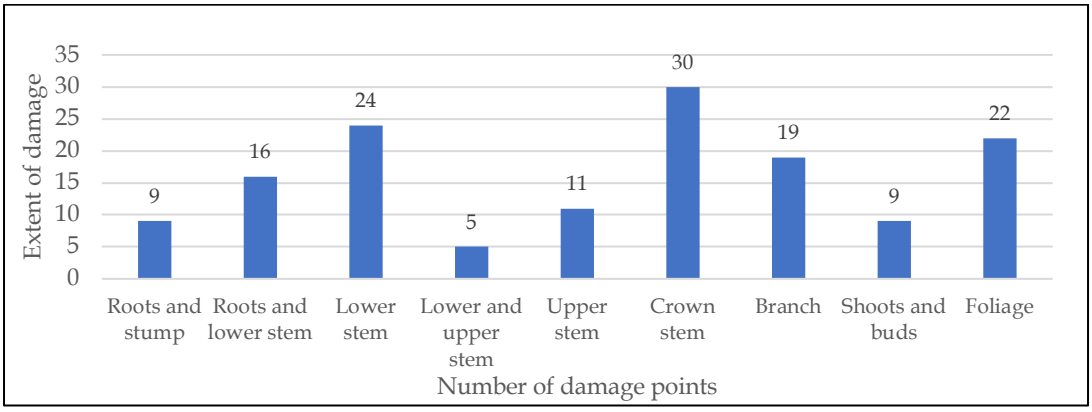


Figure 3. Number of forest damage locations in the natural forest of the customary forest area in Beungga Village

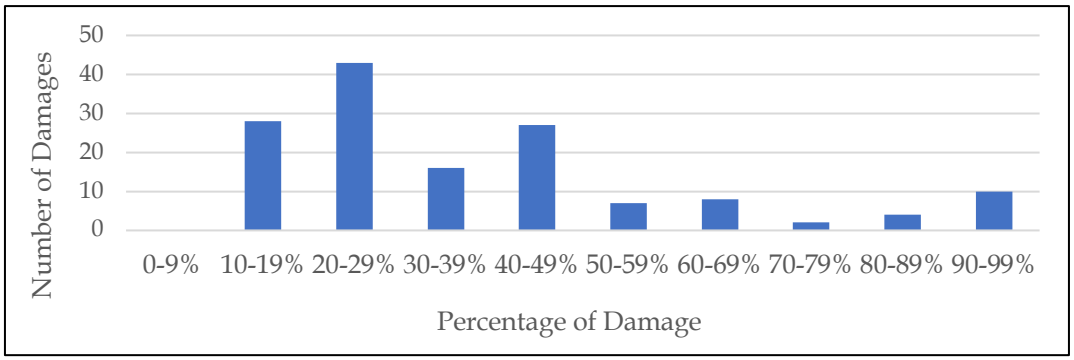


Figure 4. Severity Value in the Natural Forest of the Beungga Customary Forest Area

The tree health condition in the Beungga customary forest showed that, of 74 observed trees, 40 were healthy, 32 experienced light damage, and 1 tree each experienced moderate and severe damage, indicating that most trees remain in relatively good condition despite minor disturbances (Table 4). Lower damage index values generally reflect milder damage, while higher values indicate more serious levels, allowing the damage index to serve as a quantitative indicator of overall tree health.

Table 4. Damage Index Values in the Natural Forest of the Customary Forest Area

No	Value	Health Class	Number
1	0<5	Healthy	40
2	6 - 10.	Light Damage	32
3	11 - 15.	Moderate Damage	1
4	16 ≥ 20	Severe Damage	1
Total			**74**

Crown condition in the Beungga customary forest was generally classified as good (Table 5), with live crown ratio, foliage transparency, and dieback dominated by the "good" category (values of 55, 56, and 67, respectively), while crown density also indicated good condition (43) and crown diameter was predominantly moderate (47). These results suggest that crown physiology remains sufficiently optimal to support growth and ecological function, although the predominance of moderate crown diameter values indicates some pressure on crown development.

Table 5. Crown Condition in the Natural Forest of the Customary Forest Area

No	Crown Condition	Criteria		
		Good	Moderate	Unsatisfactory
1	Live Crown Ratio	55	18	1
2	Crown Density	43	23	8
3	Foliage Transparency	56	14	4
4	Crown Diameter	25	47	2
5	Dieback	67	5	2

Crown condition in Beungga, assessed from live crown ratio, crown density, crown transparency, crown diameter, and dieback, was dominated by the "good" category, with 32 trees classified as high, 29 moderate, 11 low, and 2 very low out of 74 trees (Table 6), indicating that most trees possess crown conditions supporting growth and vitality. This VCR pattern reflects the interrelationship among crown parameters, where crown diameter and live crown ratio determine crown size and density, while density is inversely related to transparency, overall indicating optimal light-capture capacity in Beungga's trees.

