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ITTO PROJECT NO. PD 16/95 REV. 2 (F)

FOREST HEALTH MONITORING TO MONITOR THE SUSTAINABILITY OF INDONESIAN TROPICAL RAIN FOREST

MOF - ITTO - SEAMEO BIOTROP - USDA Forest Service

VOLUME II

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International Tropical Timber Organization
Yokohama, Japan

SEAMEO BIOTROP
Southeast Asian Regional Center for Tropical Biology
Bogor, Indonesia

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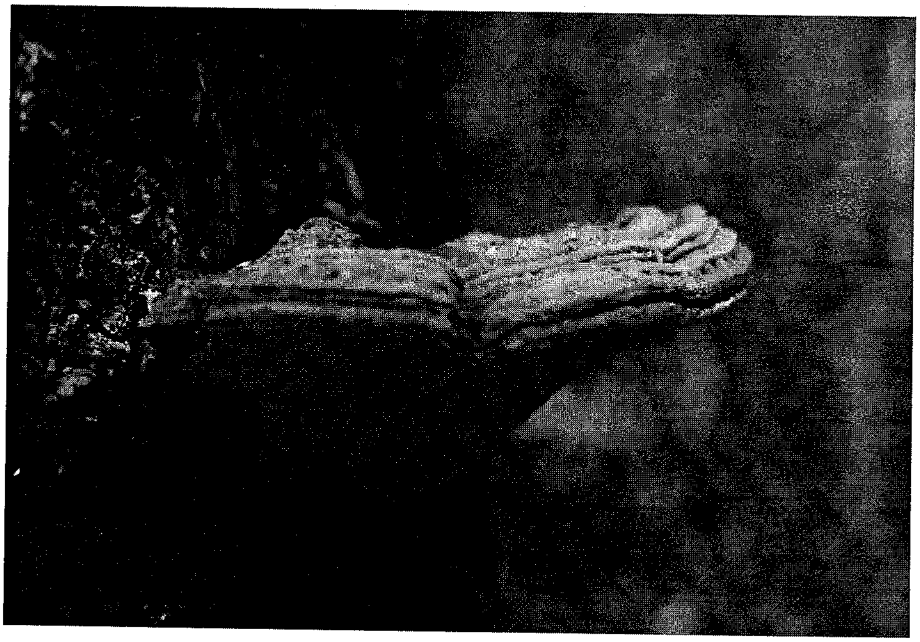

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PREFACE

Changes which occur in the forest ecosystem will always create an impact, positive as well as negative ones. Toward the implementation of ecolabelling, many forest state enterprises and the forest concession holders start reorganizing the future demands to manage forests on sustainable basis. Forests should be managed wisely according to the concept of sustainable forest management.

In 1990, ITTO (International Tropical Timber Organization) has prepared guidelines/indicators on how to manage tropical forests properly. In order to implement those guidelines, SEAMEO-BIOTROP submitted a research project proposal to ITTO entitled Forest Health Monitoring to Monitor the Sustainability of Indonesian Tropical Rain Forests, called INDO-FHM. The objectives of INDO-FHM were to find the attributes, indicators and trends which influence the health and conservation of tropical forest; to establish monitoring plots, demonstration and training plots; technology transfer of FHM methodology and software; and to undertake training programs. Indicators used among others are: (1) Production (growth and mortality, vegetation structures, biotic and abiotic stand damage); (2) Site quality; (3) biodiversity; and (4) Forest vitality (crown structure).

Previously, research activities in Forest Health Monitoring have been carried out only in the temperate forests. Indonesia is the first country to conduct FHM research in the tropical ecosystem.

The INDO-FHM research was conducted from 1996 – 2000, with the financial support from the ITTO, USDA-Forest Service, the Ministry of Forestry of the Republic of Indonesia, and SEAMEO BIOTROP. A series of training was also conducted for the Indonesian crews (85 persons), Indonesian scientists (28 persons), and Southeast Asian scientists (14 persons).

To disseminate the knowledge and experience generated in conducting the research on Forest Health Monitoring, three volumes of Technical Reports were made.

Finally, SEAMEO BIOTROP would like to thank ITTO, USDA-Forest Service, and the Government of Indonesia for their valuable support.

SEAMEO BIOTROP
Southeast Asian Regional Centre
for Tropical Biology,

Prof. Dr. H. Sitanala Arsyad
Director

CONTENTS

SPHERICAL DENSIOMETER MANUAL

Technical Report No. 10

Supriyanto
Kasno

ABSTRACT

A special tool specifically developed for the FHM is the spherical densiometer. The spherical densiometer (SD) is a concave or convex mirror with definite focus position used to measure the estimation of density of a unit area (0.1 ha) of tree crowns. This manual provides the brief background on the development of SD and step-by-step instruction on how to use it. The procedures in calculating the canopy density as well as canopy opening are also briefly presented.

Key words: *Spherical Densiometer, canopy density, canopy opening*

I. INTRODUCTION

Light intensity reaching on forest-floor much affects on forest regeneration and survival rate and self-pruning of seedlings, saplings, and poles. A light intensity may be presented in various unit e.g. lux, candles, mol/m^2, percent (%). Photosynthetic Actively Radiation (PAR) and Leaf Area Index (LAI) can also be used. There is various equipment such as Lux Meter, Fish Eye Lens, and Photosensor. To measure qualitatively the percentage of light penetrating into forest-floor through tree crown, aside of expensive, the equipment are not practical and much depend upon the solar direction (morning, mid-day, and afternoon). More over the use of LAI has to measure the total leaf area and horizontal projection of the crown.

From the practical point of view and data accuracy, alternative cheap equipment is urgently needed. Spherical Densiometer (SD) either concave or convex type may be meets the requirements. Under a forest canopy, if SD is put on the correct position, the projection of a unit area of crown may be seen on the surface of the equipment. Crowns and their gaps may be clearly differentiated by observing on the silhouette of the crown on spherical surface. The shadows represent the crown mass and the light represents the spaces and gaps.

II. USE SPECIFICATION

Spherical Densiometer is specifically used to measure the estimation of density of a unit area (0.1 ha) of tree crowns in relation to the ability in penetrating light into the grown through the crown spaces and gaps. By knowing the percentage of light below the crown, the percentage of the canopy can be known. The percentage of light penetrating into the grown tells about the crown efficiency in catching the light for photosynthesis activity.

III. SPECIFICATION OF EQUIPMENT

The shape and size of Spherical Densiometer is presented on Figure 1. The SD is a concave or convex mirror with definite focus position in order to cover the silhouette of about 0.1 ha of the crown area. The SD has 5.5 cm in length, is placed in a rectangle wooden box. The box has 7.5 cm in length, 7.5 cm in width and 1 cm thick. The box is equipped with horizontal water pass and cover having same shape and size therefore the total thickness is 2 cm. The use of water pass is aimed to set the SD on a horizontal position. The surface of the mirror is divided by grid lines crossing each other in such away forming 24 rectangles (Figure 1) or 25 rectangles.

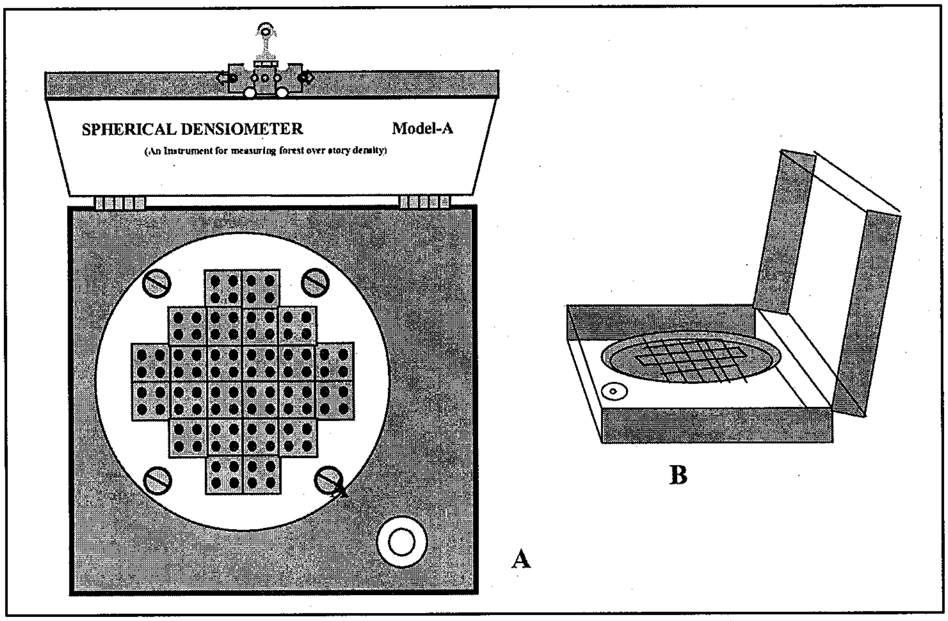

Figure 1. The Shape of Spherical Densiometer: Upper-View (A), Side View (B)

IV. PROCEDURE OF OPERATION

1. Place the SD on a horizontal position about 30-40 cm away from your navel, assuming that you are the operator, to make your vision into the mirror most comfortable but with no silhouette of your head in the mirror. Such position may form about 45^0 angle if an imaginary straight line runs from your eyes to the mirror and crosses a horizontal line.

2. If the SD has been placed in the correct position, the observation is then ready to start. The sky light and dark view are visible in the mirror. Before computing the real canopy opening, it must be remembered that each rectangle has four parts represented by four spots (dots). Each dot represents one percent of canopy opening. As an example, suppose a rectangle showing sky light in one part, it means the rectangle has score 1. If the rectangle has about two parts showing sky light, it means the rectangle has score 2. If the rectangle has about three parts showing sky light, it means the rectangle has score 3. If most parts of the rectangle show sky light, it means the rectangle has score 4. Suppose the result of the observation showing total sky light from all rectangles is 40, it means that the score is 40.
3. Compute the canopy opening by multiplying the score of rectangle with the correction factor. The correction factor of SD is 1.04%. As an example, suppose the result of an observation has the score of 40 (sky light), the canopy opening (CO) is 40x1.04% = 41.6 %. When you use the SD with 25 rectangles, you don't need to multiply with the correction factor, you will have the CO = 41 or 42.
4. Compute the canopy density (CD) by subtracting 100% - CO%. As an example, CO = 41.6 %, then the CD = 100% - 41.6% = 60.4 %.
5. To have a more accurate data of measuring a unit canopy opening or canopy density, it is suggested to measure some sites with different positions (PAR points). The number of PAR points in the operational practice of the Forest Health Monitoring Program is 7 sites. The first is a site called the center of circular plot with radius of 7.32 m. The other 6 sites are on the position with the following azimuths: 30^0, 90^0, 150^0, 210^0, 270^0, and 330^0, respectively. On each site, CO or CD is recorded on four positions, e.g. north, east, south, and west. Therefore, there are four data on each site. The final data of CO or CD is the average of 28 data.
6. In referring to example in point no. 5, the following is more detail example of computation of Canopy Opening and Canopy Density :

Table 1. Data on Number of Sky-light Spots Collected from 7 PAR Points Forest Health Monitoring Plot

Sites/Azimuth	**North**	**East**	**South**	**West**
Center	20	24	18	22
30^0	25	24	28	22
90^0	12	14	10	14
150^0	15	17	13	15
210^0	20	22	22	24
270^0	30	34	32	30
330^0	28	26	26	24
Average	**25**	**23**	**21**	**21**

The average Canopy Opening of the plot is :

$$(25 + 23 + 21 + 21) / 4 = 22.5\ \%$$

The Canopy Density is :

$$100\% - 22.5\ \% = 87.5\%$$

INDO-FHM TALLY SHEET
Spherical Densiometer Tally Sheet

Cluster/ Plot	PAR Points	Number of Sky-Light Spots				
		North	East	South	West	Average
/1	Center					
	30^0					
	90^0					
	150^0					
	210^0					
	270^0					
	330^0					
/2	Center					
	30^0					
	90^0					
	150^0					
	210^0					
	270^0					
	330^0					
/3	Center					
	30^0					
	90^0					
	150^0					
	210^0					
	270^0					
	330^0					
/4	Center					
	30^0					
	90^0					
	150^0					
	210^0					
	270^0					
	330^0					

Figure 2. Spherical Densiometer Tally Sheet

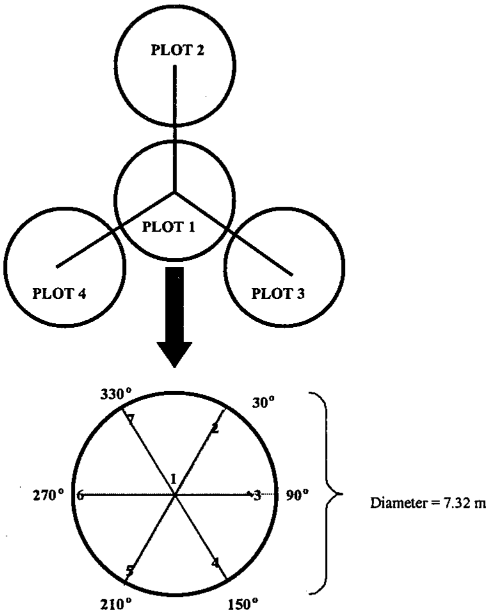

Figure 3. FHM Plot and PAR Points (1 – 7) Where Canopy Opening are Measured

ACKNOWLEDGEMENT

This Technical Report No. 10 on the **Spherical Densiometer Manual** has been prepared to fulfill Objective 1 point 2.2 of the Work-plan of ITTO Project PD 16/95 Rev. 2 (F): Forest Health Monitoring to Monitor the Sustainability of Indonesian Tropical Rain Forest.

The authors would like to thank ITTO, Ministry of Forestry (GOI), PT. INHUTANI II and PT. Asialog Concession Holder for their support. Appreciation also goes to the Project Steering Committee members for their suggestions.

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PRESENT STATUS OF FOREST VITALITY

Technical Report No. 11

Simon Taka Nuhamara
Kasno

ABSTRACT

This report discusses the present status of the damage of trees encountered in several cluster-plots in Pulau Laut and Jambi. In this report, the tree level index and the plot level index were drawn so as to examine the present status of the damage on trees in different clusters. To give an overview on the health status of the several trees, the mapped trees in each subplot or cluster are indicated and discussed

***Key words**: Forest health, damage, vitality, plot level index, tree level index*

I. INTRODUCTION

The Indo-Malayan rain forest is the second most extensive groups of forest in the world (Pringle, 1969). Today this rain forest has been more extensively disturbed by timber exploitation. As a consequence, drastic ecological change will in turn influence the future of both individual tree vitality and the forest health as well.

Forest trees are shaped by multitude of abiotic and biotic influences (Cline, 1995). There are various plant damage such as caused by mechanical, physical, chemical and biological factors. Improper logging activity may injure or kill the logged trees seedlings, saplings, poles and trees of economic plant species. Such unintended logging damages are examples of mechanical factors produced by human activity. Therefore, an accurate record of damage is critical for overall assessment of tree health on Forest Health Monitoring (FHM) plots. Damage caused by pathogens, insects, air pollution, other natural and artificial activities affect the growth and survival of trees. Damage caused by any of these agents, either singly or in combination, can significantly affect forest health.

Damage symptoms may be persistent or ephemeral. Identifying the signs and symptoms of damage provides valuable information concerning the forest's condition and indicates possible causes of deviation from expected conditions. The damage indicator acts as an early warning, providing information on sustainability, resiliency, productivity, and aesthetics (Cline, 1995).

All damages are manifested by reduced growth, loss of biomass, poor crown condition, and ultimately mortality. Damage to locations of lower priority must occur repeatedly, or must be of sufficient severity before survivability is threatened. In most cases, when damage to lower priority locations does occur, it generally predisposes the higher priority location to damage and these damages then ultimately reduce tree survivability. This tendency goes to more or less toward declining trees (Figures 1 and 2) (Manion, 1981).

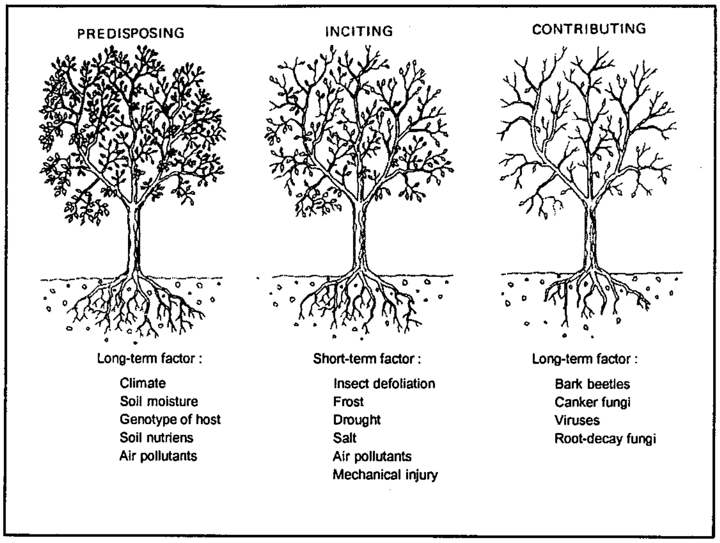

Figure 1. Categories of Factors Influencing Declines (After Manion, 1981)

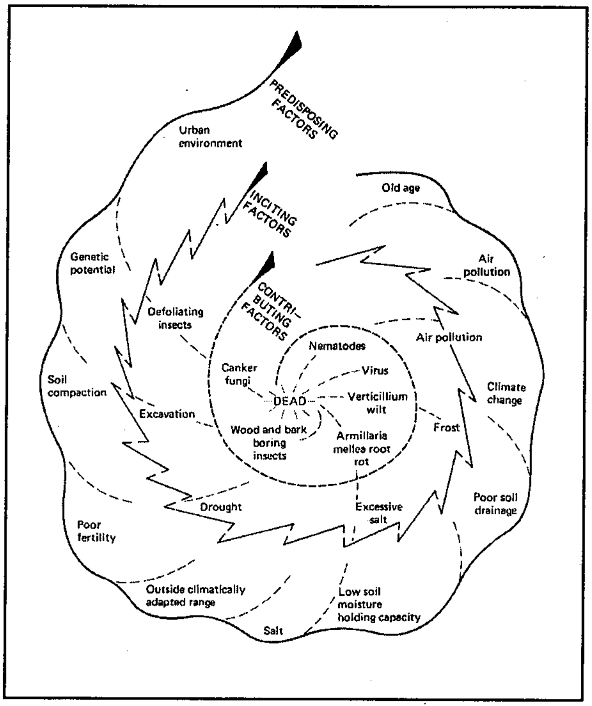

Figure 2. Decline Diseases Spiral (After Manion, 1981)

This quantitative assessment presents specific damage categories, estimates the status of the damage indicator on tree health and the possible causes of mortality. The collected information will create better understanding and provide basis for observing change and eventually tendency of the tropical rain forest health in the future.

II. MATERIALS AND METHODS

The plots used for this study are the same plots used for other indicators studied and established in Pulau Laut, South Kalimantan (7 clusters with exception, no observation made on cluster 3 yet), and at PT. Asialog in Jambi (4 clusters). The mentioned clusters have a standard design as presented in Figure 3.

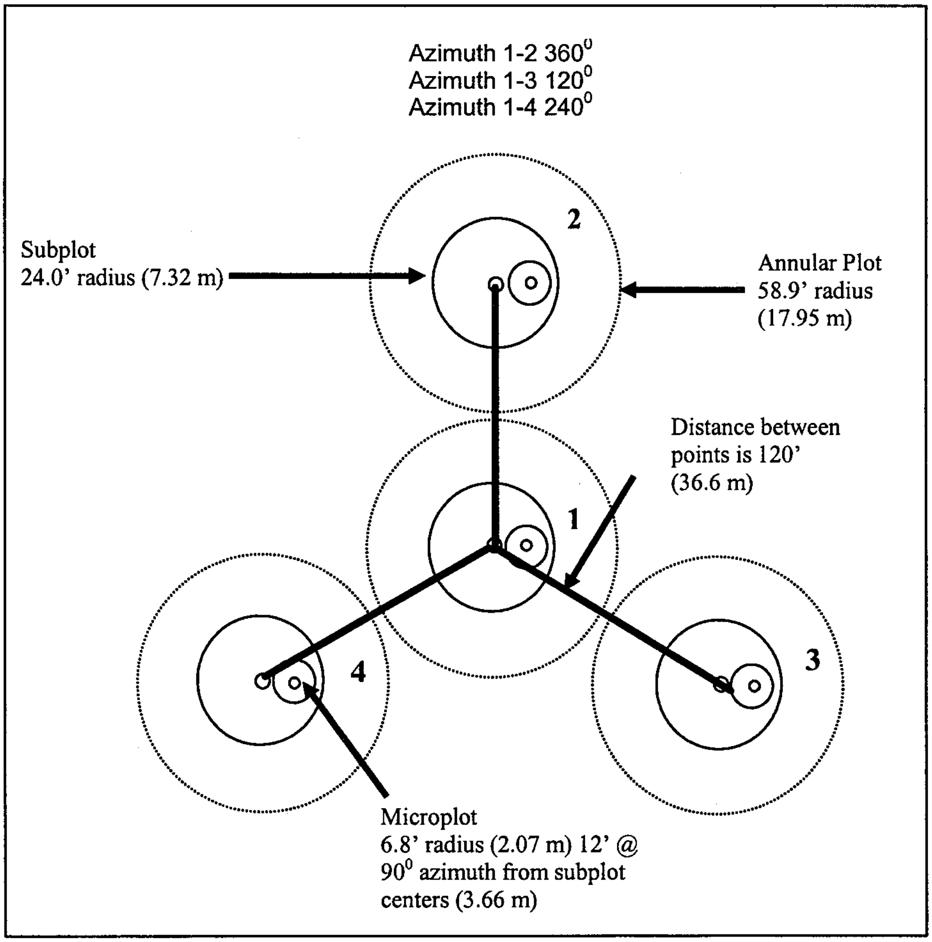

Figure 3. National FHM Plot Layout

Damage signs and symptoms are recorded on all live trees at 20 cm DBH and larger on each 1/60 hectare subplot that is classified as forest. Damage signs and symptoms are prioritized according to location on the tree in the following order : roots, roots and lower bole, lower bole, lower and upper bole, upper bole, crown stem, branches, buds and shoots, and foliage (Figure 4 and Table 1).

