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Factors Affecting Community-Managed Forest Health

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Abstract Forest quality is essential to be comprehended as a healthy forest would provide various benefits. The quality of forests may be found through the measurement of forest health. Internal and external factors could be measured to determine the level of forest health. Internal factors are factors related to the biophysical state of the forest ecosystem, whereas external factors are related to the manager's state. Forest health could be identified in forests managed by communities, such as forest areas managed by the Sustainable Community Forest System Group (SHK) located at Teluk Pandan District, Pesawaran Regency, Lampung Province. This study aims to identify internal and external factors related to the conservation forests' health managed by SHK Lestari. This research utilized the multiple linear analysis method. The results indicated internal factors that improved the forest health levels are biodiversity indicators, in which the parameter is tree type diversity index (H'), the vitality indicators, in which the parameter is tree damage (Cluster-plot Level Index - CLI) and visual crown ratio (VCR), as well as tread quality index, in which parameter is soil pH value. External factors that affect forest health levels are farmers' level of knowledge (FKL), farmers' motivation (FMo), and farmers' participation (FP).

Keywords Forest Health, Internal Factors, External Factors, SHK Lestari, Multiple Linear Analysis

1. Introduction

Forests have abundant natural resources that could offer benefits, both direct and indirect benefits. The abundant benefits of forests allow forests to have significant contributions to the national development. Therefore, the preservation of forests must be considered. The preservation of the forest could be determined by understanding the forest health. Efforts to control forest level of destruction could guarantee and facilitate benefits and the forests' function which is known as forest health [1].

Forest health could be identified in forests managed by communities, such as forest areas managed by the Sustainable Community Forest System Group (SHK) located in Teluk Pandan District, Lampung Province. This area is part of the conservation area of Wan Abdul Rachman Forest Park (Tahura WAR).

Forest land's tenure by communities in and around the forest are very important factors for the research, as there is a historical relationship between the forest land tenure that has been carried out in managing natural resources. Communities around the forest have long lived with the rules, values and norms that prevailed for generations. This has strengthened the rights to natural resources recognized by the community [2].

Based on [3] research, the status and changes in the conservation forests' health managed by SHK Lestari on average are in the moderate category. This could be caused by several factors, such as factors related to the biophysical conditions of forest ecosystems (internal factors) [4] as

well as the condition of managers (external factors).

Internal factors are generally seen from ecological indicators of forest health, namely biodiversity indicators, productivity indicators, vitality indicators, and tread quality indicators. External factors are generally seen from the condition of the managers, such as the level of knowledge, motivation, participation, and the way of management is conducted. Based on the aforementioned, this study aims to identify internal and external factors related to the conservation forests' health managed by SHK Lestari.

2. Materials and Methods

SHK Lestari forest management area is the location of study, which is included in Tahura WAR conservation forest, Teluk Pandan District, Lampung Province. The study utilized internal factor data and external factor data. Internal factor variable data used were biodiversity with tree type diversity index parameters, vitality with tree damage and header conditions parameters, and tread quality with soil pH parameters. [3] measured the forest health's ecological indicators using the FHM method to obtain the data on internal factor variables. SIPUT (*Sistem Informasi Pemantauan Kesehatan Hutan*) software is utilized to calculate and analyze the internal factor data.

Data on external factors utilized the variables, including the level of knowledge of farmers, farmer participation, farmer motivation, and forest management. External factor data was obtained through the interview method of 32 respondents (forest management farmers in SHK Lestari Group management areas) through questionnaires. The withdrawal of samples at the research site was carried out by using the purposive sampling method. Internal factor data and external factors that have been obtained were then analyzed to identify the relations by using regression analysis methods.

Variable X as an internal factor of forest health (diversity of tree species, CLI, VCR, and soil pH) in which the data was obtained from the calculation of ecological indicators of forest health and external factors (farmer knowledge level, farmer participation, farmer motivation, and forest management) in which the data was obtained from questionnaire interviews of 32 respondents. Variable Y (dependent variable) as the forest health was gathered the forest health final value for each cluster plot.