In the Beungga customary forest, the average TDLI value fell within the light damage category (3), while the average VCR was classified as moderate (3), together indicating adequate physiological function despite minor disturbances (Table 7). The combined TDLI and VCR results showed an average tree health score of 6.7, categorized as very healthy, with all cluster-level plots recording scores between 6 and 7, consistently classified as very healthy.

Table 6. Visual Crown Rating (VCR) Values in the Natural Forest of the Customary Forest Area

No	VCR Value	Number of Individual Trees
1	High (4)	32
2	Moderate (3)	29
3	Low (2)	11
4	Very Low (1)	2
Total		**74**

Table 7. Tree health status of natural forest clusters

Cluster	Density Type	TDLI Class	Category	VCR Class	Category	Health Value	Category
Cluster 1	Moderate	4	Healthy	3	Moderate	7	Very Healthy
Cluster 2	High	4	Light Damage	3	Moderate	7	Very Healthy
Cluster 3	Very High	3	Light Damage	2	Moderate	6	Healthy
Average	**–**	**3**	**Light Damage**	**3**	**Moderate**	**6.7**	**Very Healthy**

Overall, the relatively good ecological condition of Beungga customary forest, as indicated by the low level of tree damage and favorable crown conditions, suggests that vegetation functions remain well maintained. Maintaining vegetation cover plays an important role in sustaining forest carbon stocks. Conversely, forest degradation and changes in forest cover can reduce the capacity for carbon storage [19], [20] . This finding is consistent with Marifatul et al. (2023), who demonstrated that forest health assessments based on multiple indicators can provide a comprehensive representation of ecosystem condition and stability. Similarly, Bussotti et al. (2024) emphasized that crown condition is an important indicator of tree vitality and responses to environmental stress [21]. Nevertheless, the occurrence of illegal logging and forest encroachment indicates that anthropogenic pressures remain present and may increase tree damage and compromise forest health if they persist over time. Therefore, continued tree-health monitoring and strengthening of community-based forest management are important to maintain the ecological condition of the Beungga customary forest.

c. Anthropogenic Analysis of Tree Damage

The results indicate that open wounds were the dominant type of tree damage in the Beungga customary forest, accounting for approximately 33% of all recorded damage. This pattern suggests that mechanical disturbances are currently the primary form of tree injury within the study area. Open wounds

are commonly associated with the use of sharp tools during forest resource utilization, small-scale timber extraction, and other community activities, although they may also result from natural disturbances such as falling branches or animal activities. Ecologically, these wounds represent a critical point of vulnerability because they disrupt the protective bark tissues and facilitate the entry of pathogenic fungi, bacteria, and wood-decaying organisms, which may gradually reduce tree vitality if the damage is left untreated [22] [23]. Therefore, although open wounds were generally classified as minor damage, their ecological consequences may become more pronounced over time through cumulative pathogen infection and stem decay.

The dominance of open wounds observed in this study is consistent with previous Forest Health Monitoring (FHM) studies, which reported that mechanical injuries are among the most common indicators of tree damage in tropical forests subjected to moderate human disturbance [24] [25]. However, unlike production forests or highly disturbed conservation areas where severe crown deterioration frequently accompanies stem injuries, the Beungga customary forest exhibited relatively good crown conditions despite the occurrence of mechanical damage, suggesting that current anthropogenic disturbances remain localized and have not yet caused widespread physiological decline [26]. Although interviews and field observations confirmed the occurrence of illegal logging, forest encroachment, and forest resource utilization, these activities have not substantially reduced overall tree health, as reflected in the average tree health score of 6.7 (very healthy), indicating that most trees maintain adequate physiological function, photosynthetic activity, and crown integrity despite physical injuries.

Another important ecological interpretation is the role of customary forest governance. Customary regulations and community-based monitoring in Beungga customary forest appear to limit the intensity of anthropogenic disturbances and prevent more severe ecological degradation. Similar observations have been reported by Rosenfield et al. (2023), who emphasized that ecological integrity depends not only on reducing external disturbances but

also on maintaining effective governance systems capable of preserving ecosystem stability and resilience [27]. Consequently, the relatively good tree health observed in this study likely reflects the combined effects of moderate disturbance intensity and effective local governance.

Overall, anthropogenic activities in the Beungga customary forest mainly cause mechanical damage, while the ecosystem remains resilient and maintains its ecological function. However, illegal logging and forest encroachment could reduce this resilience, highlighting the need for stronger community participation, monitoring, and customary regulations to sustain tree health and forest ecosystems.

4. Conclusion

The results showed that tree health in the Beungga customary forest was generally classified as very healthy, with an average health score of 6.7. Although several types of tree damage, particularly open wounds, were observed, the generally favorable crown condition indicates that most trees have maintained their physiological functions. Field observations, interviews, and questionnaire surveys identified illegal logging, forest encroachment, and forest resource utilization as the main anthropogenic activities occurring within the study area. These findings provide baseline information on tree health conditions and the presence of anthropogenic disturbances in the Beungga customary forest, which can serve as a reference for future monitoring programs and further studies employing inferential statistical analyses to evaluate the relationship between anthropogenic factors and tree health.

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