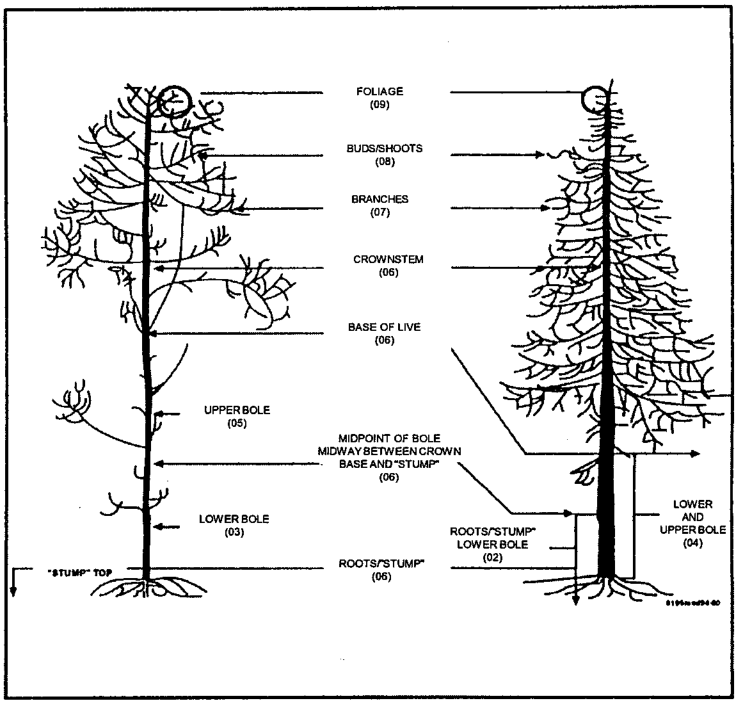

Figure 4. Location Codes for the Damage Indicator

Only those damage categories that could kill the tree or decrease the long-term survival of the trees are recorded on FHM plots. Minimum thresholds and severity classes exist for appropriate damage categories.

Table 1. Location Codes and Descriptions in order of Highest to Lowest Priority for Tree Survivability

Code	Definition
0	No damage
1	Exposed roots and "stump" (12 inch (30 cm) in height from ground level)
2	Roots and lower bole
3	Lower bole (lower half on the trunk between the "stump" and base of the live crown)
4	Lower and upper bole
5	Upper bole (upper half on the trunk between "stump" and base of the live crown)

Table 1. (Continuation)

Code	Definition
0	No damage
1	Exposed roots and "stump" (12 inch (30 cm) in height from ground level)
2	Roots and lower bole
3	Lower bole (lower half on the trunk between the "stump" and base of the live crown)
4	Lower and upper bole
5	Upper bole (upper half on the trunk between "stump" and base of the live crown)

Within any given location, the hierarchy of damage follows the numeric order of damage types possible for that location (Johnson and Lyon, 1988; Sinclair et al., 1987). The numeric order denotes decreasing significance as the code number goes up, i.e. damage 01 is more significant to the tree health than damage 31 (Table 2). In this report, damage code 31 is proposed to be reserved for liana. Trees in plot that are already logged over are recorded based on the appropriate catastrophic causal agent and the code is 700 (see Table 3). Subsequently, this level of evaluation is not repeatable and no tree-level index is computed. A maximum of three damages are recorded for each tree, beginning at the lowest location (highest priority). If a tree has more than three damages that meet the threshold levels, the first three that are observed starting at the roots are recorded. For those damages that have a severity threshold, severity is recorded in 10 percent classes up to 99 percent, beginning with the threshold value. All damages with no severity threshold are recorded as "0" severity.

The number of measurements per plot is dependent on the number of trees 20 cm DBH present on each subplot, up to a maximum of three measurements per tree.

Two personnels if possible are responsible for all measurement to adequately collect the data. In many cases, binoculars help to identify damage in the upper bole and above. Linear tape assists to determine whether specific damage categories meet threshold and to assign a severity class.

Table 2. Damage Codes, Descriptions, and Threshold in order from Highest to Lowest Significance to the Tree Health

Code	Description	Severity Threshold (in 10 % Classes to 99%)
01	Cancer	≥ 20% of circumference at the point of occurrence
02	Conks, fruiting bodies, and other indicators of advanced decay	none, except for ≥ 20% for roots > 3 feet (0.91 m) from bole
03	Open wounds	≥ 20% of circumference at the point of occurrence
04	Resinosis/gummosis	≥ 20% of circumference at the point of occurrence
11	Broken bole or roots (< 3 feet (0.91 m) from bole	none
12	Brooms on roots or bole	≥ 20% of roots
13	Broken or dead roots (> 3 feet (0.91 m) from bole	≥ 20% of roots
21	Loss of apical dominance, dead terminal	≥ 1% of crown stem
22	Broken or dead	≥ 20% of branches or shoots
23	Excessive branching or brooms	≥ 20% of branches or brooms
24	Damaged foliage or shoots	≥ 30% of foliage
25	Discoloration of foliage	≥ 30% of foliage

Obvious signs of catastrophic events such as fire, bark beetles, wilts, beaver, wind, or logging may cause mortality to trees when no previous significant signs damage were present or unrelated to previous damage. Identification of these major agent groups has in fact help to explain sudden, unexpected causes of mortality.

Cause of death has been recorded for all trees 20 cm DBH and larger on the subplot that were recorded as live trees during the previous inventory (Table 3). The causal agent group that most likely kill the tree is specified and the appropriate 3-digit code for each cut or dead tree is recorded.

Table 3. Causes of Death Codes and Descriptions

Code	**Definition**
001	Tree dead when first encountered
100	Insect
200	Disease
201	Fire

Table 3. (Continuation)

300	Blister Rust (CA)
400	Animal
500	Weather
600	Suppression/Competition
700	Logging and related human damage
800	Unknown
999	Other then described above, needs explanation in notes

Source : Cline, 1995

Formulation of the Damage Index

In computing the damage indexes, the authors have been trying to adopt the model proposed by Cline, 1995 with some modification following the single data sheet mode of computation (Dr. Mielke Manfred, personal communication).

Component of the damage indicator comprised of three separate components : *type of damage, location of damage*, and *severity of damage.*

In other words,

damage = f(type, location, severity)

For each individual tree, a maximum of three damages can be recorded. By assigning each component numerical values, a cumulative numerical damage estimate for each tree can be developed using the following model :

damage = [xDamagetype*yLocation*zSeverity]

where : x, y and z = weighing values based on the relative effect of each component for the growth and survival of a tree.

For example, the highest value for damage type is 2 (two) and is given to the damage type with code 11 and the smallest for damage type is 1 (one) and is given to the damage type 22, 23, and so on. The highest value for the location is also 2 (two) and is given to location 1 and 2 (one and two). At the end of severity 1 (10%), the value is 1.1 until 1.9 (^{3} 90%). Specifically for 0 (<20 %), the value is 1.5.

Tree Level Damage = [Damage Type1*Location1*Severity1] +
[Damage Type2*Location2*Severity2] +
[Damage Type3*Location3*Severity3]

Plot Level Index = Average damage [tree1, tree2, tree3, ...]

III. RESULTS AND DISCUSSIONS

3.1. Results

3.1.1. Damage Level Index

The tree-level index as well as the plot-level index of most important tree species observed in six out of seven clusters established in Pulau Laut, South Kalimantan is presented in Table 4. In Figure 5, the plot-level index is again purposely drawn so as to show the overall tendency of the tree species. *Anthocephalus chinensis* seems to have the highest plot-level index (6.80), then followed consecutively by *Eusideroxylon zwageri* (4.80), *Diospyros curraniopsis* (4.08), *Dipterocarpus caudiferus* (3.80), *Diospyros macrophylla* (3.28), *Shorea leprosula* (2.95), *Shorea polyandra* (2.19), *Shorea parvifolia* (1.35) and finally *Shorea johorensis* (1.23).

In the case of trees in all 4 clusters in Jambi, both the tree-level as well as the plot-level index are presented in Tables 4 and 5 and Figure 5. There are 7 tree species considered important at least at the present time.

Table 4. Tree and Plot-level Index of Most Commercial Forest Tree Species in Pulau Laut, South Kalimantan

No	Species	Damage		Tree-level Index		Plot-level Index	
		Type	Location	value	n	value	n
1	*Shorea polyandra*	01	3	3.33	1		
		01	7	2.09	1		
		21	6	2.95	1	2.19	3
2	*Shorea parvifolia*	22	7	1.20	1		
		24	9	1.50	1	1.35	2
3	*Shorea leprosula*	21	6	2.95	1	2.95	1
4	*Shorea johorensis*	21	6	1.35	1		
		21	7	1.20	1	1.23	2
5	*Dipterocarpus caudiferus*	01	3	5.81	1		
		22	7	1.80	1	3.80	2
6	*Diospyros macrophylla*	03	3	3.60	3		
		21	6	2.95	1	3.28	4
7	*Diospyros curraniopsis*	02	1	4.08	1	4.08	1
8	*Eusideroxylon zwageri*	03	2	4.80	1	4.80	1
9	*Anthocephalus chinensis*	03	3	6.60	1	6.80	1

Table 5. Tree and Plot-level Index of Most Commercial Forest Tree Species in Jambi

No	Species	Damage		Tree-level Index		Plot-level Index	
		Type	Location	value	n	value	n
1	*Shorea acuminata*	22	7	1.30	1	1.30	1
2	*Shorea bracteolata*	31	9	1.50	1	1.50	1
3	*Shorea ovalis*	01	3	4.45			
		22	7	1.50			
		24	9	1.20	1	2.38	3
4	*Dyera costulata*	22	7	1.20	1	1.20	1
5	*Koompassia malaccensis*	22	7	1.50	1		
		24	9	1.90	1	1.70	2
6	*Palaquium obovatum*	31	9	1.20	1	1.20	1
7	*Alstonia scholaris*	02	3	2.95	1	2.95	1

Alstonia scholaris showed the highest plot-level index (2.95) then followed consecutively by *Shorea ovalis* (2.38), *Koompassia malaccensis* (1.70), *Shorea bracteolata* (1.50), *Shorea acuminata* (1.30), *Dyera costulata* (1.20) and the same with *Palaquium obovatum* (1.20).

3.1.2. Damage type, location and severity

3.1.2.1. Damage type

From the damage type of the trees in all the clusters observed in Pulau Laut, the number of trees showing damage type of open wound are of 15 trees or 34.09% (the highest); then followed by loss of apical dominance (10) or 22.72%. Next to apical dominance was damage type of broken branch (8) 18.18%, liana (5) 11.36%, and root (4) 9.09% (Table 6).

Table 6. Recapitulation of Damage Type Assessment at Different Clusters on Trees in Pulau Laut and Jambi

Damage		Numbers of trees of clusters															
		1		2		3		4		5		6		7		Σ	
		P	J	P	J	P	J	P	J	P	J	P	J	P	J	P	J
Type	x	x = a weighting value base on the relative effect on different damage type															
01	1.9	2	1	-	2		-	-	-	2		-		-		**4**	**3**
02	1.7	-	2	1	2		-	1	1	-		-		-		**2**	**5**
03	1.5	3	-	3	-		-	1	-	4		1		3		**15**	-
04	1.5	-	-	-	-		-	-	-	-		-		-		-	-
11	2.0	-	-	-	-		-	-	-	-		-		-		-	-
12	1.6	-	-	-	-		-	-	-	-		-		-		-	-
13	1.5	-	-	-	-		-	-	-	-		-		-		-	-
21	1.3	-	4	2	9		5	3	5	1		3		1		**10**	**23**
22	1.0	-	8	3	9		-	1	8	3		1		-		**8**	**25**
23	1.0	-	-	-	-		-	-	-	-		-		-		-	-
24	1.0	-	9	2	1		-	1	-	-		2		-		**5**	**10**
25	1.0	-	-	-	-		-	-	-	-		-		-		-	-
26	1.0	-	-	-	1		-	-	-	-		-		-		-	-
31	1.0	-	-	-	6		-	-	-	-		-		-		-	**6**

Note : P : Pulau Laut ; J : Jambi

Damage type in Jambi's clusters remarkably indicated that broken branch was the most common damage type for 25 trees (34.72%); followed by loss of apical dominance (23 trees or 31.94%), damaged foliage or shoot (10 trees or 13.89%), conk or other decay indicator for 5 trees (6.94%), and canker type for 3 trees (4.17%).

In short, open wound, apical dominance and broken branch were the most serious damage type in Pulau Laut at the time. While in Jambi, broken branch, apical dominance, damaged foliage and decay or conk are recorded.

Table 7. Recapitulation of Damage Location Assessment at Different Clusters on Trees in Pulau Laut and Jambi

Damage		Numbers of trees of clusters															
		1		2		3		4		5		6		7		Σ	
		P	J	P	J	P	J	P	J	P	J	P	J	P	J	P	J
LCN	y	y = a weighting value based on the relative effect on each location															
0	0.0	-	-	-	-		-	-	-	-		-		-		-	-
1	2.0	-	1	1	3		-	1	-	-		-		-		2	4
2	2.0	1	-	-	3		-	-	-	1		-		-		2	3
3	1.8	2	3	1	2		-	-	1	3		1		2		8	6
4	1.8	-	-	-	-		-	-	-	1		-		-		1	-
5	1.6	-	-	2	-		-	1	-	1		-		1		5	-
6	1.2	-	3	3	8		5	4	5	1		3		1		12	21
7	1.0	1	8	2	7		-	1	8	3		1		-		7	23
8	1.0	-	-	-	-		-	-	-	-		-		-		-	-
9	1.0	-	9	2	7		-	1	-	-		2		-		5	16

Note : P : Pulau Laut ; J : Jambi ; LCN : Location

Table 8. Recapitulation of Damage Severity Assessment at Different Clusters on Trees in Pulau Laut and Jambi

Damage		Numbers of trees of clusters															
		1		2		3		4		5		6		7		Σ	
		P	J	P	J	P	J	P	J	P	J	P	J	P	J	P	J
SVY	z	z = a weighting value based on the relative effect on severity															
0	1.5	-	-	-	-		-	-	-	-		-		-		-	-
1	1.1	1	1	-	-		-	-	1	-		-		-		1	2
2	1.2	-	12	1	5		1	2	5	4		-		-		7	23
3	1.3	-	2	1	3		1	-	1	1		-		2		4	7
4	1.4	-	2	2	2		-	-	2	-		2		-		4	6
5	1.5	1	3	1	2		-	3	2	-		1		-		6	7
6	1.6	1	-	2	5		-	-	-	1		1		-		5	5
7	1.7	-	-	1	-		-	1	-	2		2		-		6	-
8	1.8	-	-	1	-		-	2	-	1		1		-		5	-
9	1.9	2	3	5	4		3	-	3	1		-		2		10	13

Note : SVY : Severity ; P : Pulau Laut ; J : Jambi

3.1.2.2. Damage Location

As damage type and damage location combination is the most influencing interaction that will determine the long term survival of the tree, data in Pulau Laut reveals that crown stem (12 trees), lower bole (8), and branch (7) are the logic consequence of the damage type as briefly elaborated before. Similarly, what have been found in Jambi are broken branch (23 trees), crown stem (21), leave covered by liana (16), lower bole (6), roots (4), and roots and lower bole (3) (Table 7).

3.1.2.3. Damage Severity

In terms of severity, the number of trees showing high severity are 10 trees found in Pulau Laut indicating severity of 9 (90%). The others are scattered of which 7, 6, 5 and 4 trees showed a severity of 20%, 50%, 60%, 30%, and 40%, respectively. In Jambi clusters there are 23 trees showing severity of 2 (20 %).

1.2.4. Damage on Some Lesser Known Species

Tree-level damage of some lesser known tree species in study areas (Pulau Laut and Jambi) are presented in different Annexes (see Annexes 1 - 10). In addition, the plot-level index for these lesser known tree species could easily be computed, since in most clusters/plots of both areas, trees of the same species are rarely found. In other words, for this 1997 data collection, the plot-level indexes are mostly or nearly the same as in tree-level index.

3.2. Discussions

3.2.1. Damage Level Index

Referring to the single sheet damage index provided by Manfred Mielke (Data calculating in 1995), the maximum possible value (three damage types) possible for a single tree is 21.66. If this figure is then used as a tool for weighting the health status of the observed trees in different plots of both in Pulau Laut and Jambi, it could clearly show that all trees are physiognomically good (Table 4 and Figure 5). For tree-level index, *A. chinensis* gave the highest value (6.60); and since it was of a single tree its plot-level index is also 6.60 (see Annex 6). This figure was obtained based on its single damage type (03, open wound), damage location 3 (lower bole) and severity 9.

The Dipterocarp group such as *Shorea polyandra, S. leprosula, S. parvifolia, S. johorensis, S. ovalis, S. bracteolata, S. acuminata* and *Dipterocarpus caudiferus* which are the dominant commercial species in the study areas have lower plot-level index ranging from 1.23 through 3.80 (See Tables 4 and 5). Other economical tree species like *D. macrophylla* has plot-level index of 3.28 or even *D. curraniopsis* has higher plot-level index (4.08). The local hard and durable wood of *Eusideroxylon zwageri* has plot-level index of 4.80. The value 4.80 observed on *E. zwageri* is considered relatively high enough as compared to the values of different Dipterocarp group mentioned above.

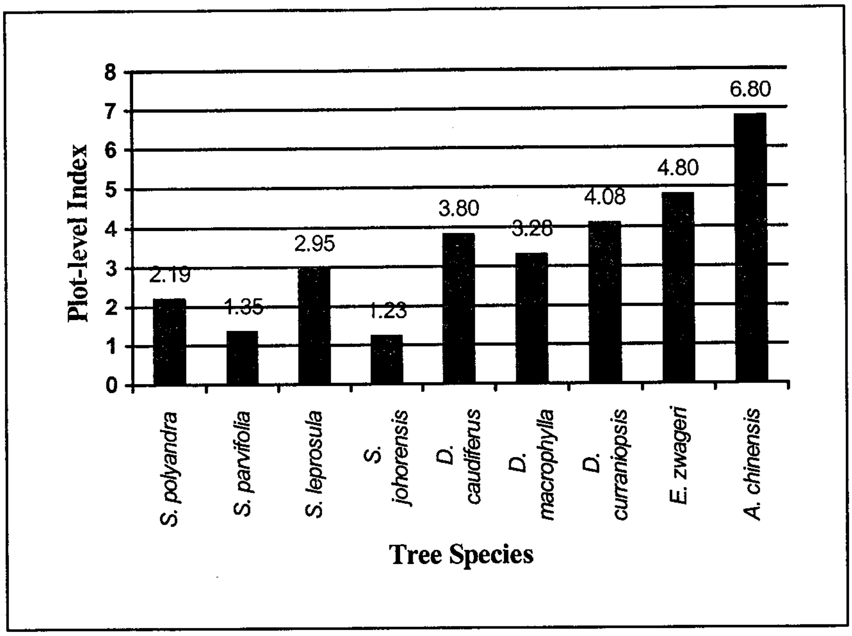

Figure 5. Diagram Showing the Plot-level Index of Some Economical Tree Species Observed on Six Clusters in Pulau Laut, Kalimantan

The significance of having such plot-level index is eventually set for possible regional and/or ecological CDFs (Cumulative Distribution Function) comparison. Toward this point, question might be addressed to the representativeness of the sample plots established.

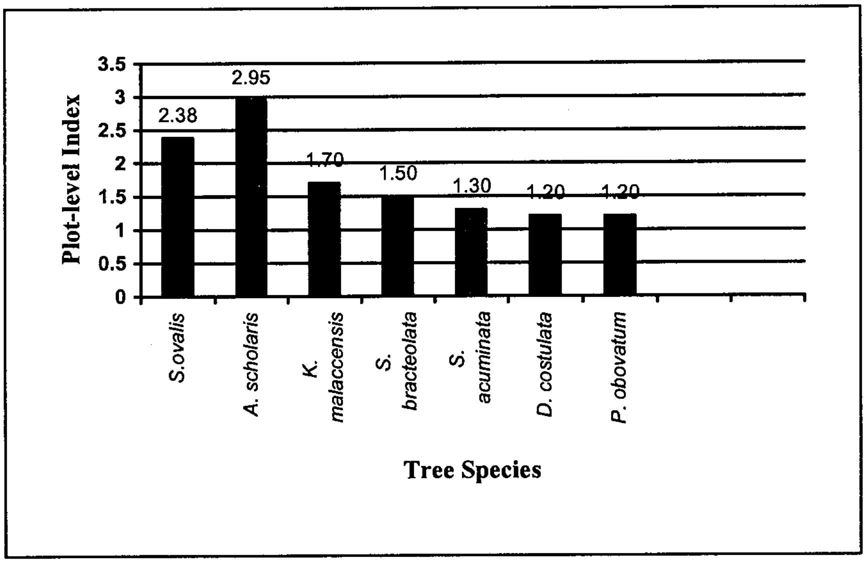

Figure 6. Diagram Showing the Plot-level Index of Some Economical Tree Species Observed on Four Clusters in Jambi

But, regardless the species variation in the two areas for example (Pulau Laut and Jambi), the data collected gave some valuable information that in general, the plot-level index of Dipterocarp group in Jambi is lower (0.69) than in Pulau Laut (1.10), (see also Figures 5 and 6, and Table 9).

Table 9. Regional Plot-level Index of Dipterocarps Group

No.	Pulau Laut	n	PLI	No.	Jambi	n	PLI
1	*S. johorensis*	2	1.27	1	*S. acuminata*	1	1.30
2	*S. leprosula*	1	2.95	2	*S. bracteolata*	1	1.50
3	*S. parvifolia*	2	1.35	3	*S. ovalis*	4	1.34
4	*S. polyandra*	3	3.20				
		Total	8.77			Total	4.14
		Average	1.10			Average	0.69

Note : PLI : Plot-level Index

3.2.2. Damage Type

The different damage types observed on the different tree species is believed as an excess that in one or another way is related to logging activities conducted during 1970th and is perhaps continued nowadays. It is apparent that the common damage type and its damage location combination in Pulau Laut and Jambi are of : **loss of apical dominance, broken branch, open wounds, other decay indicators or conk.**

Considering the damage types indicated above, all of them will eventually lead to a heart-rot problem.

IV. CONCLUSIONS

The information collected for forest vitality status revealed that in the two study areas e.g. Pulau Laut and Jambi, more or less the same typical damage type and its damage location combination have been observed. Those are : apical dominance, broken branch, open wounds, and other decay indicator or conk. This clearly indicates an evidence for heart-rot problem in the next cutting cycle. During this forest health assessment, not much biotic damage type has been observed.

Similarly, from the damage severity point of view, yet — there is a tendency that the damage incidence in Pulau Laut are relatively highest as compared to Jambi.