Should the significance value be < 0.05 or t value was > t table, this indicates that the variable X has affects variable Y. However, should the significance value be > 0.05 or t value was < t table, then this indicates that the variable X does not affect variable Y.

3. Results and Discussion

3.1. Assessment of Forest Health Changes

Data measured in 2 assessments of forest health change were biodiversity indicators in which the parameter was the tree type diversity index (H'), vitality indicators in which the parameter was the tree damage (Cluster-plot Level Index - CLI) and the visual crown ratio (VCR) [5] [6] [7] [8], as well as tread quality index which parameter was the soil pH value. This research was conducted twice, in December 2019 and December 2020. Each parameter of the ecological indicator of forest health obtained an average value based on both measurements. This is presented in Table 1.

Table 1. Average value parameters of conservation forest health's ecological indicators on each FHM cluster-plot

Parameters of conservation forest health's ecological indicators	Parameters of conservation forest health's ecological indicators	
	1st measurement	2nd measurement
H’	1.01	1.01
CLI	2.45	2.23
VCR	3.17	3.64
Soil pH	5.08	5.59

Description:
H'= Tree Species Diversity Index
CLI = Cluster-plot Level Index
VCR = Visual Crown Ratio

The status and change in forest health values at the research site derived from the multiplication of forest health indicators' weighted values and parameter scores. Conservation forest health threshold values are 5.48 – 7.81 as good category, 3.15 – 5.47 as moderate category, and 0.82 – 3.14 as bad category. After the calculation, the final average value of forest health on the first measurement was 3.65 and the second measurement was 4.54. Thus, it could be concluded that the forest health value on both measurements at the average research site fall into the moderate category.

Based on the forest health final average value on both measurements, forest health at the location of study has shown signs of improvements. Improvement of conservation forest's health condition could be due to the stability of the tree species diversity's value which could have an effect on growth of the trees [9]. Furthermore, stable biodiversity values are established by a good silvicultural system [10].

The application of the silviculture system could be made by using weed control. Weed control aims to reduce the number of weed populations below the economic or ecological threshold [11]. Weeding activities are also required to be carried out so that there is no competition for light, soil moisture, and nutrients between weeds and plants. In addition, should this weeding activity was not carried out, the plant would become undernourished [12].

Decreased condition of tree damage could also affect the increase in the health value of forests. Reducing the condition of tree damage could also affect the increase in the value of forest health. Therefore, a healthy conservation forest must comprise of healthy tree stands, thus it is very important to comprehend the level of tree damage as an early warning. It also could provide information about forest sustainability and flexibility [13]. Tree damage symptoms are seen in texture, size, color, and shape [114] [15].

Tree damage usually occurs due to pathogens, pests, the drought of natural conditions or activities often carried out by humans, such as logging [16]. Efforts that could be done to eradicate pests and diseases are maintenance activities such as weeding and cultivation. Weeding techniques must be carried out appropriately as if the techniques were not conducted appropriately, it would interfere with the forest trees and forest floor vegetation so as to disrupt their growths [17].

Damage to the trees caused by natural conditions may be caused by availability of oxygen, air pollution, light, climate, nutrients, humidity, and temperature [18]. However, based on the field observations, the aspect causing the most damage to the tress were broken branches and broken leaves/shoots. Broken branches were generally created from tree borer pests that prefer to attack the branch due to its softer nature. This type of damage to broken branches could be overcome by tree maintenance, such as pruning branches that have been indicated by fungi and parasites [14] [19].

Symptoms caused by the type of damage to the leaves / dead shoots are the death of the ends on the tree. This could be caused by low temperatures, dry seasons, pest attacks, and diseases that attack the leaves [20]. The damage suffered by the leaves became one of the locations of alarming damage. Leaves serve as a place for photosynthesis to provide energy to the growth process. [21] explained that if the leaves were damaged, the photosynthesis result would be little or not optimal, thus this condition would cause low energy or food reserves for tree growth and causes stunted the tree growth.

In addition, the increased pH value of the soil may also affect the increase in the health value of forests. This indicates that the tree will experience optimal growth if the forest is supported by good soil fertility [22]. Good soil fertility could be caused by fertilization activities carried out by managing farmers. All soil would require application of significant fertilizer element for the establishment and maintenance of any plants community [23]. The most commonly used fertilizer is organic fertilizer. Indirectly, organic fertilizers positively affect plants to improve soil nutrition, store soil organic carbon, and increase the soil pH value [24].

Organic matter in organic fertilizers could increase soil cation exchange capacity, soil pH, and crop yield [25]. Organic matter also improves the soil's biological, chemical, and physical properties. Biologically, organic matter influences the activities of macroflora and microfauna organisms, chemically plays a role in providing N, P, and K and physically plays a role in improving soil structure [26]. Organic matters also affect soil fertility rate and organic material content is an indicator of soil fertility [27].

3.2. Factors Affecting the Health of Conservation Forests

Factors affecting the conservation forests' health level could be found through multiple linear regression tests. This multiple linear regression test consists of one bound variable, namely the forest health final value (NKH) and eight free variables, namely biodiversity indicators in which the parameter was tree type diversity index (H'), vitality indicators in which the parameter were CLI and VCR, as well as tread quality index in which parameter was soil pH value as an internal factor and farmer's knowledge level (FKL), farmer participation (FP), farmer motivation (FMo), and forest management (FMa) as external factors. Linear regression tests were performed for the results of the first and second measurement studies. The results of the linear regression test multiple of the internal factors of the first measurement are shown in Table 2.

Table 2. Linear Regression Test Results in Multiple Influence of Free Variables (Internal Factors) On Variables Bound to The First Measurement

Variable	Unstandardized Coefficients		Standardized Coefficients	t	Significant
	B	SE	Beta		
(Const.)	-2.435	4.317		-.564	.053
X1 (VCR)	.081	.894	.054	.090	.943
X2 (CLI)	.323	.838	.272	.385	.766
X3 (H' Tree)	1.060	.951	.832	1.116	.046
X4 (Soil pH)	1.165	1.171	.478	.995	.042
R = 0.909[a] R Square = 0.129. F = 304.952 Sig = 0.049[b]					

Description:
H'= Tree Species Diversity Index
CLI = Cluster-plot Level Index
VCR = Visual Crown Ratio

The equation of the multiple linear regression formula was obtained based on table 2 are as follows:

$$Y = -2.435 + 0.081X1 + 0.323X2 + 1.060X3 + 1.165X4$$

Description:
Y = bound variable
A = constant (Y value if X1, X2, X3,…Xn = 0)
X1, X2, X3, X4 = free variable
B = regression coefficient

Determination analysis results in Table 2 obtained the number R Square of 0.129 (12.9%). This indicates the percentage of free variable influence contribution (VCR, CLI, H' Tree, and Soil pH) to the bound variable (forest health final value) of 12.9%. The constant correlation coefficient value is 2.435, meaning that should each free variable be 0 (zero), the forest health's final value shall be 2.435. The regression coefficient test results collectively obtained the value F calculated by 304.952 and sig value of 0.049 < 0.005. This means that the free variable (H' Tree and soil pH collectively have a significant effect on the final value of forest health.

Table 3 presents the linear regression test multiple results of second measurement internal factors. The determination analysis results in Table 3 obtained the number R Square of 0.998 (99.8%). This shows the percentage of free variable influence contribution (VCR, CLI, H'Tree, and Soil pH) to the bound variable (forest health final value) of 99.8%. The constant correlation coefficient value is 2.694, meaning that should the free variable be 0 (zero), the forest health final value shall be 2.694. The regression coefficient test results collectively obtained a calculated F value of 703.250 and a sig value of 0.028 < 0.005, meaning that free variables (VCR, CLI, and H' trees) collectively have a significant effect on the the forest health final value.