ACKNOWLEDGEMENT

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Annex 1. Data on Damage Type, Location, Severity, Trees-Level Damage of Different Species in Cluster 1 Pulau Laut, 1997

ID	Species	DMT	LCN	SVY	TLI	PLI
01.1.09/PUL	*Diospyros macrophylla*	03	3	9	4.56	4.56
01.3.02/PUL	*Eusideroxylon zwageri*	03	2	6	4.80	4.80
01.3.05/PUL	*Paranephelium xertophyllum*	03	3	9	4.56	4.56
01.3.07/PUL	*Shorea polyandra*	01	7	1	2.09	
01.4.08/PUL	*Shorea polyandra*	01	3	5	4.56	3.33

Note : DMT : Damage type LCN : Location SVY : Severity
TLI : Tree-level index PLI : Plot-level index

Annex 2. Data on Damage Type, Location, Severity, Trees-Level Damage of Different Species in Cluster 2 Pulau Laut, 1997

ID	Species	DMT	LCN	SVY	TLI	PLI
02.1.02/PUL	*Paranephelium sp. 1*	22	7	4	1.40	1.40
02.2.11/PUL	*Diospyros macrophylla*	21	6	9	2.95	2.95
02.2.13/PUL	*Mahang	24	9	6	1.60	1.60
02.2.16/PUL	*Paranephelium xertophyllum*	02	1	4	4.76	4.76
02.3.07/PUL	*Diospyros macrophylla*	03	5	3	3.12	3.12
02.3.10/PUL	*Mahang	03	5	8	4.32	4.32
02.3.23/PUL	*Acalypta caturus*	22	7	6	1.60	1.60
02.4.02/PUL	*Paranephelium xertophyllum*	03	3	2	3.24	
02.4.09/PUL	*Paranephelium xertophyllum*	22	6	7	2.04	2.64
02.4.10/PUL	*Shorea polyandra*	21	6	9	2.95	2.95
02.4.14/PUL	*Shorea parvifolia*	24	9	5	1.50	1.50

Note : DMT : Damage type LCN : Location SVY : Severity
TLI : Tree-level index PLI : Plot-level index *) : denoting local name

Annex 3. Data on Damage Type, Location, Severity, Trees-Level Damage of Different Species in Cluster 4 Pulau Laut, 1997

ID	Species	DMT	LCN	SVY	TLI	PLI
04.1.05/PUL	*Durio acutifolius*	22	7	5	1.50	1.50
04.1.13/PUL	*kayu gatal	21	6	8	2.81	2.81
04.2.08/PUL	*Eugenia sp. 1*	03	5	2	2.88	2.88
04.3.07/PUL	*Sloanea sp. 1*	21	6	8	2.81	2.81
04.3.15/PUL	*Durio acutifolius*	21	6	5	1.35	1.35
04.3.17/PUL	*Dacryodes rostata*	24	9	7	1.70	1.70
04.3.19/PUL	*Diospyros curraniopsis*	02	1	2	4.08	4.08
04.3.24/PUL	*Shorea johorensis*	21	6	5	1.35	1.35

Note : DMT : Damage type LCN : Location SVY : Severity
TLI : Tree-level index PLI : Plot-level index *) : denoting local name

Annex 4. Data on Damage Type, Location, Severity, Trees-Level Damage of Different Species in Cluster 5 Pulau Laut, 1997

ID	Species	DMT	LCN	SVY	TLI	PLI
05.1.13/PUL	*Drypetes sp. 1*	03	4	3	3.12	3.12
05.1.16/PUL	*Durio acutifolius*	03	3	6	2.54	2.54
05.2.05/PUL	*Dipterocarpus caudiferus*	01	3	7	5.81	5.81
05.2.06/PUL	*Litsea sp. 1*	01	3	7	5.81	5.81
05.3.07/PUL	*Shorea parvifolia*	22	7	2	1.20	1.20
05.4.14/PUL	*Gluta walichii*	03	2	2	3.60	3.60
05.4.21/PUL	*Shorea leprosula*	21	6	9	2.95	2.95
05.4.24/PUL	*Nauclea sp. 1*	03	5	2	2.88	2.88
05.4.24/PUL	*Dipterocarpus caudiferus*	22	7	8	1.80	1.80
05.4.26/PUL	*Shorea johorensis*	22	7	2	1.20	1.20

Note : DMT : Damage type LCN : Location SVY : Severity
TLI : Tree-level index PLI : Plot-level index

Annex 5. Data on Damage Type, Location, Severity, Trees-Level Damage of Different Species in Cluster 6 Pulau Laut, 1997

ID	Species	DMT	LCN	SVY	TLI	PLI
06.1.23/PUL	*Lithocarpus bennetti*	03	3	4	3.78	3.78
06.2.06/PUL	*Litsea sp. 1*	21	6	8	2.81	2.81
06.2.12/PUL	*Sloanea sp. 1*	24	9	6	1.60	1.60
06.2.15/PUL	*Palaquium dasyphyllum*	22	7	4	1.40	1.40
06.4.10/PUL	*Dipterocarpus caudiferus*	24	9	5	1.50	1.50
06.4.17/PUL	*Palaquium dasyphyllum*	21	6	7	2.65	2.65
06.4.26/PUL	*Xanthophyllum heteropleurum*	21	6	7	2.65	2.65

Note : DMT : Damage type LCN : Location SVY : Severity
TLI : Tree-level index PLI : Plot-level index

Annex 6. Data on Damage Type, Location, Severity, Trees-Level Damage of Different Species in Cluster 7 Pulau Laut, 1997

ID	Species	DMT	LCN	SVY	TLI	PLI
07.1.07/PUL	*kayu gatal	03	3	9	4.56	4.56
07.2.19/PUL	*Diospyros macrophylla*	03	5	3	3.12	3.12
07.3.10/PUL	*Litsea roxburghii*	21	6	3	2.03	2.03
07.4.11/PUL	*Anthocephalus chinensis*	03	3	9	6.60	6.60

Note : DMT : Damage type LCN : Location SVY : Severity
TLI : Tree-level index PLI : Plot-level index , *) : denoting local name

Annex 7. Data on Damage Type, Location, Severity, Trees-Level Damage of Different Species in Cluster 1 Jambi, 1997

ID	Species	DMT	LCN	SVY	TLI	PLI
01.1.01/JAM	*Medang	21	6	4	2.18	2.18
01.1.13/JAM	*Sarcotheca griffithii*	24	9	2	1.20	1.20
01.1.24/JAM	*Mangifera foetida*	24	9	2	1.20	1.20
01.2.01/JAM	*Gardenia anisophyllea*	21	6	5	2.34	2.34
01.2.03/JAM	*Santiria rubiginosa*	24	9	2	1.20	1.20
01.2.04/JAM	*Dyera costulata*	22	7	2	1.20	1.20
01.2.06/JAM	*Pouteria sp. 1*	22	7	5	1.50	1.50
01.2.08/JAM	*Hydnocarpus woodii*	22	7	2	1.20	1.20
01.2.12/JAM	*Pouteria sp. 1*	22	7	1	1.10	1.10
01.2.13/JAM	*Shorea ovalis*	24	9	2	1.20	
01.2.15/JAM	*Shorea ovalis*	01	3	3	4.45	2.83
01.2.16/JAM	*Koompassia malaccensis*	24	9	9	1.90	1.90
01.3.16/JAM	Sp. 09/J	24	9	4	1.40	1.40
01.3.17/JAM	*Eugenia sp. 1*	21	6	9	2.95	2.95
01.3.18/JAM	*Ochanostachys amentacea*	22	7	3	1.30	1.30
01.3.28/JAM	Sp. 14/J	02	3	2	3.67	3.67
01.3.29/JAM	Sp. 15/J	02	3	2	3.67	3.67
01.3.30/JAM	*Cyatocalyx bancana*	21	1	9	5.94	5.94
01.4.05/JAM	*Myristica sp. 1*	22	7	2	1.20	1.20
01.4.08/JAM	*Koompassia malaccensis*	22	7	0	1.50	1.50
01.4.20/JAM	*Shorea ovalis*	22	7	2	1.20	1.20
01.4.22/JAM	*Palaquium gutta*	24	9	2	1.20	1.20
01.4.15/JAM	*Koompassia malaccensis*	24	9	5	1.50	1.50
01.4.16/JAM	*Carallia brachiata*	24	9	2	1.20	1.20

Note : DMT : Damage type LCN : Location SVY : Severity
TLI : Tree-level index PLI : Plot-level index, *) : denoting local name

Annex 8. Data on Damage Type, Location, Severity, Trees-Level Damage of Different Species in Cluster 2 Jambi, 1997

ID	Species	DMT	LCN	SVY	TLI	PLI
02.1.03/JAM	*Aporusa arborea*	22	7	3	1.30	1.30
02.1.05/JAM	*Hydnocarpus woodii*	22	7	3	1.30	
02.1.08/JAM	*Hydnocarpus woodii*	24	9	2	1.20	1.25
02.1.15/JAM	*Eugenia sp. 1*	21	6	6	2.45	2.45
02.1.17/JAM	*Baccaurea sp. 1*	22	7	2	1.20	1.20
02.1.21/JAM	*Pouteria malaccensis*	21	6	6	2.45	2.45
02.2.02/JAM	*Scapium macropodum*	22	7	2	1.20	1.20
02.2.05/JAM	*Pimelodendron griffithianum*	22	7	0	1.50	1.50
02.2.09/JAM	*Memecylon sumatrensis*	01	3	3	3.42	3.42
02.2.11/JAM	*Scapium macropodum*	31	9	0	1.50	1.50
02.2.17/JAM	*Dehaasia caesia*	31	9	0	1.50	1.50
02.3.02/JAM	*Tricalysia sp. 1*	02	2	0	5.10	5.10
02.3.03/JAM	*Santiria laevigata*	02	2	0	5.10	5.10
02.3.04/JAM	*Baccaurea deflexa*	21	6	6	2.45	2.45

Annex 8. (Continuation)

ID	Species	DMT	LCN	SVY	TLI	PLI
02.3.05/JAM	*Aporusa sp. 1*	21	6	6	2.45	2.45
02.3.15/JAM	*Phoebe sp. 1*	21	6	4	2.18	2.18
02.3.17/JAM	*Gymnacranthera forbesii*	21	6	5	4.34	4.34
02.3.20/JAM	*Glochidium obscurum*	21	6	4	2.18	2.18
02.3.21/JAM	*Palaquium obovatum*	31	9	2	1.20	1.20
02.3.22/JAM	*Paranephelium sp. 1*	01	3	2	1.82	1.82
02.3.23/JAM	*Shorea ovalis*	22	7	0	1.50	1.50
02.3.24/JAM	*Santiria griffithii*	22	7	0	1.50	1.50
02.3.26/JAM	*Ochanostachys amentacea*	31	9	0	1.50	1.50
02.3.27/JAM	*Shorea bracteolata*	31	9	0	1.50	1.50
02.3.28/JAM	*Litsea sp. 1*	31	9	5	1.50	1.50
02.4.03/JAM	*Ochanostachys amentacea*	26 (LD)	2	9	7.60	7.60
02.4.06/JAM	***	22	1	9	1.90	1.90
02.4.14/JAM	***	22	1	9	1.90	1.90
02.4.21/JAM	*Pouteria malaccensis*	21	6	6	2.45	2.45
02.4.26/JAM	***	21	1	9	3.80	3.80

Note : DMT : Damage type LCN : Location SVY : Severity
TLI : Tree-level index, PLI : Plot-level index, ***: denoting the dead tree

Annex 9. Data on Damage Type, Location, Severity, Trees-Level Damage of Different Species in Cluster 3 Jambi, 1997

ID	Species	DMT	LCN	SVY	TLI	PLI
03.2.01/JAM	*Eugenia sp. 8*	21	6	2	3.12	3.12
03.2.02/JAM	***	21	6	9	2.95	2.95
03.2.04/JAM	*Dacryodes rostata*	21	6	3	2.03	2.03
03.2.07/JAM	***	21	6	9	2.95	2.95
03.2.11/JAM	***	21	6	9	2.95	2.95

Note : DMT : Damage type LCN : Location SVY : Severity
TLI : Tree-level index, PLI : Plot-level index,***: denoting the dead tree

Annex 10. Data on Damage Type, Location, Severity, Trees-Level Damage of Different Species in Cluster 4 Jambi, 1997

ID	Species	DMT	LCN	SVY	TLI	PLI
04.1.04/JAM	*Shorea acuminata*	22	7	3	1.30	1.30
04.1.14/JAM	*Radermachera gigantea*	21	6	9	2.95	2.95
04.1.16/JAM	*Pellacalyx axillaris*	21	6	5	2.34	2.34
04.1.20/JAM	*Alstonia scholaris*	02	3	5	3.06	3.06
04.2.09/JAM	***	21	6	9	2.95	2.95
04.3.03/JAM	*Macaranga populifolia*	22	7	2	1.20	1.20
04.3.04/JAM	*Coelostegia griffithii*	22	7	4	1.40	1.40
04.3.05/JAM	*Gymnacranthera forbesii*	22	7	2	1.20	1.20
04.3.07/JAM	*Blumeodendron tokbrai*	21	6	1	1.16	1.16
04.3.15/JAM	*Gymnacranthera forbesii*	22	7	2	1.20	1.20
04.3.20/JAM	*Horsfieldia wallichii*	22	7	2	1.20	1.20

Annex 10. (Continuation)

ID	Species	DMT	LCN	SVY	TLI	PLI
04.3.21/JAM	*Radermachera gigantea*	22	7	4	1.40	1.40
04.3.22/JAM	*Horsfieldia wallichii*	22	7	2	1.20	1.20
04.3.25/JAM	***	21	6	9	2.95	2.95

Note : DMT : Damage type LCN : Location SVY : Severity
TLI : Tree-level index, PLI : Plot-level index, ***: denoting the dead tree

TREE SPECIES DIVERSITY ASSESSMENT : "PRESENT STATUS AT JAMBI"

Technical Report No. 12

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Soekotjo

ABSTRACT

Forest Health Monitoring to Monitor the Sustainability of Indonesian Tropical Rain Forest (INDO-FHM) plans to track down the status and trends of biodiversity in the forests of Indonesia, that one of them is in the species level. The objective of this report is to assess the tree species diversity of FHM Clusters 3 and 4 of Jambi. Species diversity formulas used are the species richness indices (Margalef Index and Simpson Index), the species evenness index (Pielou Index), and the species diversity indices (Shannon-Weiner Index and Simpson Index). The result shows that Forest Health Monitoring Cluster Design, consisting of four annular-plots and sub-plots, could be used to express the diversity assessment within its sampling design. The area of a cluster with an area of 0.4 ha having a high number of species gives the biggest value of species richness, abundance, equitability and diversity followed by the annular plots with an area of 0.1 ha and less number of species. The sub-plots with an area of 0.017 ha having the small number of species takes the last one. The high value of species diversity indices measured in Clusters 3 and 4 at Jambi indicates that both of these two clusters recently have the high species richness, abundance and diversity.

***Key words**: Tree species diversity, annular-plots, sub-plots*

I. INTRODUCTION

Biological diversity encompasses all levels of natural variation, from the molecular and genetic levels to the ecosystem level. At the species level, we have most of our interactions with biological diversity through enjoyment of the common, strange, and beautiful forms of life or through suffering caused by the effects of pests, parasites, and diseases (Huston, 1995). Species embodies the array of diversity from gene to population and provides a measure for the diversity of communities. Species can readily be identified and classified, and they can be counted.

Indonesia must be proud of its species diversity richness. From an area that only covers 1.32 % of total earth's land, Indonesia has 10 % flowering plants species, 12 % mammals, 10 % reptiles and amphibians, 17 % birds, and 25 % fish respectively from the overall earth's species. This high species diversity, according to Beaman and Beaman (1990), apparently results from a combination of factors, among which the most important are : 1) great altitudinal and climatic range from tropical rain forest near sea level to freezing alpine conditions at the summit; 2) precipitous topography causing effective geographic and reproductive isolation of species over short distances; 3) geological history of the Malay Archipelago; 4) a diverse geology with many localised edaphic conditions; and 5) frequent climatic oscillations influenced by El Nino events.

Plant and animal diversity provides direct economic benefits in terms of food, medicine and industrial raw materials, and supplies the functional ingredients for natural ecosystems to provide an array of essential services to man — such as photosynthesis, hydrologic cycle and climate, absorption and breakdown of pollutants, and many others. It has been reported in many publications that many plant species are being used in various systems of traditional medicine practised by the medicine man. Gardeners and planners have already known how to exploit the beautiful forms of many plant species. Thousands of plant species are being used in the land conservation, in the recreation forest, and more. Palmae, rattan, pine and other species of softwood and hardwood are used as raw materials of various industries. Thus, this species diversity becomes our hidden treasures under effective, efficient, and wider utilization, and this depends on how we discover the information about this species diversity.

Forest Health Monitoring to Monitor the Sustainability of Indonesian Tropical Rain Forest (INDO-FHM) plans to track down the status and trends of biodiversity in forests of Indonesia, that one of them is in the species level. The sampling design used in the INDO-FHM is called Cluster Design based on Forest Health Monitoring : Field Methods Guide (Alexander and Bernard, 1997).

There were 11 clusters established during 1996 - 1998 plot establishment and measurement period. Seven clusters of them have been established in Pulau Laut, South Kalimantan, and four clusters more were established in Jambi. Soekotjo and Sutisna (1997) have reported the present status of tree species diversity in nine clusters (all of seven clusters in Pulau Laut and two clusters in Jambi). The establishment of Cluster 4 - at Jambi and data collection of tree species in Cluster 3 - Jambi were done in August 1998, so that the species diversity in these two clusters (Clusters 3 and 4 - Jambi) has not been reported yet.

The objective of this report is to assess the tree species diversity of Cluster 3 and Cluster 4 of Jambi. Species diversity formulas used in this report are the speciess richness indices (Margalef Index and Simpson Index), the species evenness index (Pielou Index), and the species diversity indices (Shannon-Weiner Index and Simpson Index).

II. MATERIALS AND METHODS

The sampling design used in the INDO-FHM is called Cluster Design. The cluster design is shown in Figure 1 and based on Forest Health Monitoring : Field Methods

Guide (Alexander and Bernard, 1997). Each cluster has a fixed radius of subplot (7.32 m) and annular plot (17.95 m). Each cluster contains four subplots/annular plots.

The center of subplot 1 is also considered as the center point of overall plot. The center of subplot 2 is located 360⁰ from the center point of subplot 1, at 36.6 m distance. The center of subplot 3 is located 120⁰ from the center point of subplot 1, at 36.6 m distance. The center of subplot 4 is located 240⁰ from the center point of subplot 1, at 36.6 m distance.

Plant species collected in the Forest Health Monitoring have been classified into two categories : tree and pole, depending on its diameter. The diameter of trees (or poles), widely known as DBH (Diameter at Breast Height), was measured at 1.3 m above the ground, on the uphill side of the tree. Plant species with 20.0 cm DBH or more were categorized as tree, those with DBH less than 20.0 cm and above 10 cm were categorized as pole. Tree species have been recorded both in the subplot and in the annular plot, while the poles have been recorded only in the subplot. All of the trees and poles were identified to the lowest taxonomist level, and based on these data, the species diversity were calculated at the plot-level.

The basic calculation of species diversity is to count the number of species in a sample. It is generally called species richness (or sometimes species density when the sample size is expressed in terms of area). The relative distribution of individual objects among each of the different types is usually referred to as 'evenness'. The number of species and the evenness of relative abundance are the two statistical properties used to quantify species diversity.

This report used Margalef Species Richness Index and Odum Index to assess species richness in each plot. The Margalef Index is formulated by :

$$\mathbf{R_{MAR} = (S - 1) / \ln N}$$

while the formula of Odum Index is :

$$\mathbf{R_2 = S / \log N}$$

where S = number of species and N = total number of individuals.

While the species evenness index refers to the Pielou's evenness index J' that is calculated by :

$\mathbf{J' = H' / H_{max}}$; H_{max} is determined by $\mathbf{H_{max} = \ln S}$, so then :

$$\mathbf{J' = H' / \ln S}$$

J' is lies between 0 and 1. J' will be minimum (= 0), if all individuals are of one species, and maximum (= 1), if the number of species equals the number of individuals.

Diversity is described using statistical formulas that combine species richness component and evenness component. The best known of these composite statistics used in this report is the Shannon-Weiner Index :

$$H' = -\Sigma p_i \ln (p_i)$$

where p_i is the proportion of the total sample composed of species i :

$p_i = n_i / n$; ni = the number of individuals belonging to the i th of S species in the sample

n = the total number of individuals in the sample

H will be maximum (= ln N), if all species have equal number of individu, and minimum (= ln 1 = 0), if individuals are concentrated in one species.

The other most commonly used statistics to assess species is Simpson's index λ

$$\lambda = \Sigma p_i^2$$

λ will have the value = 1, if all of the individues are of one species, and = 1/S, if they are equally divided among the species.

The last index is the species equitability index. Species equitability is the relative diversity of sample in relation to maximum possible diversity of community of S species. The species equitability index has the formula of :

$$J' = H' / H_{max}$$

III. RESULTS AND DISCUSSIONS

3.1. Results

The results of complete calculation of species diversity in Cluster 3 Jambi are presented in Tables 1 and 2. Species diversity in Cluster 4 Jambi are presented in Tables 3 and 4. List of species found in the clusters is presented in Annexes 1 – 16. Tree species distribution in Cluster 3 and 4 at Jambi is presented in Annexes 17 and 18.

Table 1. Species Diversity at Each Sub-plot on Cluster 3 Jambi

No	Criteria	Sub-plot Number				Cluster	Mean
		1	2	3	4		
1.	Species Richness						
	1.1. Margalef Index	3.186	1.443	3.083	2.596	6.211	2.577
	1.2. Odum Index	8.386	6.644	8.284	7.101	15.022	7.604
2.	Species Diversity						
	2.1. Shannon-Weiner Index	2.043	0.693	1.946	1.748	2.997	1.608
	2.2. Simpson Index	0.136	0.500	0.143	0.184	0.053	0.241
3.	Species Evenness	0.983	1.000	1.000	0.975	0.985	0.989
4.	Species Equitability	0.983	1.000	1.000	0.975	0.985	0.989

Table 2. Species Diversity at Each Annular-plot on Cluster 3 Jambi

No	Criteria	Annular-plot Number				Cluster	Mean
		1	2	3	4		
1.	Species Richness						
	1.1. Margalef Index	5.007	4.170	4.168	4.689	9.973	4.509
	1.2. Odum Index	12.298	10.563	10.470	11.627	23.525	11.239
2.	Species Diversity						
	2.1. Shannon-Weiner Index	2.718	2.398	2.441	2.599	3.666	2.539
	2.2. Simpson Index	0.070	0.091	0.092	0.078	0.029	0.083
3.	Species Evenness	0.980	1.000	0.982	0.985	0.969	0.987
4.	Species Equitability	0.980	1.000	0.982	0.985	0.969	0.987

Table 3. Species Diversity at Each Sub-plot on Cluster 4 Jambi

No	Criteria	Sub-plot Number				Cluster	Mean
		1	2	3	4		
1.	Species Richness						
	1.1. Margalef Index	1.820	2.866	2.790	2.790	6.059	2.567
	1.2. Odum Index	6.288	7.752	7.712	7.712	14.687	7.366
2.	Species Diversity						
	2.1. Shannon-Weiner Index	1.099	1.096	1.792	1.792	2.995	1.445
	2.2. Simpson Index	0.667	0.844	0.833	0.833	0.055	0.794
3.	Species Evenness	1.000	0.979	1.000	1.000	0.986	0.995
4.	Species Equitability	1.000	0.979	1.000	1.000	0.986	0.995

Table 4. Species Diversity at Each Annular-plot on Cluster 4 Jambi

No	Criteria	Annular-plot Number				Cluster	Mean
		1	2	3	4		
1.	Species Richness						
	1.1. Margalef Index	5.533	6.061	6.293	6.213	12.946	6.025
	1.2. Odum Index	13.411	14.684	15.215	15.021	30.306	14.583
2.	Species Diversity						
	2.1. Shannon-Weiner Index	2.868	2.955	2.983	2.997	3.913	2.951
	2.2. Simpson Index	0.063	0.055	0.056	0.053	0.025	0.057
3.	Species Evenness	0.957	0.987	0.980	0.984	0.956	0.977
4.	Species Equitability	0.957	0.987	0.980	0.984	0.956	0.977

3.2. Discussions

Diversity measures take into account two factors : species richness, that is, number of species, and evenness (sometimes known as equitability), that is, how equally abundant the species are (Magurran, 1988).