Table 3. Linear Regression Test Results in Multiple Influence of Free Variables (Internal Factors) On Variables Bound by Second Measurement

Variable	Unstandardized Coefficients		Standardized Coefficients	t	Significant
	B	SE	Beta		
(Const.)	2.694	.138		19.573	.032
X1 (VCR)	.331	.025	.433	13.333	.098
X2 (CLI)	-.642	.032	-.626	-19.905	.032
X3 (H'Tree)	.918	.057	1.021	16.197	.039
X4 (Land pH)	-.657	.081	-.629	-8.124	.078
R = 1.000[a], R Square = 0.998. F = 703.250, Sig = 0.028[b]					

Description:
H' = Tree Species Diversity Index
CLI = Cluster-plot Level Index
VCR = Visual Crown Ratio

The equation of the multiple linear regression formula was obtained based on table 4 as follows:

$$Y = 2.694 + 0.331X1 – 0.642X2 + 0.918X3 + 0.657X4$$

Information:
Y = bound variable
A = constant (Y value if X1, X2, X3,…Xn = 0)
X1, X2, X3, X4 = free variable
B = regression coefficient

Regression test results show that the four forest health's internal factors affect the forest health final value, namely biodiversity indicators in which the parameter was tree type diversity index (H'), vitality indicators in which the parameter were CLI and VCR, as well as the tread quality index in which parameter was soil pH value. Partial test results (test t) of the effect of internal factor-free variables on boundvariables are as follows:

Effect of Tree Damage (CLI) on the Forest Health Final Value

The CLI t-count value is negative 19.905 and the sig value is 0.039 <0.05 with a negative regression coefficient value of 0.642 in the second measurement (Table 3). This suggests the CLI has a negative and significant effect on the forest health final value. The negative correlation coefficient (0.642) values mean that if the CLI value drops by 1%, then the final value of forest health will increase by 0.642%, assuming another free variable the value remains.

The results showed the average CLI value was relatively low. Low CLI values are due to not many types of damage to trees contained in cluster-plot research. The presence of pests and pathogens can cause tree damage that affects the health of forests [28]. At the research site, damage to leaves and shoots due to pests and diseases is commonly found. The process of photosynthesis and plant growth can be inhibited caused by damage to the leaves [29].

Open wound damage is another type of damage that is commonly found in the research location. This type of damage will interfere with the activity of transporting water and nutrients from the soil to the leaves. Disruption of nutrients and water transport will result in an imbalance of nutrient and water supply to the part of the tree above it and reduced carbohydrate reserves [30].

Effect of Biodiversity or Species Diversity (H' Trees) on the Forest Health Final Value

The positive tree's T count value H' was 16.197 and the sig value of 0.032 < 0.05 with a positive regression coefficient value of 0.918 on the first and second measurements (Table 2 and Table 3). This suggests that forest health final value was positively and significantly affected by H' tree. The positive correlation coefficient value (0.918) means that should the value of H' trees rise by 1%, then the final value of forest health shall increase by 0.918%, assuming other free variables' value remains.

Tree species diversity often has a positive effect on tree growth [9]. Stable community growth and maintained forest ecological balance are reflected in the high value of biodiversity [31]. High stability indicates a forest that has high capability to overcome disturbances [32]. Due to the low diversity of tree species, the value of tree species

diversity in research sites tends to be low. The dominating tree species were Gnetum gnemon *(melinjo),* bitter bean *(Parkia speciosa),* and durian *(Durio zibethinus).*

Effect of Tread Quality (Soil pH Value) on the Forest Health Final Value

The t value of positive soil pH was 0.995 and the value of sig was 0.042 <0.05 with a positive regression coefficient of 1.165 in the first measurement (Table 2). This indicates that forest health final value was positively and significantly affected by the pH of the soil. The value of the positive correlation coefficient (1.165) means that should the pH value of the soil rise by 1%, then the final value of forest health shall increase by 1.165%, assuming other freevariable's value remains.

A high soil pH value in a location could indicate that the soil in that location has a high soil fertility rate as the soilis able to ensnare and provide nutrients better and it could withstand plant nutrients. Plant nutrition in available form was indispensable for plant growth.

Soil formation is determined by the effects and interactions of various factors such as raw materials (parent rock), climate, flora and fauna, topography, time, and anthropogenic effects. Soil acquires a variety of properties (natural chemicals and biologicals) that are directly related to its use for particular purpose [33].

Table 4. Linear Regression Test Results in Multiple Influence of Free Variables (External Factors) On Variables Bound to First Measurement

Variable	Unstandardized Coefficients		Standardized Coefficients	t	Significant
	B	SE	Beta		
(Const.)	4.069	.679		5.994	.105
X5 (FKL)	.672	.175	.345	3.843	.162
X6 (FP)	4.879	.298	.1799	16.366	0.39
X7 (FMo)	4.569	.300	1.828	15.224	.042
X8 (FMa)	.500	.161	-.253	-3.109	.198
R = 1.000[a] R Square = 0.996. F = 301.833 Sig = 0.043[b]					

Information:
FKL = Farmer Knowledge Level
FP = Farmer Participation
FMo = Farmer Motivation
FMa = Forest Management

Table 4 presents the linear regression test multiple results of the first measurement external factors. The determination analysis results (Table 4) obtained the number R Square of 0.996 (99.6%). This shows the percentage of freevariable influence contribution (FKL, FP, FMo, and FMa) to the bound variable (forest health final value) of 99.6%.The constant correlation coefficient value was 4.069, meaning that should each free variable be 0 (zero), the forest health final value shall be 4.069. The regression coefficient test results collectively obtained the value F calculated 301.833 and sig value of 0.043 < 0.005, which means that the independent variables (FP and FMo) collectively have a significant effect on the forest health final value.

The equation of the multiple linear regression formula was obtained based on table 4 are as follows:

$$Y = 4.069 + 0.672X5 + 0.4879X6 + 4.569X7 + 0.500X8$$

Information:
Y = bound variable
A = constant (Y value if X1, X2,X3,…Xn = 0)
X5, X6, X7, X8 = free variable
B = regression coefficient

Determination analysis results (Table 4) obtained the number R Square of 0.996 (99.6%). This shows the percentage of free variable influence contribution (FKL, FP, FMo, and FMa) to the bound variable (forest health final value) of 99.6%. The constant correlation coefficient value was 4.069, meaning that should each free variable be 0 (zero), the forest health final value shall be 4.069. The regression coefficient test results collectively obtained the value F calculated of 301.833 and sig value of 0.043 < 0.005, which means that free variables (FP and FMo) collectively have a significant effect on the forest health final value.

Table 5. Linear Regression Test Results in Multiple Influence of Free Variables (External Factors) On Variables Bound to First Measurement

Variable	Unstandardized Coefficients		Standardized Coefficients	t	Significant
	B	SE	Beta		
(Const.)	4.069	.679		5.994	.105
X5 (FKL)	.672	.175	.345	3.843	.162
X6 (FP)	4.879	.298	.1799	16.366	0.39
X7 (FMo)	4.569	.300	1.828	15.224	.042
X8 (FMa)	.500	.161	-.253	-3.109	.198
R = 1.000[a] R Square = 0.996. F = 301.833 Sig = 0.043[b]					

Information:
FKL = Farmer Knowledge Level
FP = Farmer Participation
FMo = Farmer Motivation
FMa = Forest Management

Table 5 shows the linear regression test multiple results of external factors of the second measurement. The determination analysis results (Table 5) obtained the number R Square of 0.998 (99.8%). This shows the percentage of free variable influence contribution (FKL, FP, FMo, and FMa) to the bound variable (forest health final value) of 99.8%. The constant correlation coefficient value was 1.974, meaning that should each free variable be 0 (zero), the forest health final value shall be 1.974. The regression coefficient test results collectively obtained a calculated F value of 559.750 and a sig value of 0.032 < 0.005, which means that free variables (FKL and FP) collectively have a significant effect on the forest health

final value. The equation of the multiple linear regression formula was obtained based on table 5 are as follows:

$$Y = -1.975 + 0.813X5 + 1.144\ X6 + 0.287X7 - 0.662X8$$

Information:
Y = bound variable
A = constant (Y value if X1, X2, X3,…Xn = 0)
X5, X6, X7, X8 = free variable
B = regression coefficient

Farmers' Knowledge Levels (FKL) Effect on the Forest Health Final Value

The FKL positive t value is 3.843 and sig value 0.043 < 0.05 with a positive regression coefficient value of 0.672 on the second measurement (Table 5). This shows that forest health final value was positively and significantly affected by FKL. The positive correlation coefficient (0.672) value means that should the FKL value rise by 1%, the forest health final value shall increase by 0.672%, assuming other free variables' value remains.