3.2.1. Species Richness

Species richness indices are essentially a measure of the number of species in a defined sampling unit. Species richness measures provide an instantly comprehensible expression of diversity (Magurran, 1988).

Both of the species richness indices used in this report — Margalef Index and Odum Index — noted that these indices depend on the sample size and community level as presented on Tables 1 - 4. Species richness value in each cluster, annular-plots and sub-plots depends on the plot size.

The value for the sub-plot ranged between 1.443 and 3.186 for the Margalef Index ; and between 6.288 and 8.386 for the Odum Index, whereas the Margalef Index for the annular-plot ranged between 4.168 and 6.293 ; and between 10.470 and 15.215 for the Odum. Bigger values for Margalef and Odum Indices are found for the clusters. The Margalef Index for Sub-plots and Annular-plots on Cluster 3 are 6.211 and 9.973 respectively, whereas in Cluster 4 are 6.059 and 12.946. The Odum Index for Cluster 3 are 15.022 and 23.525 whereas 14.687 and 30.306 for Cluster 4 (see Tables 1 - 4, Cluster column).

Among the three sampling areas being taken and measured - sub-plots, annular-plots and cluster —, the values for the sub-plots take the smallest one as its smallest area (168.33 m^2) and its small number of species found (between 2 and 8 species). The clusters take the biggest with the area of 4000 m^2 (0.4 ha) and its number of species of 21, 20, 44 and 60 for the Cluster 3 Sub-plots, Cluster 3 Annular-plots, Cluster 4 Sub-plots and Cluster 4 Annular-plots, respectively. The Annular-plots take its place between the two mentioned above with the area of 1000 m^2 (0.1 ha) and the number of species between 10 and 21.

Referring to the number of species and individues found in each sub-plot, annular-plots and clusters mentioned above (Annexes 1 - 16), these values simply express that species diversity in the clusters is bigger than in annular-plots whereas that in annular-plots is bigger compared with sub-plots.

3.2.2. Species Evenness, Equitability and Diversity

Evenness is described as the distribution of abundance among the species in a community. The measure of evenness can be taken from the ratio of observed diversity to maximum diversity (Pielou, 1969). Pielou evenness index J' is constrained between 0 and 1.0 with 1.0 representing a situation in which all species are equally abundant. Thus high evenness is conventionally equated with high diversity.

The evenness value in the two clusters ranged between 0.957 and 1.000. Six plots out of sixteen have the value of 1.0 that means each species in these plots, i.e. Subplots 2 and 3 Cluster 3 ; Annular-plot 2 Cluster 3 ; and Sub-plots 1, 3, 4 Cluster 4, are equal in abundance (see Table 5).

Table 5. The Sub-plot / Annular-plot with the evenness value of 1.0 and has the maximum value of Shannon-Weiner Index

Sub-plots / Annular Plots	Evenness Value	Shannon-Weiner Index	Number of Species	Number of Individues
Sub-plot 2 Cluster 3	1.0	0.693	2	2
Sub-plot 3 Cluster 3	1.0	1.946	7	7
Sub-plot 1 Cluster 4	1.0	1.099	3	3
Sub-plot 3 Cluster 4	1.0	1.792	6	6
Sub-plot 4 Cluster 4	1.0	1.792	6	6
Annular-plot 2 Cluster 3	1.0	2.398	11	11

Species equitability is the relative diversity of sample in relation to maximum possible diversity of community of S species. Thus the species equitability will have the same value with the species evenness when being counted in the same sample location (see Table 6).

Table 6. The Same Value for the Evenness and Equitability Value

Sub-plots / Annular Plots	Evenness Value	Equitability Value
Sub-plot Cluster 3	0.985	0.985
Sub-plot Cluster 4	0.986	0.986
Annular plot Cluster 3	0.987	0.987
Annular plot Cluster 4	0.956	0.956

Shannon-Weiner and Simpson Diversity Indices crystallize richness and evenness into a single figure. Shannon-Weiner *H* diversity will be minimum when there is only one species in the sample and maximum (= ln N) if all species have equal number of individu. This maximum value of Shannon-Weiner diversity was obtained in Sub-plots 2 and 3 Cluster 3, Sub-plots 3 and 4 Cluster 4, and Annular-plot 2 Cluster 3 (see Table 5).

Simpson's diversity index λ will have the value = 1 / S if the individues are equally divided among the species. The fifth plot mentioned above has fulfilled this criterion.

The values of Shannon-Weiner and Simpson's indicate that these indices depends on the sample size as shown by the clusters compared with annular-plots and sub-plots (Tables 1 - 4). Larger areas will give higher values for Shannon-Weiner but lesser values for the Simpson's.

These diversity values from Shannon-Weiner and Simpson indicate that the abundance and richness in both Cluster 3 and 4 Jambi are relatively high.

The elements of biodiversity — species richness, diversity and evenness — at Forest Health Monitoring Establishment Plots in Cluster 3 and 4 Jambi have been described and quantified. Remeasurement of those plots will be used to have better information on biodiversity, its distribution, its trends and its elements change with its causes for wise management of the forest's resources.

IV. CONCLUSIONS

The species richness and diversity depend on the sample size area and the number of species. Larger areas and more numbers of species give the higher values than the small area with less number of species, except for the Simpson's which has the opposite as its characteristic.

Forest Health Monitoring Cluster Design, consisting of four annular-plots and sub-plots, could be used to express the diversity assessment within its sampling design. The area of cluster of 0.4 ha with the high number of species gives the biggest value of species richness, abundance, equitability and diversity followed by the annular plots of 0.1 ha and less number of species. The subplots of 0.017 ha with the small number of species takes the last one.

The high value of species diversity indices measured in Clusters 3 and 4 at Jambi indicates that both of these two clusters recently have the high species richness, abundance and diversity.

Better information on biodiversity, its distribution, and its causes is needed for wise management of the forest's resources.

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Annex 1. List of Tree Species in Subplot 1 Cluster 3 Jambi

Trees ID	Species Name	Family
03.1.05/JAM	*Artocarpus nitidus*	Moraceae
03.1.09/JAM	*Crallia brachiata*	Rhizoporaceae
03.1.08/JAM	*Cyathocalyx bancana*	Annonaceae
03.1.24/JAM	*Cyathocalyx bancana*	Annonaceae
03.1.03/JAM	*Horsfieldia wallichii*	Myristicaceae
03.1.02/JAM	*Pternandra coerulescens*	Melastomataceae
03.1.04/JAM	*Shorea ovalis*	Dipterocarpaceae
03.1.01/JAM	*Shorea platyclados*	Dipterocarpaceae
03.1.06/JAM	*Tricalysia* sp. 2	Rubiaceae

Annex 2. List of Tree Species in Subplot 2 Cluster 3 Jambi

Trees ID	Species Name	Family
03.2.04/JAM	*Dacryodes rostrata*	Burseraceae
03.2.01/JAM	*Eugenia* sp. 8	Myrtaceae

Annex 3. List of Tree Species in Subplot 3 Cluster 3 Jambi

Trees ID	Species Name	Family
03.3.09/JAM	*Dacryodes rostrata*	Burseraceae
03.3.12/JAM	*Dehaasia caesia*	Lauraceae
03.3.08/JAM	*Gironniera subaequalis*	Ulmaceae
03.3.06/JAM	*Hydnocarpus woodii*	Flacourtiaceae
03.3.04/JAM	*Nephelium lappaceum*	Sapindaceae
03.3.03/JAM	*Shorea parvifolia*	Dipterocarpaceae
03.3.02/JAM	*Sindora leiocarpa*	Caesalpiniaceae

Annex 4. List of Tree Species in Subplot 4 Cluster 3 Jambi

Trees ID	Species Name	Family
03.4.11/JAM	*Aporusa sphaeridophora*	Euphorbiaceae
03.4.06/JAM	*Dillenia sumatrana*	Dilleniaceae
03.4.07/JAM	*Dillenia sumatrana*	Dilleniaceae
03.4.09/JAM	*Nephelium* sp. 1	Sapindaceae
03.4.08/JAM	*Ochanostachys amentacea*	Olacaceae
03.4.01/JAM	*Pternandra coerulescens*	Melastomataceae
03.4.05/JAM	*Scaphium macropodum*	Sterculiaceae

Annex 5. List of Tree Species in Subplot 1 Cluster 4 Jambi

Trees ID	Species Name	Family
04.1.03/JAM	*Aglaia ganggo*	Meliaceae
04.1.02/JAM	*Coelostegia griffithii*	Bombacaceae
04.1.01/JAM	*Macaranga pruinosa*	Euphorbiaceae

Annex 6. List of Tree Species in Subplot 2 Cluster 4 Jambi

Trees ID	Species Name	Family
04.2.06/JAM	*Actinodaphne* sp. 1	Lauraceae
04.2.08/JAM	*Dacryodes rostrata*	Burseraceae
04.2.04/JAM	*Eugenia* sp. 8	Myrtaceae
04.2.07/JAM	*Hydnocarpus woodii*	Flacourtiaceae
04.2.03/JAM	*Knema latifolia*	Myristicaceae
04.2.02/JAM	*Nephelium lappaceum*	Sapindaceae
04.2.01/JAM	*Xanthopyllum* sp.4	Polygalaceae
04.2.05/JAM	*Xanthopyllum* sp.4	Polygalaceae

Annex 7. List of Tree Species in Subplot 3 Cluster 4 Jambi

Trees ID	Species Name	Family
04.3.02/JAM	*Alstonia scholaris*	Apocynaceae
04.3.07/JAM	*Blumeodendron tokbrai*	Euphorbiaceae
04.3.04/JAM	*Coelostegia griffithii*	Bombacaceae
04.3.01/JAM	*Ervatamia sphaerocarpa*	Apocynaceae
04.3.06/JAM	*Litsea ferruginea*	Lauraceae
04.3.03/JAM	*Macaranga populifolia*	Euphorbiaceae

Annex 8. List of Tree Species in Subplot 4 Cluster 4 Jambi

Trees ID	Species Name	Family
04.4.09/JAM	*Artocarpus fulvicortex*	Moraceae
04.4.07/JAM	*Dacryodes rostrata*	Burseraceae
04.4.08/JAM	*Gardenia* sp. 1	Rubiaceae
04.4.02/JAM	*Radermachera gigantea*	Bignoniaceae
04.4.05/JAM	*Sandoricum koetjope*	Meliaceae
04.4.06/JAM	*Xylopia malayana*	Annonaceae

Annex 9. List of Tree Species in Annular-plot 1 Cluster 3 Jambi

Trees ID	Species Name	Family
03.1.05/JAM	*Artocarpus nitidus*	Moraceae
03.1.15/JAM	*Barringtonia* sp.2	Lecythidaceae
03.1.22/JAM	*Carallia brachiata*	Rhizoporaceae
03.1.09/JAM	*Carallia brachiata*	Rhizoporaceae
03.1.08/JAM	*Cyathocalyx bancana*	Annonaceae
03.1.24/JAM	*Cyathocalyx bancana*	Annonaceae
03.1.11/JAM	*Dacryodes rostrata*	Burseraceae
03.1.13/JAM	*Dacryodes rostrata*	Burseraceae
03.1.20/JAM	*Dyera costulata*	Apocynaceae
03.1.21/JAM	*Garcinia nervosa*	Gutteraceae
03.1.03/JAM	*Horsfieldia wallichii*	Myristicaceae
03.1.18/JAM	*Knema cinerea*	Myristicaceae
03.1.17/JAM	*Koompassia malaccensis*	Caesalpiniaceae
03.1.10/JAM	*Koompassia malaccensis*	Caesalpiniaceae
03.1.23/JAM	*Mallotus penangensis*	Euphorbiaceae
03.1.02/JAM	*Pternandra coerulescens*	Melastomataceae
03.1.16/JAM	*Shorea leprosula*	Dipterocarpaceae
03.1.04/JAM	*Shorea ovalis*	Dipterocarpaceae
03.1.01/JAM	*Shorea platyclados*	Dipterocarpaceae
03.1.06/JAM	*Tricalysia* sp. 2	Rubiaceae

Annex 10. List of Tree Species in Annular-plot 2 Cluster 3 Jambi

Trees ID	Species Name	Family
03.2.17/JAM	*Alseodaphne bancana*	Lauraceae
03.2.15/JAM	*Cratoxylum arborescens*	Hypericaceae
03.2.16/JAM	*Croton argyratus*	Euphorbiaceae
03.2.14/JAM	*Dacryodes costata*	Burseraceae
03.2.04/JAM	*Dacryodes rostrata*	Burseraceae
03.2.10/JAM	*Dysoxylum* sp. 2	Meliaceae
03.2.01/JAM	*Eugenia* sp. 8	Myrtaceae
03.2.18/JAM	*Gynotroches axillaris*	Rhizoporaceae
03.2.12/JAM	*Pternandra coerulescens*	Melastomataceae
03.2.13/JAM	*Ptychopyxis* sp. 1	Euphorbiaceae
03.2.09/JAM	*Shorea ovalis*	Dipterocarpaceae

Annex 11. List of Tree Species in Annular-plot 3 Cluster 3 Jambi

Trees ID	Species Name	Family
03.3.16/JAM	*Artocarpus nitidus*	Moraceae
03.3.17/JAM	*Dacryodes rostrata*	Burseraceae
03.3.09/JAM	*Dacryodes rostrata*	Burseraceae
03.3.12/JAM	*Dehaasia caesia*	Lauraceae
03.3.18/JAM	*Dyera costulata*	Apocynaceae
03.3.08/JAM	*Gironniera subaequalis*	Ulmaceae
03.3.06/JAM	*Hydnocarpus woodii*	Flacourtiaceae
03.3.04/JAM	*Nephelium lappaceum*	Sapindaceae
03.3.03/JAM	*Shorea parvifolia*	Dipterocarpaceae
03.3.02/JAM	*Sindora leiocarpa*	Caesalpiniaceae
03.3.20/JAM	*Santiria griffithii*	Burseraceae
03.3.19/JAM	*Sindora leiocarpa*	Caesalpiniaceae
03.3.22/JAM	*Xanthopyllum* sp. 3	Polygalaceae
03.3.14/JAM	*Xanthopyllum vitellinum*	Polygalaceae

Annex 12. List of Tree Species in Annular-plot 4 Cluster 3 Jambi

Trees ID	Species Name	Family
03.4.11/JAM	*Aporusa sphaeridophora*	Euphorbiaceae
03.4.20/JAM	*Aporusa sphaeridophora*	Euphorbiaceae
03.4.23/JAM	*Croton argyratus*	Euphorbiaceae
03.4.12/JAM	*Diospyros pseudomalabarica*	Ebenaceae
03.4.06/JAM	*Dillenia sumatrana*	Dilleniaceae
03.4.07/JAM	*Dillenia sumatrana*	Dilleniaceae
03.4.16/JAM	*Garcinia* sp. 2	Gutteraceae
03.4.13/JAM	*Gironniera subaequalis*	Ulmaceae
03.4.09/JAM	*Nephelium* sp. 1	Sapindaceae

Annex 12. (Continuation)

Trees ID	Species Name	Family
03.4.08/JAM	*Ochanostachys amentacea*	Olacaceae
03.4.17/JAM	*Palaquium gutta*	Sapotaceae
03.4.01/JAM	*Pternandra coerulescens*	Melastomataceae
03.4.05/JAM	*Scaphium macropodum*	Sterculiaceae
03.4.25/JAM	*Shorea acuminata*	Dipterocarpaceae
03.4.22/JAM	*Shorea ovalis*	Dipterocarpaceae
03.4.14/JAM	*Tricalysia* sp. 2	Rubiaceae

Annex 13. List of Tree Species in Annular-plot 1 Cluster 4 Jambi

Trees ID	Species Name	Family
04.1.03/JAM	*Aglaia ganggo*	Meliaceae
04.1.25/JAM	*Aglaia ganggo*	Meliaceae
04.1.32/JAM	*Alangium javanicum*	Alangiaceae
04.1.20/JAM	*Alstonia scholaris*	Apocynaceae
04.1.11/JAM	*Beilschmiedia kuntsleri*	Lauraceae
04.1.19/JAM	*Blumeodendron tokbrai*	Euphorbiaceae
04.1.02/JAM	*Coelostegia griffithii*	Bombacaceae
04.1.15/JAM	*Coelostegia griffithii*	Bombacaceae
04.1.26/JAM	*Dracontomelon dao*	Anacardiaceae
04.1.27/JAM	*Dracontomelon dao*	Anacardiaceae
04.1.08/JAM	*Durio oxleyanus*	Bombacaceae
04.1.12/JAM	*Gynotroches axillaris*	Rhizoporaceae
04.1.28/JAM	*Gynotroches axillaris*	Rhizoporaceae
04.1.17/JAM	*Horsfieldia wallichii*	Myristicaceae
04.1.21/JAM	*Horsfieldia wallichii*	Myristicaceae
04.1.23/JAM	*Horsfieldia wallichii*	Myristicaceae
04.1.09/JAM	*Koompassia malaccensis*	Caesalpiniaceae
04.1.01/JAM	*Macaranga pruinosa*	Euphorbiaceae
04.1.16/JAM	*Pellacalyx axillaris*	Rhizoporaceae
04.1.07/JAM	*Pimelodendron griffithianum*	Euphorbiaceae
04.1.10/JAM	*Radermachera gigantea*	Bignoniaceae
04.1.13/JAM	*Radermachera gigantea*	Bignoniaceae
04.1.14/JAM	*Radermachera gigantea*	Bignoniaceae
04.1.24/JAM	*Radermachera gigantea*	Bignoniaceae
04.1.18/JAM	*Rhodamnia cinerea*	Myrtaceae
04.1.05/JAM	*Rhodamnia cinerea*	Myrtaceae
04.1.06/JAM	*Santiria laevigata*	Burseraceae
04.1.30/JAM	*Santiria laevigata*	Burseraceae
04.1.31/JAM	*Santiria oblongifolia*	Burseraceae
04.1.04/JAM	*Shorea acuminata*	Dipterocarpaceae
04.1.22/JAM	*Sterculia macrophylla*	Sterculiaceae

Annex 14. List of Tree Species in Annular-plot 2 Cluster 4 Jambi

Trees ID	Species Name	Family
04.2.06/JAM	*Actinodaphne* sp. 1	Lauraceae
04.2.22/JAM	*Aquilaria malaccensis*	Thymelaceae
04.2.23/JAM	*Artocarpus dadah*	Moraceae
04.2.18/JAM	*Artocarpus elasticus*	Moraceae
04.2.08/JAM	*Dacryodes rostrata*	Burseraceae
04.2.16/JAM	*Dacryodes rostrata*	Burseraceae
04.2.12/JAM	*Dialium platycepalum*	Caesalpiniaceae
04.2.26/JAM	*Engelhardtia serrata*	Juglandaceae
04.2.04/JAM	*Eugenia* sp. 8	Myrtaceae
04.2.19/JAM	*Gymnacranthera bancana*	Myristicaceae
04.2.07/JAM	*Hydnocarpus woodii*	Flacourtiaceae
04.2.03/JAM	*Knema latifolia*	Myristicaceae
04.2.25/JAM	*Koompassia malaccensis*	Caesalpiniaceae
04.2.02/JAM	*Nephelium lappaceum*	Sapindaceae
04.2.10/JAM	*Parinari glaberrima*	Rosaceae
04.2.13/JAM	*Polyathia hypoleuca*	Annonaceae
04.2.11/JAM	*Polyathia hypoleuca*	Annonaceae
04.2.20/JAM	*Rhodamnia cinerea*	Myrtaceae
04.2.17/JAM	*Shorea ovalis*	Dipterocarpaceae
04.2.14/JAM	*Shorea parvifolia*	Dipterocarpaceae
04.2.15/JAM	*Shorea parvifolia*	Dipterocarpaceae
04.2.01/JAM	*Xanthopyllum* sp.4	Polygalaceae
04.2.05/JAM	*Xanthopyllum* sp.4	Polygalaceae

Annex 15. List of Tree Species in Annular-plot 3 Cluster 4 Jambi

Trees ID	Species Name	Family
04.3.02/JAM	*Alstonia scholaris*	Apocynaceae
04.3.07/JAM	*Blumeodendron tokbrai*	Euphorbiaceae
04.3.04/JAM	*Coelostegia griffithii*	Bombacaceae
04.3.19/JAM	*Dracontomelon dao*	Anacardiaceae
04.3.16/JAM	*Durio oxleyanus*	Bombacaceae
04.3.01/JAM	*Ervatamia sphaerocarpa*	Apocynaceae
04.3.23/JAM	*Eugenia* sp. 8	Myrtaceae
04.3.15/JAM	*Gymnacranthera forbesii*	Myristicaceae
04.3.05/JAM	*Gymnacranthera forbesii*	Myristicaceae
04.3.20/JAM	*Horsfieldia wallichii*	Myristicaceae
04.3.22/JAM	*Horsfieldia wallichii*	Myristicaceae
04.3.08/JAM	*Horsfieldia wallichii*	Myristicaceae
04.3.09/JAM	*Knema latifolia*	Myristicaceae
04.3.10/JAM	*Koompassia malaccensis*	Caesalpiniaceae
04.3.06/JAM	*Litsea ferruginea*	Lauraceae
04.3.03/JAM	*Macaranga populifolia*	Euphorbiaceae
04.3.14/JAM	*Mangifera caesia*	Anacardiaceae
04.3.12/JAM	*Mangifera foetida*	Anacardiaceae
04.3.13/JAM	*Myristica maxima*	Myristicaceae
04.3.17/JAM	*Nauclia subdita*	Rubiaceae
04.3.24/JAM	*Palaquium rostratum*	Sapotaceae

Annex 15. (Continuation)

Trees ID	Species Name	Family
04.3.18/JAM	*Pterospermum javanicum*	Sterculiaceae
04.3.21/JAM	*Radermachera gigantea*	Bignoniaceae
04.3.11/JAM	*Shorea parvifolia*	Dipterocarpaceae

Annex 16. List of Tree Species in Annular-plot 4 Cluster 4 Jambi

Trees ID	Species Name	Family
04.4.16/JAM	*Artocarpus fulvicortex*	Moraceae
04.4.09/JAM	*Artocarpus fulvicortex*	Moraceae
04.4.07/JAM	*Dacryodes rostrata*	Burseraceae
04.4.21/JAM	*Dacryodes rostrata*	Burseraceae
04.4.27/JAM	*Endospermum diadenum*	Euphorbiaceae
04.4.23/JAM	*Eugenia* sp. 2	Myrtaceae
04.4.30/JAM	*Gardenia anisophyllea*	Rubiaceae
04.4.08/JAM	*Gardenia* sp. 1	Rubiaceae
04.4.20/JAM	*Gymnacranthera bancana*	Myristicaceae
04.4.10/JAM	*Gymnacranthera forbesii*	Myristicaceae
04.4.13/JAM	*Gymnacranthera forbesii*	Myristicaceae
04.4.22/JAM	*Koompassia malaccensis*	Caesalpiniaceae
04.4.14/JAM	*Macaranga pruinosa*	Euphorbiaceae
04.4.12/JAM	*Nauclea orientalis*	Rubiaceae
04.4.28/JAM	*Nauclea subdita*	Rubiaceae
04.4.29/JAM	*Nephelium* sp. 1	Sapindaceae
04.4.24/JAM	*Palaquium rostratum*	Sapotaceae
04.4.11/JAM	*Pellacalyx axillaris*	Rhizoporaceae
04.4.25/JAM	*Prunus acuminata*	Rosaceae
04.4.17/JAM	*Radermachera gigantea*	Bignoniaceae
04.4.02/JAM	*Radermachera gigantea*	Bignoniaceae
04.4.05/JAM	*Sandoricum koetjope*	Meliaceae
04.4.26/JAM	*Sapium baccatum*	Euphorbiaceae
04.4.15/JAM	*Vernonia arborea*	Compositae
04.4.06/JAM	*Xylopia malayana*	Annonaceae

ASSESSMENT OF PRODUCTION INDICATOR IN FOREST HEALTH MONITORING TO MONITOR THE SUSTAINABILITY OF INDONESIAN TROPICAL RAIN FOREST

Technical Report No. 13

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ABSTRACT

The health of a forest ecosystem may be determined by employing assessment procedure if they are productive, biologically and structurally diverse, large and not fragmented, balanced in size class distribution and resilient to the stressors. Continuity of timber production is one of indicators of a well-managed tropical forest ecosystem and must be maintained through better understanding of the dynamics, structure, mortality, in growth and up growth of trees. The net growth reflects the disturbance, stressors, growth and mortality in the forest ecosystem. The production indicator is relatively easy to measure and interprets high index stability.