The level of knowledge would affect the awareness and mindset of forest farmers to maintain forest sustainability to maintain the forest's health. Good forest conditions would increase the productivity of these forests so that farmers can still use forest products as a source of livelihood. Farmers' knowledge could increase if they are active in participating in discussions or meetings, thus becoming more open to management decisions in conducting forest management.

The level of knowledge may be increased with the conduct of counseling activities [34]. This extension activity will increase farmers' insights on how to manage forests so that forest health could be improved. Extension workers are expected to act as teachers, mentors, advisors, information transmitters, and farmer partners as development communicators.

Farmer's Participation (FP) Effect on the Forest Health Final Value

The FP count value is positive 16.366 and sig value 0.043 < 0.05 with a positive regression coefficient value of 4.879 on the first measurement (Table 4). This shows that forest health final value was positively and significantly affected by FP. The positive correlation coefficient value (4.879) means that should the FP value rise by 1%, the forest health final value shall increase by 4.879%, assuming other free variables 'value remains.

The FP count value is positive of 16.783 and the sig value of 0.032 < 0.05 with a positive regression coefficient value of1.144 on the second measurement (Table 5). This shows that forest health final value was positively and significantly affected by FP. The positive correlation coefficient value (1.144) means that should the FP value rise by 1%, the forest health final value shall increase by 1.144%, assuming other free variables' value remains.

Farmers' participation is the most important component in forest management and preservation [35]. High participation makes farmers more motivated in managing land, causing farmers to understand the conditions in the field better. This would allow the farmers to conduct good management decisions so that forests remain healthy and sustainable. The participation of farmers here is intended as the intensification of forest managers participating in community-based forest management (PHBM) activities. Participation in this study was seen based on the intensity of farmers' presence and contribution of thought during the meeting activities held by SHK Lestari. Farmers' participation through deliberations in the formulation of regulations has ensured compliance with this regulation as there is agreement between all members of the community [36].

The active participation of farmers could be influenced by the level of ability of farmers in conducting forest management, having high willingness to be involved in managing forests and supporting opportunities. High participation makes farmers more intense in managing forest land to have a better understanding of how to properly forest management. It was also supported by farmers who understand field conditions [37] so that the forest's health could be preserved. Furthermore, the participation of farmers in management programs would foster experience and a sense of belonging that at a later stage would be able to increase the sense of common responsibility and willingness to preserve forest areas.

Farmer's Motivation (FM) Effect on the Forest Health Final Value

The positive FM count value of 15.224 and sig value of 0.043 < 0.05 resulted in a positive regression coefficient value of 4.569 on the first measurement (Table 4). This suggests that forest health final value was positively and significantly affected by FM. The positive correlation of the coefficient (4.569) value means that should the FM value rise by 1%, the forest health final value shall increase by 4.569%, assuming other free variable's value remains. FM serves as the farmers' motivation to achieve the expected goals in managing their arable land.

High farmer motivation makes farmers feel encouraged to try to manage forests through appropriate management measures, both in economic, ecological, and social aspects, thus the forests are properly maintained and managed and the forest's health could be preserved [14]. Furthermore, high levels of motivation would motivate farmers to tend to plant many trees on their land [38]. More trees planted would positively impact the forest's health.

Therefore, the health of conservation forests at the research site has improved which was due to the active participation of the farmers at SHK Lestari Group in conducting forest management. The intensity of active management could be driven by various supporting factors, including the farmer's level of knowledge, active participation, and the motivation in managing the existing forest. This is supported by their management activities, such as silviculture actions, maintenance (fertilization,

disruption, weeding), and disease pest management.

4. Conclusions

The community's health level of forest management was affected by some factors, such as internal and external factors. Internal factors that persuaded forest health were biodiversity indicators in which the parameter was tree type diversity index (H'), vitality indicators in which the parameter were CLI and VCR, as well as the tread quality index in which parameter was soil pH value. External factors that affect forest health were farmer knowledge level (FKL), farmer motivation (FMo), and farmer participation (FP).

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