Key words: *Mortality, basal area, net growth*

I. INTRODUCTION

Forest management has always a value driven and a must to achieve sustainable development. The adoption of ecosystem management philosophy adds non traditional values, such as sustainability, and biodiversity, as well as placing new emphasis on human dimension including long-term incentive and benefits to local forest dependent communities, and the recognition of the right on indigenous people.

The International Tropical Timber Organization (ITTO) guidelines, based on the 1990 International Meeting, specify 5 groups of indicators for well-managed tropical ecosystems: resource security, the continuity of timber production, the conservation of flora and fauna, an acceptable level of environmental impact, and socio-economic benefit.

Those indicators should be evaluated and adapted to a specific ecosystem. Ecosystem fragmentation influences the species diversity, vegetation structure, and elasticity to the stressors and productivity. Sustainable forest management should maintain the ecosystem integrity. The health of forest ecosystem must be maintained. Forest ecosystems are healthy if they are productive, biologically and structurally diverse, large and not fragmented, balanced in size class distribution and resilient to the stressors.

Monitoring system to evaluate forest health should provide information to land owners and managers about ecological status of forest, what changes are occurring, what are the causal agents of the change, whether the changes indicate a trend, what the expected management decisions would result on the existing conditions.

Tropical rain forests provide wide arrays of products, among them is timber. The continuity of timber production must be maintained through better understanding of dynamics, structure, mortality, growth, in-growth, and up-growth.

The objective of this study is to assess the production indicator in Forest Health Monitoring to Monitor the Sustainability of Indonesian Tropical Rain Forest.

II. MATERIALS AND METHODS

To test the adaptability of production indicator in Forest Health Monitoring, mortality, diameter growth and net growth were measured.

Forest Health Monitoring plots were established in Pulau Laut using the Forest Health Monitoring Field Guide Methods (USDA Forest Service, 1997), Figure 1, called INDO-FHM plots.

Each FHM plot consists of a series of fixed area; circular subplots tied to a cluster plot of four points that area spaced 36.6 m apart. A cluster design was chosen because it has been proven to be cost-effective for extensive surveys. The key sampling unit for most tree measurements is the 1/60 - hectare subplot. Each subplot includes a 1/750 - hectare micro-plots, offset from subplot center to avoid trampling.

Trees within the diameter 20 cm up were measured in annular plots (r = 17.95 m), trees within the diameter 10 - 20 cm were measured in subplot (r = 7.32 m), saplings were measured in subplots (r =7.32) and seedlings were measured in micro-plots (r = 2.1 m).

Trees, poles, sapling, and seedlings were tagged for their identity and it will be used for the next re-measurements. The Diameter Breast Height and number of individual for trees, pole, sapling were measured periodically. The number of seedling per micro-plot was also counted periodically.

The formulas for the mortality, growth, and regeneration indices are standard formulations commonly used on forest mensuration literature (Cline, 1995).

2.1. Mortality Rate

Mortality is calculated as an average annual death rate per area. Since the demonstration plots of Forest Health Monitoring were visited every year and only the four subplots were measured, an annual mortality rate per hectare M would be calculated as:

$M = 14.872 \cdot D / (4 \cdot P)$,

where D is the number of tree > 10.0 cm dbh which have died since the previous visit and P is the proportion of plot in forested condition classes (0.1 – 1.0) and 14.872 represents the expansions factor to blow up the four subplots to one hectare and is a term used to normalize the death rate to an annual rate.

2.2. Basal Area Growth

Basal area growth is calculated as the change in basal area of survivor trees. Basal area per hectare is calculated at each time period as the sum for all live trees of :

$$14.872 \cdot 0.00007854 \cdot dbh \cdot dbh / P,$$

where 0.00007854 is the correction factor to change dbh in centimeters to tree basal area in square meter, 14.872 is again the expansion factor for the plot, and P is again the proportion of the plot in forested condition classes (0.1 – 1.0).

2.3. Net-Growth

Net growth is the change in basal area over time. That change represents changes in individual tree basal area, loss of basal area due to mortality, gain in basal area due to in-growth, and loss of basal area due to forest management.

If B_t and B_{t+u} are the basal area per hectare at times *t* and *t + u,* respectively, then

$$(B_{t+u} - B_t) / u$$

is the average annual net growth per hectare. If condition class boundaries change over time, then areas are computed for the new condition classes and this calculation is performed for trees which have remained in that zone.

III. RESULTS AND DISCUSSIONS

Data on mortality rate for Pulau Laut and Jambi are presented in Table 1.

The mortality rate in FHM Cluster plots 4, 5 and 6 occurred very high because of forest fire in 1998 and followed by illegal cutting. Most of the trees with diameter >20 cm were cut illegally by the people surrounding the forest for wood construction and the land was occupied for agricultural activities. Some crops such as maize, rice, peanut were planted in the degraded area. These activities would diminish entirely of the forest including loss of standing stocks (seedling, sapling, pole and trees), biodiversity, ecosystem disintegraty. It means that the illegal cutting disturbs the sustainability of production in terms of quantity.

In normal development (Cluster plots 1,2,7) where the illegal cutting does not occur , the mortality rate is lower than in disturbed forest. While in plantation forest of Shorea polyandra practically there isn't any tree mortality during the observation period.

Table 1. Mortality of the Pole and Trees During 3 Years in FHM Plots at Pulau Laut and Jambi

Location	Cluster Plot	Poles (Sub plot) (N/Ha)	Trees (An. plot) (N/Ha)	Remarks
Pulau Laut	1	7.44	13.80	TPTI, Limited Production Forest, Buffer Zone, Logged in 1978. Dominated by *Shorea polyandra.*
	2	22.31	44.62	Protection forest (Biodiver -sity Conservation area). Dominated by *Shorea polyandra.*
	3	0.00	0.00	Plantation forest of *Shorea polyandra.* Planted in 1976.
	4	85.61	18.54	Seed Production Area (SPA), Forest fire, Illegal cutting. Dominated by *Dipterocarpus sp.*
	5	126.41	252.82	Seed Production Area (SPA), Forest fire, Illegal cutting. Limited Production Forest.
	6	85.51	193.34	Seed Production Area (SPA), Forest fire, Illegal cutting, Dominated by *Dipterocarpus sp.*
	7	3.72	3.72	TPTI, Limited Production Forest Buffer Zone, Logged in 1978. Dominated by *Shorea polyandra.*
Jambi	1	48.33	74.36	TPTI, Limited Production Forest Logged in 1995. Mixed species.
	2	18.59	37.18	TPTI, Limited Production Forest Logged in 1995. Mixed species.
	3	66.94	100.39	TPTI, Limited Production Forest Logged in 1984. Mixed species.
	4	7.44	33.46	TPTI, Limited Production Forest Virgin Forest. Mixed species.

The mortality of poles and trees after logging activity in Jambi (Clusters 1,2,3, PT Asialog) showed higher mortality than that in virgin forest (Cluster 4). It is possible that the logging activities produced some damages to the residual stand, and the logging effects appeared seriously to the poles and trees mortality 3 years after logging.

Trees growth (diameter) is influenced by the tree density. The space competition is the most important factor. A gap will be formed when tree(s) die. The open space will be occupied by pioneer species or will stimulate the diameter growth of adjacent trees. The diameter growth of poles and trees in FHM cluster plots can be seen in Table 2.

Table 2. Diameter Growth of the Trees in FHM Plots at Pulau Laut and Jambi

Location	Cluster Plot	Poles Subplot (cm/year)	Trees Ann. plot (cm/year)	Remarks
Pulau Laut	1	0.32	0.68	TPTI, Limited Production Forest, Buffer Zone, Logged in 1978. Dominated by *Shorea polyandra.*
	2	0.31	0.38	Protection forest (Biodiversity Conservation area). Dominated by *Shorea polyandra.*
	3	0.60	0.73	Plantation forest of *Shorea polyandra*, planted in 1976.
	4	0.63 *	0.99 *	Seed Production Area (SPA), Forest fire, Illegal cutting. Dominated by *Dipterocarpus sp.*

Table 2. (Continuation)

Location	Cluster Plot	Poles Subplot (cm/year)	Trees Ann. plot (cm/year)	Remarks
Pulau Laut	5	0.63 *	0.89 *	Seed Production Area (SPA), Forest fire, Illegal cutting. Limited Production Forest. Dominated by *Dipterocarpus sp.*
	6	0.61*	0.60 *	Seed Production Area (SPA), Forest fire, Illegal cutting, Dominated by *Dipterocarpus sp.*
	7	0.74	0.72	TPTI, Limited Production Forest Buffer Zone, Logged in 1978. Dominated by *Shorea polyandra.*
Jambi	1	0.37	0.40	TPTI, Limited Production Forest Logged in 1995. Mixed species.
	2	0.43	0.43	TPTI, Limited Production Forest Logged in 1995. Mixed species.
	3	0.29	0.46	TPTI, Limited Production Forest Logged in 1984. Mixed species.
	4	0.29	0.36	TPTI, Limited Production Forest Virgin Forest. Mixed species.

* The remaining live-poles or trees only.

The diameter growth of species in poles (10 - 19 cm) is lower than the diameter growth of the trees (>20 cm), ranging from 0.31 cm to 0.72 cm per year in Pulau Laut, while in Jambi ranging from 0.29 to 0.43 cm per year. Tree diameter growth in Pulau Laut ranged between 0.68 cm to 0.99 cm per year, while in Jambi 0.36 cm to 0.46 cm per year.

The diameter growth in cluster 4, 5, and 6 in Pulau Laut was higher due to the illegal cutting that provide larger space to facilitate faster diameter growth. The diameter growth of *Shorea polyandra* in plantations seems to be better than in natural forest. To convince this phenomenon a long-term monitoring is still needed. In general the diameter growth is still lower than the assumption used in Indonesian selective cutting and replanting system. Net-growth (m^2/Ha/year) of the stand during the observation period is shown in Table 3.

Table 3. Net - growth of poles and trees in FHM plots at Pulau Laut and Jambi

Location	Cluster Plot	Poles 10-19 cm Subplot		Trees > 20 cm Annular		Remarks
		BSA / Ha (m^2/Ha)	Net-growth (m^2/Ha/year)	BSA / Ha (m^2/Ha)	Net-growth (m^2/Ha/year)	
Pulau Laut	1	1.09	0.36	8.50	2.83	TPTI, Limited Production Forest, Buffer Zone, Logged in 1978. Dominated by *Shorea polyandra.*
	2	2.31	0.77	1.34	0.45	Protection forest (Biodiver - sity Conservation area). Dominated by *Shorea polyandra.*
	3	5.66	1.88	3.77	1.26	Plantation forest of *Shorea polyandra*

Table 3. (Continuation)

Location	Cluster Plot	Poles 10-19 cm Subplot		Trees > 20 cm Annular		Remarks
		BSA / Ha (m^2/Ha)	Net-growth (m^2/Ha/year)	BSA / Ha (m^2/Ha)	Net-growth (m^2/Ha/year)	
	4	0.85	0.28	0.31	0.10**	Seed Production Area (SPA), Forest fire, Illegal cutting
	5	0.25	0.08	0.21	0.07**	Seed Production Area (SPA), Forest fire, Illegal cutting
	6	0.83	0.27	0.37	0.13**	Seed Production Area (SPA), Forest fire, Illegal cutting
	7	7.78	2.59	13.72	4.58	TPTI* Buffer Zone, Logged in 1978.
Jambi	1	1.87	0.62	4.44	1.48	TPTI, Limited Production Forest Logged in 1995. Mixed species.
	2	3.43	1.14	4.69	1.56	TPTI, Limited Production Forest Logged in 1995. Mixed species.
	3	0.55	0.27	2.49	0.83	TPTI, Limited Production Forest Logged in 1984. Mixed species.
	4	0.74	0.37	3.46	1.15	TPTI, Limited Production Forest Virgin Forest. Mixed species.

Remark : ** low net growth due to forest fire and illegal cutting, remaining forested area 0.1 ha

Net-growth was calculated based on the diameter growth of poles or trees in the cluster plots. Net-growth in cluster plot 4,5 and 6 at Pulau Laut is very low, 0.8 - 0.27 m2/ ha/year for poles and 0.06 - 0.12 m^2/ha/year for trees. It is clear that forest disturbance (illegal cutting) decreases the standing stock and the net-growth. While in cluster plot 1 and 7 at Pulau Laut their net-growth is very high 0.36 - 2.59 m^2/ha/year for poles and 2.83 - 4.58 m^2/ha/year for trees. These cluster plots are dominated by *Shorea polyandra*.

Net-growth of stand in cluster plot 1,2,3 and 4 at Jambi was 0.24 – 1.14 m^2/ha/ year for poles and 0.82 - 1.56 m^2/ha/year for trees.

IV. CONCLUSIONS

The production indicator can be measured using mortality, diameter growth, and net growth. This indicator is easy to measure, to interpret, easy to handle. Net-growth can illustrate the disturbance, stressors, and mortality.

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ASSESSMENT OF PRODUCTION INDICATOR IN FHM-NFI PLOT SYSTEM IN JAMBI AND SOUTH KALIMANTAN

Technical Report No. 14

Supriyanto

ABSTRACT

Field-testing of production indicator was conducted in PT Sumpol Forest Concession Holder, South Kalimantan and in PT Asialog, Jambi. FHM plots were overlaid on NFI plot system. Two NFI cluster plots, grid number 503209620 and 503209600 in South Kalimantan and one cluster plot grid number 483209760 in Jambi were selected. Vegetation maps of Meratus Mountain and it surrounding, South Kalimantan was made using satellite image, prior to the plot establishment for indicator testing. The diameter of all the trees with the diameter > 10 cm in the plot were measured for the basal area calculation. The results showed that the production indicator could be easily implemented in NFI plot system. The total basal area recorded in FHM plot system was higher than in NFI plot system. Reproducibility of production indicator in NFI plot system was good.

Key words: *NFI, basal area, indicator*

I. INTRODUCTION

Forest Health Monitoring (FHM) was first developed in the U.S. in 1991. The FHM is an ecological approach to evaluate forest ecosystems for condition, changes, trends, causal agents and mechanisms to monitor the condition and changes in forest ecosystems. It is a ground-based estimates of the condition and trends in the forests, by monitoring the proportions of forest population that are in poor, sub nominal, nominal or optimal condition of each indicator.

One group of criteria to be addressed in INDO-FHM is environmental criteria, which will address biodiversity composition, abundance, habitat suitability and ecosystem processes (growth, regeneration, mortality, stand structure) and productivity. The environmental indicator tested in the demonstration plot was production indicator. These indicators should be tested in NFI plot system to address the forest sustainability in term of biodiversity to assess the healthy of forest ecosystem.

The objective of this study was to assess the production indicator used in FHM within NFI plot systems.

II. MATERIALS AND METHODS

FHM cluster plot number 9 and 8 were established and overlaid to NFI plots (number 503209620 and 503209600) respectively. Those plots are located at PT Sumpol Timber, South Kalimantan. FHM cluster plot number 4 was established and overlaid on NFI plot number 573209760. FHM cluster plot number 4 is located at PT Asia Log, Jambi. The NFI plot system is shown in Figure1. The overlay of FHM plot on NFI plot system is shown in Figure 2. The FHM plot model and data recording followed the Forest Health Monitoring Field Methods Guide (International-Indonesia) issued by the EPA (1997).

The FHM center plot of plot 1 was located in the crossing point between two diagonal lines of the NFI Permanent Sample Plot (PSP). In this case, the position of FHM plot number 2 will be partly (5 m) outside of NFI Permanent Sampling Plot (See Figure 2).

FHM plot establishment (Figure 3) and tree data recording system followed the Forest Health Monitoring Field Method Guides (International- Indonesia) issued by EPA (1997). The trees with diameter over than 10 cm were measured and recorded. The data of NFI was taken from the inventory results conducted by the Agency of Forest and Estate Crops Planning, Ministry of Forestry and Estate Crops (MOFEC) in 1998. The NFI data was recorded 3 months before FHM plots establishment.

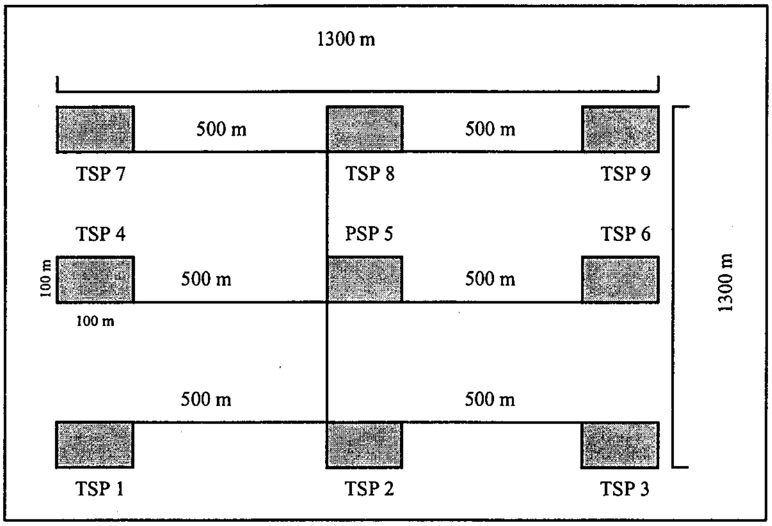

Figure 1. National Forest Inventory Plot System
TSP : Temporary Sampling Plot , PSP : Permanent Sampling Plot (Hidden Plot)

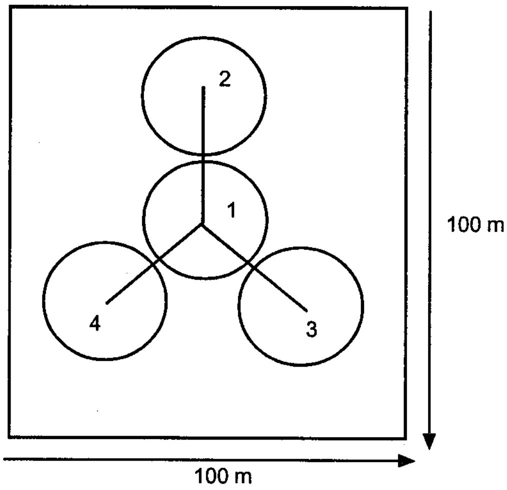

Figure 2. Overlay of FHM Plot on NFI Permanent Sampling Plot (PSP)

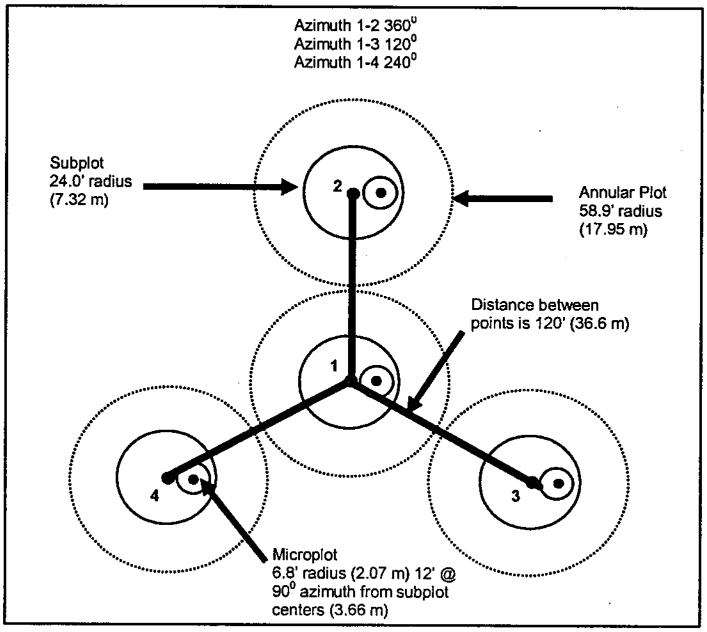

Figure 3. National FHM plot layout is designed around four points (subplot centers)

The NFI data was recorded every 5 years using census system (100%). The scientific name of tree species found in FHM cluster plots was identified at the Laboratory of Botany, Forestry Research and Development Agency (FORDA).

The trees with the diameter over than 10 cm were mapped. Tree position (azimuth and distance) and diameter data were recorded in standardized tally sheet. Herbarium of the trees in FHM plots were also collected and identified in Laboratory of Botany, the Forestry Research and Development Agency. The tree identity tagged by NFI system located in FHM plot system was also recorded and identified for the identification checking purposes, especially for scientific name verification. On the other hand, the species coder-decoder software of the NFI project of Indonesia was used for checking the species name. This coder and decoder system is designed for translating the local name to scientific name (Setyarso and Muhadiono, 1991).

III. RESULTS AND DISCUSSIONS

Measurement of current tree diameter and number of trees per hectare is substantially important to know the current status of tree stocking. It will be used to provide the base-line data of the forest condition. Indonesia has developed the National Forest Inventory system. It is important to compare the effectiveness of NFI plot system versus FHM plot system on production indicator. This production indicator was measured using basal area of trees with diameter more than 10 cm.

Measurement of tree population in NFI plot system was conducted using census system, while in FHM system tree population was measured using sample plot system. It is possible that the accuracy of both systems is different. The basal area obtained in both systems is presented in Table 1.

Table 1. Basal Area Measurement in NFI and FHM Plots

Plot System	Location Plot	Trees ≥ 10 cm (N / Ha)	Basal Area (cm^2 / Ha)	Basal Area (m^2 / Ha)
NFI	Sumpol 503209620	141	119296.99	11.92969
FHM	Sumpol Cluster 9	68	155738.9	15.57389
NFI	Sumpol 503209600	128	157339.91	15.73399
FHM	Sumpol Cluster 8	45	94889.9	9.48899
NFI	Jambi 483209760	208	180010.41	18.0010
FHM	Jambi Cluster 4	285	238245.7	23.8245

Note: Measurement in Cluster Plot 8 was done 3 months after forest fire.

Table 1 showed that the basal area measured in FHM plot system was higher than in NFI plot system (Cluster plot 9 and 4), while in cluster plot 8 the basal area in NFI system was higher than in FHM plot. In this regard, it is quite difficult to compare both systems in term of productivity, but in term of efficiency the FHM plot system is easier to be implemented. The advantage of FHM system is much easier to monitor the tree growth individually. In term of time for measurement , the FHM plot system was quicker than NFI plot system.

IV. CONCLUSIONS

Production indicator could be easily implemented in NFI plot system. The total basal area recorded in FHM plot system was higher than in NFI plot system. Reproducibility of production indicator in NFI plot system was good.

ACKNOWLEDGEMENT

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The authors would like to thank ITTO, Ministry of Forestry (GOI), PT. INHUTANI II Forest Concession Holder and PT. Asialog Concession Holder for their support. Appreciation also goes to the Project Steering Committee members for their suggestions.

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ASSESSMENT OF BIODIVERSITY INDICATOR IN FOREST HEALTH MONITORING FOR SUSTAINABLE FOREST MANAGEMENT : "TREE SPECIES DIVERSITY"

Technical Report No. 15

Erianto Indra Putra
Uhaedi Sutisna
Soekotjo

ABSTRACT

Most of our interactions with biological diversity occurred on the species level. Species embody the array of diversity from gene to population and provides a measure for the diversity of communities. Species can readily be identified and classified, and they can be counted. The objective of this study is to assess the biodiversity indicator in forest health monitoring for sustainable forest management. Tree species diversity (status, changes, and trends) was measured in FHM plot design. Species diversity formulas used to assess the diversity indicator are the species richness indices (Margalef Index and Simpson Index), the species evenness index (Pielou Index), and the species diversity indices (Shannon-Weiner Index and Simpson Index). The result showed that at the initial measurements, all of the cluster plots in Pulau Laut and Jambi have high species diversity. Changes and trends in tree species diversity show that when there is no disturbance, the value will be relatively constant. When there is forest disturbance, the value of species diversity decreases. The decreasing value of species diversity was found in Cluster plots 4, 5 and 6, due to forest fire and illegal cutting, while the values found in the other cluster plots remained constant.

Key words: *Species diversity, species richness, forest disturbance*

I. INTRODUCTION

Biological diversity encompasses all levels of natural variation, from the molecular and genetic levels to the ecosystem level. At the species level, we have most of our interactions with biological diversity through enjoyment of the common, strange, and beautiful forms of life or through suffering caused by the effects of pests, parasites, and diseases (Huston, 1995). Species embodies the array of diversity from gene to population and provides a measure for the diversity of communities. Species can readily be identified and classified, and they can be counted.

Forest Health Monitoring to Monitor the Sustainability of Indonesian Tropical Rain Forest (INDO-FHM) plans to track down the status, change and trends of biodiversity in Indonesian forests, and one of them is in the species level. The sampling design used in the INDO-FHM is called Cluster Plot Design based on Forest Health Monitoring : Field Methods Guide (International – Indonesia) (Alexander and Bernard, 1997).

The objective of this study is to assess the biodiversity indicator in forest health monitoring and its responsiveness to the size sampled area. Tree species diversity (status, change, and trends) was measured in FHM plot design.

II. METHODS

Eleven cluster-plots were established in 1996, 1997 and 1998. Seven cluster-plots were established in Pulau Laut, South Kalimantan, and four cluster-plots were established in Jambi. The cluster-plot design is based on the Forest Health Monitoring Field Method Guide (International-Indonesia, 1997) (see Figure 1). The data recorded in the subplot were the trees with the diameter of 10 cm up, while in the annular were only for the diameter of 20 cm up. Herbarium specimens were also taken for tree identification.

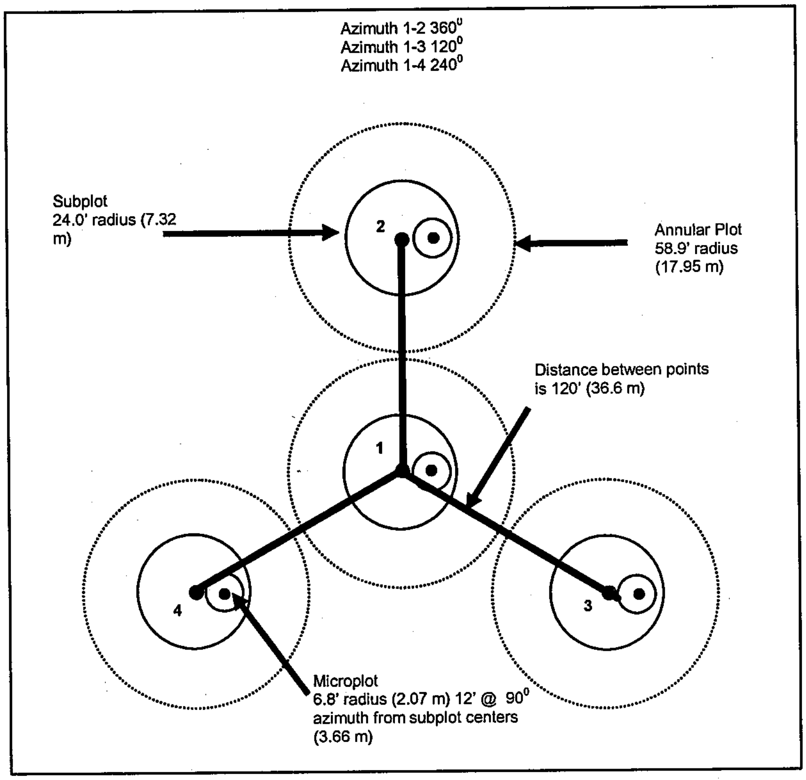

Figure 1. FHM Cluster Design

The forest functions of each cluster-plots are presented in Table 1.

Table 1. Forest Functions of FHM Cluster-plots

Location	Cluster-plot	Forest Function	Remarks
Pulau Laut	1	Limited Production Forest (Buffer Zone)	Logged in 1968
	2	Protection Forest (Genetic Resource Area)	Biodiversity Conservation
	4	Limited Production Forest	Seed Production Forest
	5	Limited Production Forest	Seed Production Forest
	6	Limited Production Forest	Seed Production Forest
	7	Limited Production Forest (Buffer Zone)	Logged in 1968
Jambi	1	Limited Production Area	Logged in 1995
	2	Limited Production Area	Virgin Forest
	3	Limited Production Area	Logged in 1995 (Seed Production Area)
	4	Limited Production Area	Virgin Forest

Calculation of tree diversity used in this report were species richness, species diversity, species evenness and species equitability.

Species richness is statistically defined by Margalef Index and Odum Index. The Margalef Index is formulated by :

$$\mathbf{R_{MAR} = (S - 1) / \ln N}$$

while the formula of Odum Index is :

$$\mathbf{R_2 = S / \log N}$$

where S = number of species and N = total number of individuals.

The species evenness refers to the Pielou's evenness index J' that is calculated by :

$\mathbf{J' = H' / H'_{max}}$; H_{max} is determined by $\mathbf{H'_{max} = \ln S}$, so then :

$$\mathbf{J' = H' / \ln S}$$

J' is ranged between 0 and 1. J' will be minimum (= 0), if all individuals are of one species, and maximum (= 1), if the number of species equals the number of individuals.

Tree diversity is described using statistical formulas that combine species richness component and evenness component. The best known of these composite statistics used in this report is the Shannon-Weiner Index :

$$\mathbf{H' = - \Sigma\, p_i \ln (p_i)}$$

where p_i is the proportion of the total sample composed of species i :

$\mathbf{p_i = n_i / n}$; ni = the number of individuals belonging to the i th of S species in the sample

n = the total number of individuals in the sample

H' will be maximum (= ln N), if all species have equal number of individu, and minimum (= ln 1 = 0), if individuals are concentrated in one species.

The other most commonly used statistic to assess species diversity is Simpson's index λ :

$$\lambda = \Sigma p_i^2$$

λ will have the value = 1, if all of the individues are of one species, and = 1/S, if they are equally divided among the species.

The last index is the species equitability index. Species equitability is the relative diversity of sample in relation to maximum possible diversity of community of S species. The species equitability index has the formula of :

$$J' = H' / H'_{max}$$

Each of diversity indices was measured both in subplot (tree DBH of 10 cm up) and in annular plot (tree DBH of 20 cm up only) in order to compare the responsiveness of the indices to the size of sampled area.

III. RESULTS AND DISCUSSIONS

3.1. Species Richness

Species richness indices are essentially a measure of the number of species in a defined sampling unit. Species richness measures provide an instantly comprehensible expression of diversity (Magurran, 1988).

3.1.1. Pulau Laut

Figure 1 shows that the species richness in Clusters 4, 5 and 6, Pulau Laut, were decreased for the annular-plot as well as for the sub-plot. Species richness in annular-plot Cluster 4 is decreased from 3.710 (1996) to 2.065 (1999) while in Cluster 5 from 3.878 (1996) to 1.491 (1999) and Cluster 6 from 4.075 (1996) to 2.146 (1999). This decreasing value for species richness in the mentioned cluster are relatively high from year to year, especially from 1998 to 1999 as 29.95%, 47.11%, and 41,78% for Cluster 4, 5, and 6, respectively. The highest decreasing species richness from 1996 to 1999 is found in annular-plot Cluster 5 as 61.55%followed by Cluster 6 (47.34%) and Cluster 4 (42.42%).

The decreasing species richness from 1996 to 1999 in the sub-plot of Clusters 4, 5 and 6 are higher than in annular plot as 46.60% for Cluster 4, 84.66% for Cluster 5, and 65.91% for Cluster 6.

On the other hand, the species richness in Clusters 1, 2, and 7 were relatively stable since there were no disturbance occurred in these plots. History of each established plot in Pulau Laut described briefly in TR 1-Plot Establishment (Supriyanto and Gintings, 2001).

Species richness in Cluster 1 and 2 were relatively stable with a little tend to increase in their subplots as 7.28% and 10.79% for Cluster 1 and Cluster 2, respectively. This increasing was originated from the upgrowth of several species from sapling stage to the pole stage, The natural mortality caused by diseases made the little decreasing value of species richness in annular plots Cluster 1 and 2, and sub-plot and annular plot of Cluster 7. The decreasing value are as 4.55% (annular plot Cluster 1), 0.29% (annular plot Cluster 2), 10.72% (sub-plot Cluster 7), and 6.25% (annular plot Cluster 7). The status, change and trends of natural diseases on each FHM plots are provided in TR 18 on the Damage Assessment (Nuhamara et al., 2001).

Table 1. Status, Change and Trends of Species Richness by using Margalef Index in FHM Plots, Pulau Laut, South Kalimantan

No.	Location	Subplot				Annular plot			
		1996	1997	1998	1999	1996	1997	1998	1999
1	Cluster 1	0.626	0.659	0.659	0.707	1.649	1.574	1.574	1.574
2	Cluster 2	1.741	1.741	1.932	1.932	3.067	3.067	2.967	3.058
4	Cluster 4	2.204	2.018	1.827	1.177	3.710	3.416	2.948	2.065
5	Cluster 5	2.353	1.931	1.608	0.361	3.878	3.476	2.819	1.491
6	Cluster 6	2.502	2.204	2.193	0.853	4.075	3.941	3.686	2.146
7	Cluster 7	1.007	0.899	0.899	0.899	1.527	1.443	1.443	1.429

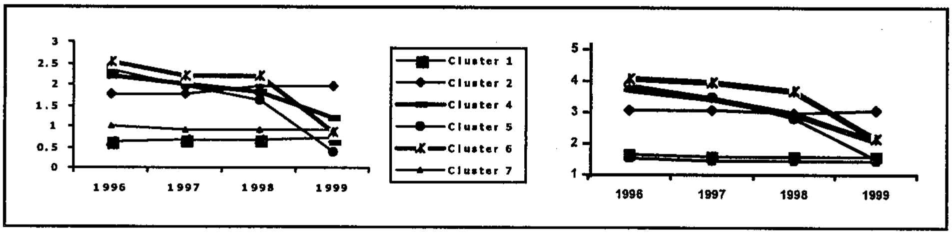

Figure 1. Trends of Species Richness of FHM Sub-plot (A) and Annular-plot (B), Pulau Laut, South Kalimantan, using Margalef-Species Richness Index

Decreasing trends were also found in Clusters 4, 5, and 6 when the species richness is calculated with Odum Index (Table 2 and Figure 2). The species richness in subplot Cluster 4 is decreased from 6.263 to 4.894 (21.86%), and from 9.274 to 6.997 (24.55%) for the annular-plot. Species richness in subplot Cluster 5 is decreased from 6.496 to 2.076 (68.04%), and from 9,657 to 4,611 (51.32%) for the annular-plot. Species richness in subplot Cluster 6 is decreased from 6.922 to 2.643 (61.82%), and from 10.101 to 7.364 (27.10%) for the annular-plot.

As Margalef Index, the Odum gives relatively stable value in the species richness of Clusters 1, 2 and 7 Pulau Laut. Species richness in sub-plot Clusters 1 and 2 are increased 12.26% and 11.02%, respectively, while the species richness in subplot Cluster 7 is decreased 6.10%. Species richness in annular plot Clusters 1, 2, and 7 are decreased 3.96%, 1.14%, and 5.37%, respectively.

Decreasing species richness on Clusters 4, 5 and 6 were due to the forest fire incidence in 1997 followed by uncontrolled illegal cutting for cultivation done by local people surrounding the forest in 1998 up to now. This condition indicates that the forest fire and uncontrolled illegal cutting diminishing the richness of species encounter in the respective area

Species richness in annular-plot was always having a bigger value than in sub-plot (Tables 1 and 2). These phenomena thus indicate that the species richness indices (both for Margalef' and Odum') depend on the sample size and community level. The Margalef' showed the value of 0.626 up to 2.898 in sub-plot, whereas the value for annular-plot was ranged between 1.429 and 4.075. The Odum was ranged between 2.014 and 6.922 for sub-plot, and between 4.072 and 10.101 for annular plot.

Decrease in species richness in subplot was always bigger than in annular plot. This indicates that the loss of species occurred in the subplot is bigger than the loss in the annular. It also indicates that the sample size of disturbed area influence the range of the loss species occurred. The loss will be higher as the sample size is become smaller.

Table 2. Status, Change and Trends of Species Richness by using Odum Index in FHM plots, Pulau Laut, South Kalimantan

No.	Location	Subplot				Annular plot			
		1996	1997	1998	1999	1996	1997	1998	1999
1	Cluster 1	2.014	2.116	2.116	2.261	4.648	4.464	4.464	4.464
2	Cluster 2	5.011	5.011	5.563	5.563	7.814	7.814	7.624	7.725
4	Cluster 4	6.263	6.120	5.883	4.894	9.274	8.676	7.690	6.997
5	Cluster 5	6.496	5.882	4.753	2.076	9.657	8.824	7.994	4.611
6	Cluster 6	6.922	6.504	6.645	2.643	10.101	9.816	9.249	7.364
7	Cluster 7	3.478	3.266	3.266	3.266	4.302	4.114	4.112	4.072

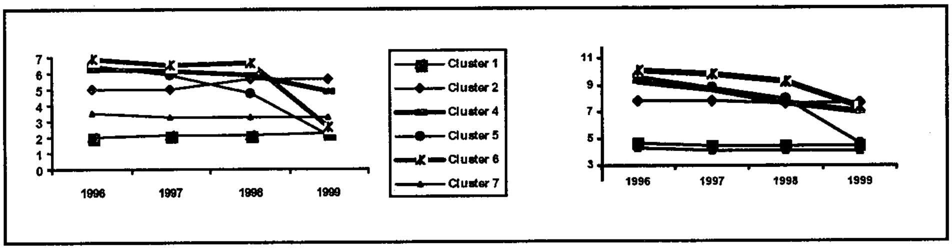

Figure 2. Trends of Species Richness of FHM Sub-plot (A) and Annular-plot (B), Pulau Laut, Using Odum Index

3.1.2. Jambi

Both Margalef and Odum Indexes showed the constant value of species richness in Jambi (Tables 3 and 4, Figures 3 and 4). Decreasing value was occurred by trees natural mortality as found in the subplot of Clusters 1, 2 and 4 (21.3%, 4.63%, and 3.71%, respectively) and in the annular-plot of Clusters 1 and 4 (17.86% and 1.61%). Increasing value was originated from the natural upgrowth and was found in the subplot of Cluster 3 (15.92%) and in the annular-plot of Clusters 2 and 3(4.48% and 1.24%). This relatively stable species richness value was due to the relatively stable condition of the observed plot in Jambi. There were no illegal cutting activity and other human-caused damage occurred in these cluster plots. This condition, as compared with the condition in Clusters 1, 2 and 7 Pulau Laut indicated that when there are no disturbances occurred in and surrounding the area, the species richness in the respective area will be remained constant.

As mentioned before, the species richness depends on the sample size and community level. This fact was also found in Jambi. The species richness in Annular plot was always has a bigger value than in subplot (Tables 3 and 4, Figures 3 and 4). The Margalef' showed the value of 2.262 up to 3.878 in sub-plot, whereas the value for annular-plot was ranged between 4.509 and 6.275. The Odum was ranged between 7.039 and 9.686 for sub-plot, and between 11.239 and 15.153 for annular plot.

Table 3. Status, Change and Trends of Species Richness by using Margalef Index in FHM Plots, Jambi

No.	Location	Subplot				Annular plot			
		1996	1997	1998	1999	1996	1997	1998	1999
1	Cluster 1	3.342	3.342	2.878	2.630	6.275	6.275	5.448	5.154
2	Cluster 2	3.826	3.826	3.790	3.649	6.178	6.178	6.057	6.455
3	Cluster 3		2.262	2.577	2.622		4.509	4.509	4.565
4	Cluster 4			2.567	2.472			6.025	5.928

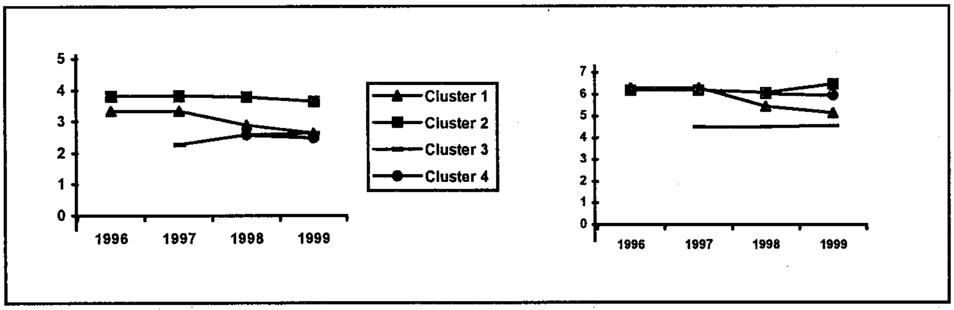

Figure 3. Trends of Species Richness of FHM Sub-plot (A) and Annular-plot (B), Jambi, using Margalef-Species Richness Index

Table 4. Status, Change and Trends of Species Richness by using Odum Index in FHM plots, Jambi

No.	Location	Subplot				Annular plot			
		1996	1997	1998	1999	1996	1997	1998	1999
1	Cluster 1	8.731	8.731	7.742	7.291	15.153	15.153	13.295	12.655
2	Cluster 2	9.756	9.756	9.686	9.377	14.765	14.765	14.497	15.230
3	Cluster 3		7.721	7.603	7.721		11.239	11.239	11.296
4	Cluster 4			7.365	7.039			14.583	14.367

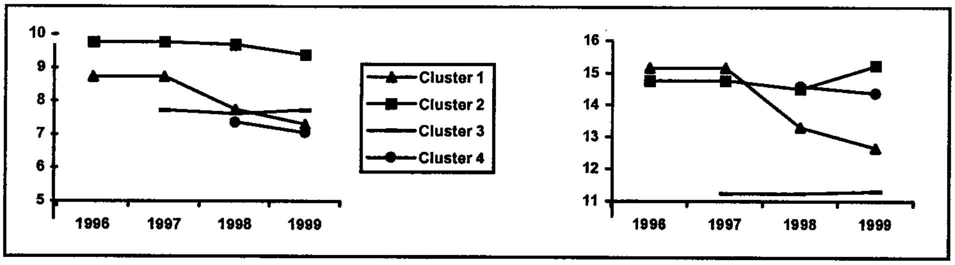

Figure 4. Trends of Species Richness of FHM Sub-plot (A) and Annular-plot (B), Jambi, Using Odum Index

3.2. Species Evenness, Equitability and Diversity

Evenness is described as the distribution of abundance among the species in a community. The measure of evenness can be taken from the ratio of observed diversity to maximum diversity (Pielou, 1969). Pielou evenness index J' is constrained between 0 and 1.0 with 1.0 representing a situation in which all species are equally abundant. Thus high evenness is conventionally equated with high diversity.

3.2.1. Pulau Laut

Species Evenness, Equitability and Diversity and Species Evenness in Clusters 4, 5 and 6, Pulau Laut, were decreased (Table 5 and Figure 5). Forest fire incidence in 1997 followed by illegal cutting in 1998 up to now has decreased the diversity of species in mentioned cluster. Reversibly, species evenness, equitability and diversity in Clusters 1, 2, and 7 were relatively stable since there was no disturbance occurred in these plots.

For the subplots, the biggest decreasing value in species evenness / equitability was found in Cluster 5 (73.46%) folowed by Cluster 6 (48.05%) and Cluster 4 (16.39%). Different case with the condition in the subplot, the species evenness / equitability was increased in Cluster 4 and Cluster 6 as 0.68% and 6.64%, respectively. This was due to the growth of some of Dipterocarpus caudiferus and Anthocephalus chinensis after forest fire incidence that made the annular plot of mentioned clusters was dominated by this two species. This phenomenon pointed out that this two species, Dipterocarpus caudiferus and Anthocephalus chinensis, are become the pioneer species with high survival rate after forest fire incidence.

The biggest decreasing value for the annular plots was found in Cluster 1 (22.32%) followed by Cluster 5 (18.76%). Tree distribution in Cluster 1 was concentrated around the sub-plots, so that there were only few of tree found in the annular. This condition made species evenness in the annular plot of Cluster 1 decreased as 22.32% although it was caused by natural mortality of the tree.

Simpson Diversity Index has the opposite value compared with Shannon-Weiner'. Small value in Simpson' is reflected to bigger value in Shannon-Weiner'. This condition made the diversity trends is increased when calculated with Simpson index (Table 7 and Figure 7) while it decreased when calculated with Shannon Weiner (Table 6 and Figure 6).

Using the Shannon Weiner, it was found that species diversity in Cluster 4, 5, and 6 was decreased drastically. Forest fire incidence followed by illegal logging activity revealed to this decreasing value. The biggest decreasing value was occur in Cluster 5 (73.46%) followed by Cluster 4 (58.32%) and Cluster 6 (46.99%).

In the other clusters (Clusters 1, 2 and 7), species diversity were remained constant. The increasing value in these plots were due to the natural tree up growth from its sapling level to the poles level or from the poles to the trees. This increasing was found in Cluster 1 (2.78%) and in Cluster 2 (2.77%). However, the decreasing value in Cluster 7 (7.78%) was come from natural mortality of fewer trees in this cluster.

Table 5. Status, Change and Trends of Species Evenness and Equitability in FHM Plots, Pulau Laut, South Kalimantan

No.	Location	Subplot				Annular plot			
		1996	1997	1998	1999	1996	1997	1998	1999
1	Cluster 1	0.398	0.407	0.407	0.408	0.672	0.535	0.535	0.522
2	Cluster 2	0.874	0.874	0.899	0.899	0.880	0.880	0.881	0.883
4	Cluster 4	0.897	0.961	0.966	0.750	0.884	0.925	0.936	0.980
5	Cluster 5	0.893	0.937	0.732	0.237	0.858	0.879	0.919	0.697
6	Cluster 6	0.949	0.960	0.970	0.493	0.888	0.885	0.887	0.947
7	Cluster 7	0.729	0.721	0.721	0.721	0.659	0.652	0.657	0.651

Table 6. Status, Change and Trends of Species Diversity by using Snannon-Weiner Index in FHM Plots, Pulau Laut, South Kalimantan

No.	Location	Subplot				Annular plot			
		1996	1997	1998	1999	1996	1997	1998	1999
1	Cluster 1	0.503	0.516	0.516	0.517	1.093	1.034	1.034	1.008
2	Cluster 2	1.408	1.408	1.447	1.447	2.060	2.060	1.999	1.989
4	Cluster 4	1.490	1.365	1.214	0.621	2.255	2.227	2.068	1.231
5	Cluster 5	1.599	1.341	1.113	0.260	2.199	2.040	1.595	0.980
6	Cluster 6	1.343	1.125	1.067	0.616	2.331	2.283	2.215	1.824
7	Cluster 7	0.799	0.726	0.726	0.726	1.028	0.983	0.992	0.984

Table 7. Status, Change and Trends of Species Diversity by using Simpson Index in FHM plots, Pulau Laut, South Kalimantan

No.	Location	Subplot				Annular plot			
		1996	1997	1998	1999	1996	1997	1998	1999
1	Cluster 1	0.475	0.468	0.468	0.469	0.485	0.505	0.505	0.517
2	Cluster 2	0.299	0.299	0.281	0.281	0.166	0.166	0.174	0.177
4	Cluster 4	0.279	0.281	0.337	0.583	0.160	0.136	0.143	0.296
5	Cluster 5	0.266	0.314	0.430	0.594	0.164	0.178	0.268	0.503
6	Cluster 6	0.226	0.310	0.298	0.422	0.139	0.150	0.159	0.197
7	Cluster 7	0.550	0.577	0.577	0.577	1.093	1.034	1.034	1.008

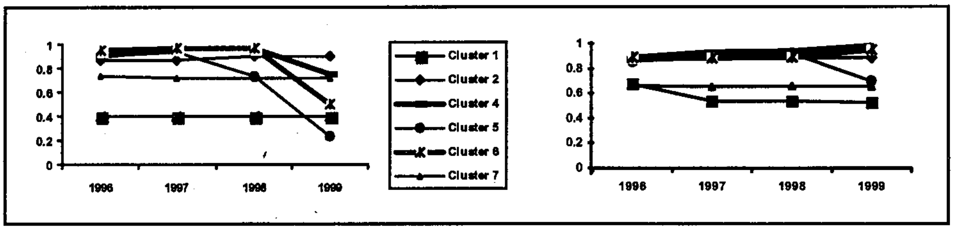

Figure 5. Trends of Species Evenness and Equitability of FHM Sub-plot (A) and Annular-plot (B), Pulau Laut

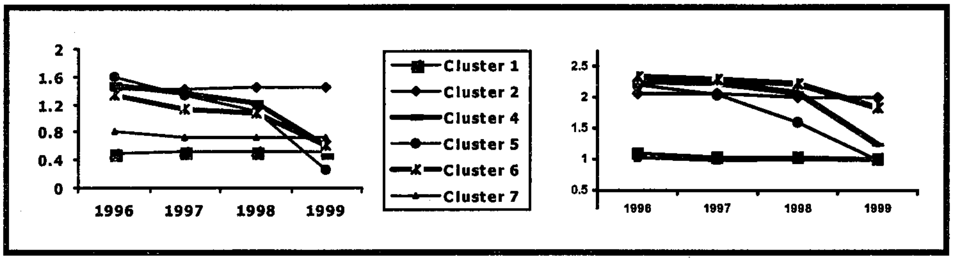

Figure 6. Trends of Species Diversity of FHM Sub-plot (A) and Annular-plot (B), Pulau Laut, Using Shannon-Weiner Index

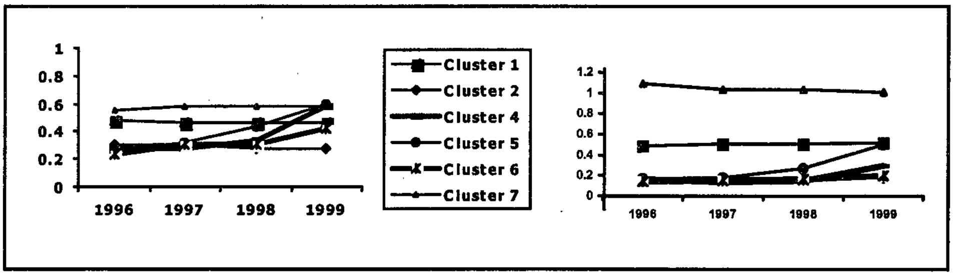

Figure 7. Trends of Species Diversity of FHM Sub-plot (A) and Annular-plot (B), Pulau Laut, Using Simpson Index

3.2.2. Jambi

Since there was no disturbance occurred in FHM plots at Jambi, species evenness, equitability and diversity were remained constant. Decreasing value was gained from the natural mortality (fall down or dead by disease), while the increasing ones was gained from in growth as well as up growth processes.

The decreasing value of species evenness and equitability was occurred in Subplot Cluster 1 (1,94%) and Subplot Cluster 2 (0.20%), while the increasing value was occurred in Annular plot Cluster 1 (0.94%), Annular plot Cluster 2 (4.11%), and Annular plot Cluster 3 (1.01%). From both of subplot and annular plot of Cluster 4, noted that it was the decreasing value in species evenness and equitability as 1.31% and 0.83%, respectively (see Table 8).

Fewer trees on these plots were fall down or dead by disease, and this will be revealed to the decrease of species evenness and equitability as well as for the species diversity. Please refer to TR 18 on the Assessment of Damage Indicator for more information on tree damage occurred in each of the FHM Plots (Nuhamara and Kasno, 2001).

The decreasing value for species evenness, equitability and diversity were affected from the changing level of some tree to one-single higher level as from saplings to poles and from poles to trees. This phenomena were well known by in growth and up growth of tree. More information on in growth and up growth of trees in FHM Plots can be found in TR 24 on the Stand Structure (Supriyanto, et. al., 2001).

The opposite behavior of Simpson Diversity Index as compared with Shannon-Weiner' made the diversity in Jambi was tend to increase when calculated with Simpson' (Figure 10) while it decreased when calculated with Shannon-Weiner' (Figure 9). However, the same interpretation could be gained from this two diversity indexes.

Calculation of species diversity using the Simpson gives the increasing trend in subplots of Clusters 1, 2 and 4. The species diversity in subplot cluster 3 has the same value in 1997 and 1999 as 0.238. The increasing trend was also found in the Annular plot of Clusters 1 and 3. The decreasing value, however, was found in annular plot of Clusters 2 and 3. This decreasing was due to the natural mortality as mentioned before.

The opposite behavior of the Shannon-Weiner compared with the Simpson made the diversity was tend to decrease in subplot of Clusters 1, 2 and 4, while the annular plot of clusters 2 and 3 tend to increase. Diversity in subplots of Cluster 3 has the same value in 1997 and 1999 as 1.617.

The comparatively constant value in species diversity, evenness and equitability in Jambi once again showed that when there is no disturbance, the evenness, equitability and diversity of species in the respective area will be remained constant.

Table 8. Status, Change and Trends of Species Evenness / Equitability in FHM Plots, Jambi

No.	Location	Subplot				Annular plot			
		1996	1997	1998	1999	1996	1997	1998	1999
1	Cluster 1	0.981	0.981	0.970	0.975	0.962	0.962	0.964	0.971
2	Cluster 2	0.978	0.978	0.978	0.976	0.973	0.973	0.974	0.977
3	Cluster 3		0.996	0.992	0.996		0.987	0.987	0.988
4	Cluster 4			0.995	0.982			0.977	0.965

Table 9. Status, Change and Trends of Species Diversity by using Shannon-Weiner Index in FHM Plots, Jambi

No.	Location	Subplot				Annular plot			
		1996	1997	1998	1999	1996	1997	1998	1999
1	Cluster 1	2.093	2.093	1.877	1.730	2.943	2.943	2.765	2.723
2	Cluster 2	2.280	2.280	2.260	2.205	2.943	2.943	2.913	2.999
3	Cluster 3		1.617	1.608	1.617		2.539	2.539	2.529
4	Cluster 4			1.445	1.430			2.951	2.891

Table 10. Status, Change and Trends of Species Diversity by using Simpson Index in FHM Plots, Jambi

No.	Location	Subplot				Annular plot			
		1996	1997	1998	1999	1996	1997	1998	1999
1	Cluster 1	0.131	0.131	0.170	0.192	0.063	0.063	0.073	0.075
2	Cluster 2	0.112	0.112	0.114	0.122	0.059	0.059	0.061	0.056
3	Cluster 3		0.238	0.240	0.238		0.083	0.083	0.084
4	Cluster 4			0.206	0.217			0.057	0.053

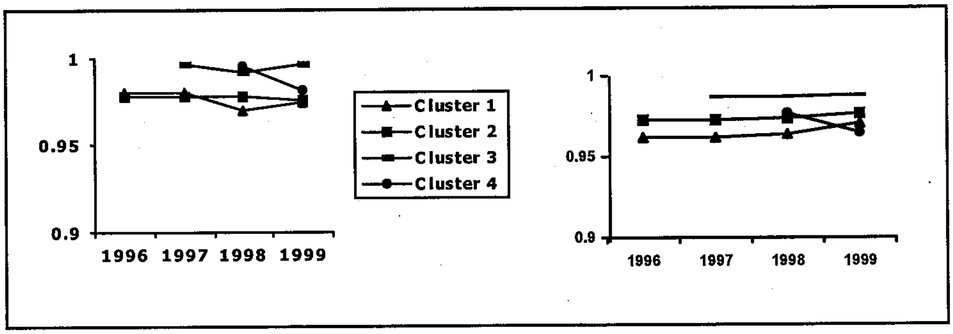

Figure 8. Trends of Species Evenness and Equitability of FHM Sub-plot (A) and Annular-plot (B), Jambi

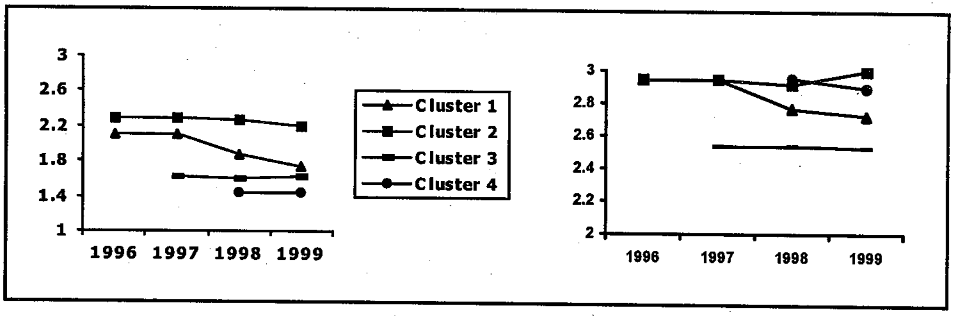

Figure 9. Trends of Species Diversity of FHM Sub-plot (A) and Annular-plot (B), Jambi, using Shannon-Weiner Index

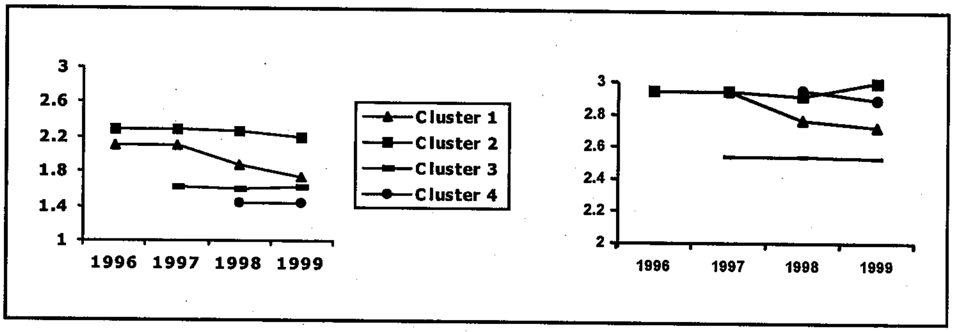

Figure 10. Trends of Species Diversity of FHM Sub-plot (A) and Annular-plot (B), Jambi, using Simpson Index

IV. CONCLUSIONS

Forest Health Monitoring Cluster Design with its annular plots and subplots could be used to express the diversity assessment within its sampling design.

Species richness, evenness, equitability and diversity in the annular plot was always has bigger value than in the subplots. This phenomena indicated that the species diversity indices depend on the sample size and community level.

Any disturbance in the forest such as forest fire and illegal logging (as occurred in FHM Clusters 4, 5, 6, Pulau Laut) will cause the decrease the tree species diversity, while when there is no disturbance, the change and trends in tree species diversity will be remained relatively stable.

Better information on biodiversity, its distribution, and its causes is needed for wise management of the forest resources.

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The authors would like to thank ITTO, Ministry of Forestry (GOI), PT. INHUTANI II and PT. Asia Log Forest Concession Holder for their support. Appreciation also goes to the Project Steering Committee members for their suggestions.

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ASSESSMENT OF BIODIVERSITY INDICATOR IN NFI-FHM PLOT SYSTEM AT SOUTH KALIMANTAN AND JAMBI PROVINCES

Technical Report No. 16

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ABSTRACT

Forest biodiversity have been identified as criterion of sustainability. In its own right, biodiversity is useful as a measure of forest health. National Forest Inventory (NFI) has been initiated in 1989, but it does not concern biodiversity that can reflect the condition of forest ecosystem. The objectives of NFI were to provide information on the location and extent of the main forest types, to estimate the standing volumes and growth, and to assess the status and change of the forest. Assessment of the biodiversity indicator in NFI plot system using FHM plot system was conducted in Jambi and South Kalimantan. FHM cluster plots were overlaid on Permanent Sampling Plot (PSP) of the NFI Plot system. The biodiversity indicator was assessed using the criteria of species richness (Margalef Index and Odum Index), species evenness (Pielou Index), and species diversity (Shannon-Weiner Index and Simpson Index). The objective of this study was to assess the biodiversity indicator used in FHM within NFI plot system. The results showed that the species names used in NFI plots were not identified correctly, FHM, therefore, adapted the names of the local species and then converted them to scientific names.

Key words: *FHM, NFI, species diversity, species richness, species evenness, species name*

I. INTRODUCTION

In 1989 the Government of Indonesia initiated the National Forest Inventory (NFI) Project, which was technically assisted by the FAO. The objectives of this project were providing information on the location and extent of the main forest types, estimating the standing volumes and growth, and assessing the status, change of the forest. The project includes forest resources assessment (FRA), forest resources monitoring (FRM), digital image analysis systems (DIAS) and geographic information systems (GIS).

To quantify the standing stock as the forest changes overtime, the NFI applies the remote sensing techniques and the systematic field sampling method. The field samples are cluster plot consisting of 3 by 3-square plots of 100 meters in size and 500 meters apart. Of which 8 at the edges and 1 at the center are treated as temporary and hidden permanent sample plots, respectively (Figure 1).

However, the systems do not concern on biodiversity and the indicators such as suggested by ITTO Guidelines, 1991, for well-managed tropical ecosystems. Those indicators are resource security, the continuity of timber production, the conservation of flora and fauna, and acceptable level of environmental impact and socio-economic benefit. The indicators of well-managed forest ecosystem must be equally defined by the environmental, economic and social attributes.

Forest Health Monitoring (FHM) was first developed in the U.S. in 1991. The FHM is an ecological approach to evaluate forest ecosystems for condition, changes, trends, causal agents and mechanisms, monitor the condition and changes in forest ecosystems. It is a ground-based estimates of the condition and trends in the forests, by monitoring the proportions of forest population that are in poor, sub nominal, nominal or optimal condition of each indicator.

One group of criteria to be addressed in INDO-FHM is environmental criteria, which will address biodiversity composition, abundance, habitat suitability and ecosystem processes (growth, regeneration, mortality, stand structure) and productivity. The environmental indicator tested in the demonstration plot was biodiversity indicator. These indicators should be tested in NFI plot system to address the forest sustainability in terms of biodiversity to assess the healthy of forest ecosystem.

The objective of this study was to assess the biodiversity indicator used in FHM within NFI plot systems.

II. MATERIALS AND METHODS

FHM cluster plot number 9 and 8 were established and overlaid to NFI plots (number 503209620 and 503209600), respectively. Those plots are located at PT Sumpol Timber, South Kalimantan. FHM cluster plot number 4 was established and overlaid on NFI plot number 573209760. FHM cluster plot number 4 is located at PT Asialog, Jambi. The NFI plot system is shown in Figure 1. The overlay of FHM plot on NFI plot system is shown in Figure 2. The FHM plot model and data recording followed the Forest Health Monitoring Field Methods Guide (International-Indonesia) issued by the EPA (1997).

The FHM center plot of plot 1 was located in the crossing between two diagonal lines of the NFI Permanent Sample Plot (PSP). In this case, the position of FHM plot number 2 will be partly (5 m) outside of NFI Permanent Sampling Plot (See Figure 2).

FHM plot establishment (Figure 3) and tree data recording system followed the Forest Health Monitoring Field Method Guides (International- Indonesia) issued by EPA (1997). The trees with diameter over than 10 cm were measured and recorded. The data of NFI was taken from the inventory results conducted by the Agency of Forest and

Estate Crops Planning, Ministry of Forestry and Estate Crops (MOFEC) in 1998. The NFI data was recorded 3 months before FHM plots establishment.

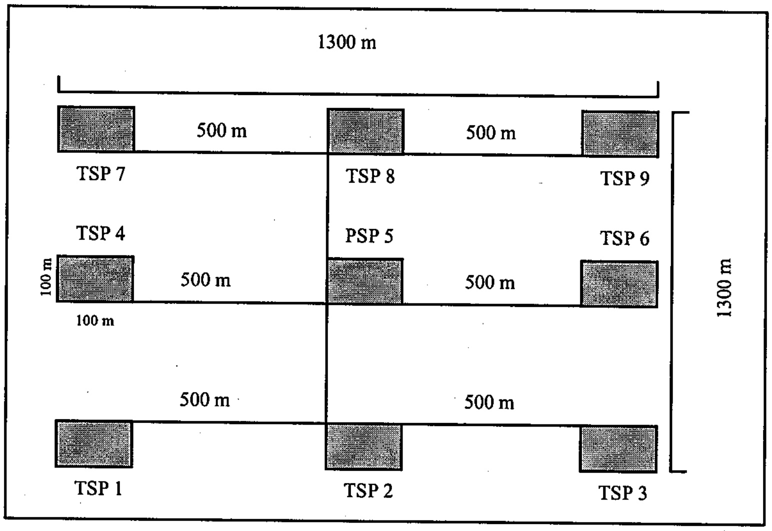

Figure 1. National Forest Inventory Plot System
TSP : Temporary Sampling Plot PSP : Permanent Sampling Plot (Hidden Plot)

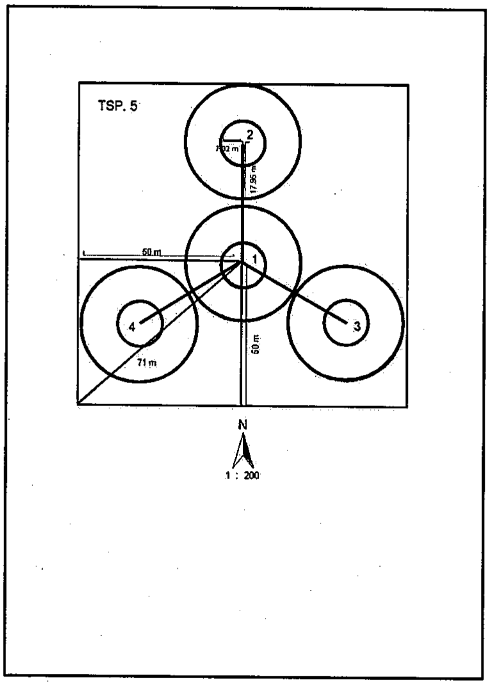

Figure 3. The Overlaid FHM Plot on NFI Permanent Sampling Plot (PSP)

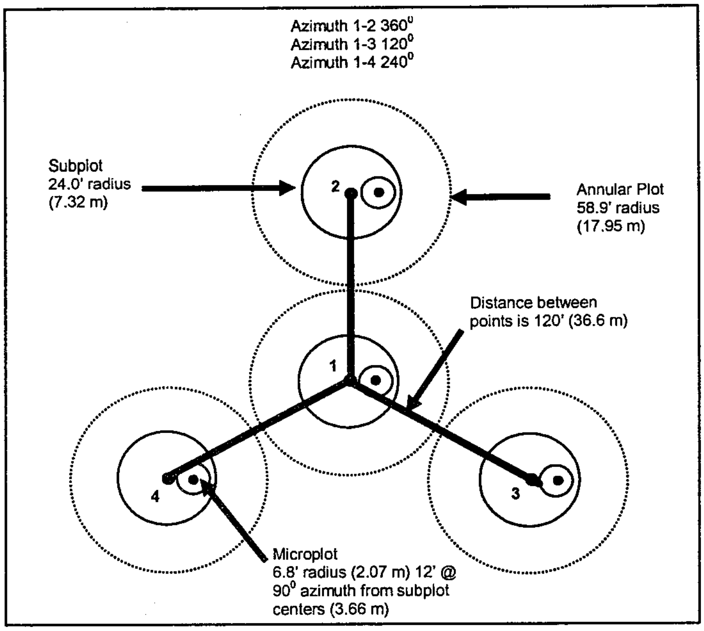

Figure 3. National FHM plot layout is designed around four points (subplot centers)

The NFI data was recorded every 5 years using census system (100%). The scientific name of tree species found in FHM cluster plots was identified at the Laboratory of Botany, Forestry Research and Development Agency (FORDA).

The trees with the diameter over than 10 cm were mapped. Tree position (azimuth and distance) and diameter data were recorded in standardized tally sheet. Herbarium of the trees in FHM plots were also collected and identified in Laboratory of Botany, the Forestry Research and Development Agency. The tree identity tagged by NFI system located in FHM plot system was also recorded and identified for the identification checking purposes, especially for scientific name verification. On the other hand, the species coder-decoder software of the NFI project of Indonesia was used for checking the species name. This coder and decoder system is designed for translating the local name to scientific name (Setyanrso and Muhadiono, 1991).

The biodiversity indicator was assessed using the criteria of Species Richness (Margalef Index, Odum Index), species diversity (Shanon-Wiener Index, Simpson Index) and species evenness.

The Margalef Index is formulated by :

$$\mathbf{R_{MAR} = (S - 1) / \ln N}$$

while the formula of Odum Index is :

$$\mathbf{R_2 = S / \log N}$$

where S = number of species and N = total number of individuals.

The species evenness index refers to the Pielou's Evenness Index J' that is calculated by :

$J' = H' / H_{max}$; H_{max} is determined by $H_{max} = \ln S$, so then :

$J' = H' / \ln S$

The best known of these composite statistics used in this study is the Shannon-Weiner Index :

$$H' = -\Sigma p_i \ln (p_i)$$

where p_i is the proportion of the total sample composed of species i :

$p_i = n_i / n$; ni = the number of individuals belonging to the i th of S species in the sample

n = the total number of individuals in the sample

The other most commonly used statistics to assess species diversity is Simpson's Index λ : $\lambda = \Sigma p_i^2$

The number of trees and the total basal area of the trees within the diameter over than 10 cm were measured. Vegetation structure in the plot was also analyzed.

III. RESULTS AND DISCUSSIONS

3.1. Species Name

The NFI Code consists of an ordinal number that each number refers to one species name. In the field, the crew only record the local name of each tree found. Incorrectness in the record of species name occur when the crew made a mistake in identifying the local name of tree and sometimes they misidentify different species (i.e. two or three species) as one local name. The weakness of NFI system to identify the species is it only depends on the crew's local name without collecting any herbarium sample from the trees.

The common trees found in FHM and NFI plot system in Jambi are listed in Table 1. The species name in NFI plot system was derived from "*The Species Coder-Decoder Software of the National Forest Inventory Project of Indonesia'*

Table 1 shows that there were 27 common trees tagged by NFI plot system in FHM plot system. The species name described in NFI plot is totally different as compared to the FHM description. Even the genus name, no one of them matched to the genus name described in FHM. Some species in NFI plot system are still written in local name, for example medang putih, damar hitam, and this means unidentified species. The species name described in NFI plot system was translated from local name to scientific name, while the species description in FHM system was done using herbarium specimens taken from the plot. The accuracy of description based on the morphological characteristic must first be considered. The information from local tree identifier is sometime confusing.

The species name in NFI and FHM method is presented in Attachment 1,2,3,4,5,6,7, and 8. It is possible that the result of mixed-name species between local name and scientific produced un-interpretable result or confusing calculation for each of biodiversity indicator.

Table 1. List of common trees found in FHM and NFI plot system in Jambi

Tree Number		Species Name	
FHM Code	NFI Code	FHM	NFI
04.1.04/JAM	RU 11 No. 11	*Shorea acuminata*	(4165) *Shorea sp.*
04.1.05/JAM	RU 7 No. 12	*Rhodamnia cinerea*	(4501) *Palaquium sp.*
04.1.08/JAM	RU 7 No. 15	*Durio oxleyanus*	(4106) *Dialium sp.*
04.1.10/JAM	RU 7 No. 14	*Radermachera gigantea*	(4106) *Dialium sp.*
04.1.11/JAM	RU 7 No. 9	*Beilschmeidea kuntsleri*	(2762) *Scaphium macropodum*
04.1.18/JAM	RU 6 No. 10	*Rhodamnia cinerea*	(6992) Medang Putih
04.1.19/JAM	RU 6 No. 18	*Blumeodendron tokbrai*	(6992) Medang Putih
04.1.24/JAM	RU 6 No. 19	*Radermachera gigantea*	(6992) Medang Putih
04.2.10/JAM	RU 14 No. 14	*Parinari glaberrima*	(4106) *Dialium sp.*
04.2.18/JAM	RU 11 No. 14	*Artocarpus elasticus*	(1101) *Endiandra rubescens*
04.2.19/JAM	RU 11 No. 22	*Gymnacranthera bancana*	(339) *Koompassia malaccensis*
04.2.20/JAM	RU 11 No. 21	*Rhodamnia cinerea*	(4165) *Shorea sp.*
04.2.23/JAM	RU 11 No. 17	*Artocarpus dadah*	(339) *Koompassia malaccensis*
04.3.01/JAM	RU 10 No. 4	*Ervatamia sphaerocarpa*	(6997) Damar Hitam
04.3.03/JAM	RU 8 No. 15	*Macaranga populifolia*	(4356) *Eugenia sp.*
04.3.06/JAM	RU 8 No. 8	*Litsea ferruginea*	(1101) *Endiandra rubescens*
04.3.09/JAM	RU 8 No. 11	*Knema latifolia*	(4356) *Eugenia sp*
04.3.11/JAM	RU 8 No. 13	*Shorea parvifolia*	(4165) *Shorea sp.*
04.3.23/JAM	RU 7 No. 10	*Eugenia sp.*	(4501) *Palaquium sp.*
04.4.03/JAM	RU 5 No. 12	Lithocarpus bennetti	(1101) *Endiandra rubescens*
04.4.08/JAM	RU 5 No. 4	*Gardenia sp.*	(6997) Damar hitam
04.4.09/JAM	RU 5 No. 3	*Artocarpus fulvicortex*	(1101) *Endiandra rubescens*
04.4.13/JAM	RU 5 No. 8	*Gymnacranthera forbesii*	(1101) *Endiandra rubescens*
04.4.15/JAM	RU 5 No. 9	*Vernonia arborea*	(1101) *Endiandra rubescens*
04.4.20/JAM	RU 5 No. 14	*Gymnacranthera bancana*	(279) *Santiria nervosa*
04.4.28/JAM	RU 5 No. 15	*Nauclea subdita*	(1101) *Endiandra rubescens*
04.4.29/JAM	RU 5 No. 28	*Nephelium sp.*	(279) *Santiria nervosa*

The number of species found in NFI and FHM plot system is shown in Table 2. The number of tree species in NFI and FHM plot was not the same. It is possible due to the mistakes made by NFI identification, since the tree species name was translated from the local name. The number of tree species in FHM cluster plot 8 was lower than in NFI plot system. It was due to forest fire occurring 3 months before FHM plot establishment.

Table 2. Number of Tree Species in NFI and FHM Plot Systems

Location	Cluster Plot Number	DBH 10-19.9	DBH >=20
Jambi Jambi	NFI Grid 483209760 FHM Cluster Plot 4	10 20	18 50
Sumpol Sumpol	NFI Grid 503209620 FHM Cluster Plot 9	24 18	32 29
Sumpol Sumpol	NFI Grid 503209600 FHM Cluster Plot 8	20 6 *	42 9

Note: Plot was disturbed by forest fire 3 months before FHM plot establishment

3.2. Species Diversity

Taking into account the results of species determination in NFI is correct, its species diversity can be done. The species name of NFI record is used for calculating the species diversity as it is. The species diversity in NFI-FHM plot was calculated using species richness, species diversity, and species evenness. Table 3 and 4 shows that the species richness decreased after forest fire in FHM cluster number 8, within the species richness in measured using Margalef or Odum Index. When there is not any disturbance, the species richness of FHM method was always higher than the NFI method.

The species diversity calculation using Shannon-Weiner Index gave a very small difference between NFI and FHM methods. The result of species evenness in NFI and FHM method is not significantly different.

The forest fire caused the difference value of species diversity between NFI grid number 503209600 and FHM plot number 8. Forest fire happened 3 months before FHM plot establishment. It can be concluded that forest fires affects significantly the results of biodiversity calculation. Some trees are dead and did not produce any sprouts that can normally be used for species determination.

Simplification in species determination in NFI plot system is shown in family of Dipterocarpaceae, for example Shorea sp. In fact this Shorea sp consists of several species. The NFI plot system was design for productivity monitoring only.

Table 3. Tree Species Diversity in NFI – FHM Plots in PT. Sumpol, South Kalimantan

No	Criteria	South Kalimantan Plots			
		NFI grid no. 503209600	FHM cluster 8*	NFI grid no. 503209620	FHM cluster 9
1.	Species Richness				
	1.1. Margalef Index	9.893	4.673	8.487	9.565
	1.2. Odum Index	23.253	11.529	19.542	22.588

Table 3. (Continuation)

No	Criteria	South Kalimantan Plots			
		NFI grid no. 503209600	FHM cluster 8*	NFI grid no. 503209620	FHM cluster 9
2.	Species Diversity				
	2.1. Shannon-Weiner Index	3.631	2.623	3.146	3.481
	2.2. Simpson Index	0.033	0.080	0.073	0.042
3.	Species Evenness	0.933	0.969	0.842	0.944

Note : * : Most of trees found in Cluster 8 were dead trees caused by forest fire in 1998

Table 4. Tree Species Diversity in NFI – FHM Plots in PT. Asia Log, Jambi

No	Criteria	Jambi Plots	
		NFI grid no. 483209760	FHM cluster 4
1.	Species Richness		
	1.1. Margalef Index	4.684	6.025
	1.2. Odum Index	11.216	14.583
2.	Species Diversity		
	2.1. Shannon-Weiner Index	2.616	2.951
	2.2. Simpson Index	0.105	0.057
3.	Species Evenness	0.803	0.977

IV. CONCLUSIONS

Biodiversity can be used for monitoring the health of forest ecosystem. NFI plots system should include the biodiversity indicator. Consequently, the description of scientific name of the species found in NFI plot system should follow the standardized method. The FHM plot system is much easier to monitor the biodiversity indicator.

ACKNOWLEDGEMENT

This Technical Report No 16 on the **Assessment of Biodiversity Indicator in NFI – FHM Plot System at South Kalimantan and Jambi Provinces** has been prepared to fulfill Objective 1 Point 2.2 of the work-plan of ITTO Project PD 16/95 Rev. 2 (F) Forest Health Monitoring to Monitor the Sustainability of Indonesian Tropical Rain Forest.

The authors would like to thank ITTO, Ministry of Forestry (GOI), PT INHUTANI II and PT. Asialog Forest Concession Holder for their supports. Appreciation also goes to the Project Steering Committee members for their suggestions.

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Annex 1. NFI-TREE SPECIES CODING SYSTEM

The NFI Code consists of an ordinal number that each number refers to one species name. In the field, the crew only record the local name of each tree found. Mistake in the record of species name occur when the crew made a mistake in identified the local name of tree and sometimes they identify different species (i.e. two or three species) as one local name. The weakness of NFI system in identify the species is they only depend on the crew's local name without collecting any herbarium samples from the trees.

This table includes some NFI Codes and the species name of the code found in NFI Plots in Jambi and Sumpol. This table was taken from 'The Species Coder-Decoder Software of the National Forest Inventory Project of Indonesia'.

NFI Code	Local Name	Other Local Name	Species Name
8	Marlapang	Sanggam	*Alangium javanicum*
31	Kasai	Landur	*Dracontomelon costatum*
35	Sumpung	Rengas	*Gluta renghas*
45	Kayu Asam	Rawah	*Mangifera minor*
50	Embacang Hutan	Rengas burung	*Melanorrhoea wallichii*
53	Pelajau	Palagan	*Pentaspadon motleyi*
85	Binhut	Banitan	*Polyalthia glauca*
98	Kubita	Mamah	*Alstonia angustifolia*
99	Pulantan	Pulantan Batu	*Alstonia angustifolia*
112	Jelutung	Nyalutung	*Dyera costulata*
133	Medang	Ngalkal	*Ilex bogoriensis*
197	Durian	Durian	*Durio zibethinus*
217	Kenari	Kedundung	*Canarium apertum*
258	Duku-duku	Kapur	*Dacryodes rugosa*
279	Kedondong	Tuak sijantar	*Santiria nervosa*
283	Kembayau	Kembayau burung	*Santiria violacea*
321	Keranji	Nyamut	*Dialium laurinum*
332	Anglai	Jumelai	*Intsia palembanica*
339	Kempas	Gemaris	*Koompassia malaccensis*
349	Sinampar	Tamparantu	*Sindora beccariana*
357	Kapas hantu	Sindur	*Sindora wallichii*
385	Batu Begalang	--	*Mictrotropis* sp.
394	Perupuk	---	*Solenospermum* sp.
475	Simpur	---	*Dillenia indica*
468	Benuang	Binuang bini	*Octomeles Sumatrana*
490	Mersawa	Katimpun	*Anisoptera marginata*
494	Resak	Pandan	*Cotylelobium malayamun*
509	Karang	Cempuka Hutan	*Dipterocarpus exalatus*

NFI Code	Local Name	Other Local Name	Species Name
511	Alaran	Keruing	*Dipterocarpus gracilis*
512	Keruing	Lasang	*Dipterocarpus grandiflorus*
524	Keladan	Lagan torak	*Dipterocarpus retusus*
570	Damak-damak	Pakit	*Shorea acuminata*
581	Meranti	Bangkirai	*Shorea coriaceae*
616	Meranti Merah	Karambaku	*Shorea ovalis*
672	Malam	---	*Diospyros bantamensis*
682	Andingan	Andringan	*Diospyros curraniopsis*
700	Mahirangan	Kaca puri	*Diospyros korthalsiana*
707	Banitan	---	*Diospyros malaccensis*
755	Kayu Buluh	Palange	*Aporusa falcifera*
789	Belanti	Perupuk	*Coccoceras borneense*
797	Kelapaan	---	*Drypetes globosa*
825	Putat	---	*Glochidion sp.*
851	Mahang	Mahan	*Macaranga pruinosa*
902	Paning-paning	Paning-paning	*Quercus bennetti*
949	Simpur	Setumpul	*Hydnocarpus setumpul*
959	Kepayang	---	*Ryparosa micromera*
972	Bintangur	---	*Callophyllum inopghylloidea*
989	Geronggang	Gerunggang	*Cratoxylon arborescens*
999	Kemanjing	Panjang	*Garcinia dioica*
1042	Canaga	---	*Engelhardtia spicata*
1101	Buluh	Uwar	*Endiandra rubescens*
1104	Ulin	Bulian	*Eusideroxylon zwageri*
1128	Mali-mali	Medang nangup	*Litsea roxburghii*
1133	Medang	Modangri	*Neolitsea triplinervis*
1160	Baniran	Banderan	*Ixonanthes petiolaris*
1178	Bungur	---	*Lagerstroemia speciosa*
1238	Bilayang	Latakmanuk	*Aglaia ganggo*
1250	Tualang	Lawawiang	*Chisocheton divergens*
1275	Singkuang	---	*Sandoricum sp. 1*
1316	Sengon	---	*Paraserianthes falcataria*
1321	Mendarahan	Langi asu	*Pithecellebium angulatum*
1343	Mentawa	---	*Artocarpus anisophyllus*
1346	Tampunang	Tarap	*Artocarpus elasticus*
1357	Tampang	Nyatoh	*Artocarpus rufescens*
1413	Margetahan	Mendarahan	*Horsfieldia irya*
1464	Jambu-jambuan	Ubar dukat	*Eugenia polyantha*
1476	Galam Tikus	Gelam	*Melaleuca leucadendron*
1650	Bungkal	Bangka gunung	*Ixora blumei*

NFI Code	Local Name	Other Local Name	Species Name
1667	Jabon	Bangkal	*Nauclea subdita*
1764	Kayu Buluan	Marintan	*Nephelium mutabile*
1783	Pulut	Pelai lilin	*Chryspophyllum roxburghii*
1819	Nyatoh	Nyatoh Batu	*Palaquium dasyphyllum*
1825	Margatahan	Nyatuh	*Palaquium hexandrum*
1843	Baitis	Nyatoh	*Palaquium rostratum*
1850	Balam	Balam surak	*Payena acuminata*
1875	Mahalayaan	---	*Polyosma intergrifolia*
1957	Dungun	---	*Brownlowia sp.*
2009	Durian burung	Kikir mangkudor	*Trigonopleura malayana*
2762	Marpayang	---	*Scaphium macropodum*
4106	Kaning	---	*Dialium* sp.
4165	Damar	---	*Shorea* sp.
4202	Mahang	---	*Macaranga* sp.
4356	Jambu-jambu	---	*Eugenia* sp.
4501	Balam-balam	---	*Palaquium* sp.
6992	Medang putih	---	medang putih
6997	damar hitam	---	damar hitam
6998	Kopi-kopi	---	kopi-kopi
6998	Kungkuni		kungkuni
6998	Kacang-kacangan		kacang-kacangan
6998	Pakan		Pakan
6998	Sapin		Sapin
6998	Sarangan Batu		sarangan batu
6998	Salam Hutan		salam hutan
6998	Rambutan Hutan		rambutan hutan
6998	Jingat		Jingat
6998	Kanigara		Kanigara
6998	Dumit		Dumit
6998	Linuh		Linuh
6998	Uwar		Uwar
8998	Rotan		Rattan

Note : NFI Code 8998 is used for the rattan, 699x is for unidentified species, 4xxx is for the species that identified only for the genus name

Annex 2. List of Tree Species in FHM Cluster-plot 8, South Kalimantan

FHM ID	Species Name	Family
08.1.01/SUM	*Anthocephalus cadamba*	Rubiaceae
08.1.02/SUM	*Neonauclea lanceolata*	Rubiaceae
08.1.03/SUM	*Planchonia valida*	Lecythidaceae
08.2.03/SUM	*Neonauclea lanceolata*	Rubiaceae
08.2.04/SUM	*Planchonia valida*	Lecythidaceae
08.2.05/SUM	*Planchonia valida*	Lecythidaceae
08.3.01/SUM	*Cephalomappa* sp.	Euphorbiaceae
08.3.03/SUM	*Diospyros macrophylla*	Ebenaceae
08.3.07/SUM	*Durio oxleyanus*	Bombacaceae
08.3.08/SUM	*Durio acutifolius*	Bombacaceae
08.4.01/SUM	*Baccaurea javanica*	Euphorbiaceae
08.4.03/SUM	*Mirtaceae* sp.1	Myrtaceae
08.4.04/SUM	*Alseodaphne helophila*	Lauraceae
08.4.05/SUM	*Burseraceae* sp. 1	Burseraceae
08.4.06/SUM	*Eusideroxylon zwageri*	Lauraceae
08.4.09/SUM	*Durio acutifolius*	Bombacaceae
08.4.10/SUM	*Macaranga hypoleuca*	Euphorbiaceae
08.4.11/SUM	*Ficus nervosa*	Moraceae
08.4.12/SUM	*Artocarpus anisophyllus*	Moraceae
08.4.13/SUM	*Diospyros macrophylla*	Ebenaceae

Annex 3. List of Tree Species in FHM Cluster-plot 9, South Kalimantan

FHM ID	Species Name	Family
09.1.01/SUM	*Saccopetalum horsfieldii*	Annonaceae
09.1.02/SUM	*Aglaia* sp. 1	Meliaceae
09.1.03/SUM	*Euphoria malaiensis*	Sapindaceae
09.1.04/SUM	*Eugenia* sp. 1	Myrtaceae
09.1.05/SUM	*Beilschmiedia wightii*	Lauraceae
09.1.06/SUM	*Garcinia* sp. 1	Gutteraceae
09.1.07/SUM	*Swintonia spicifera*	Anacardiaceae
09.1.08/SUM	*Ganua kingiana*	Sapotaceae
09.1.09/SUM	*Aporusa falcifera*	Euphorbiaceae
09.1.10/SUM	*Neoscortechinia kingii*	Euphorbiaceae
09.1.11/SUM	*Polyalthia glauca*	Annonaceae
09.1.12/SUM	*Gironniera subaequalis*	Ulmaceae
09.1.13/SUM	*Terminalia belerica*	Combrotaceae
09.1.14/SUM	*Payena acuminata*	Sapotaceae
09.1.15/SUM	*Dipterocarpus grandiflorus*	Dipterocarpaceae
09.1.16/SUM	*Swintonia spicifera*	Anacardiaceae

FHM ID	Species Name	Family
09.1.17/SUM	*Ctenolophon parvifolius*	Linaceae
09.1.19/SUM	*Ilex bogoriensis*	Aquifoliaceae
09.1.20/SUM	*Dipterocarpus caudiferus*	Dipterocarpaceae
09.1.21/SUM	*Dipterocarpus caudiferus*	Dipterocarpaceae
09.2.01/SUM	*Quercus argentea*	Fagaceae
09.2.02/SUM	*Diospyros malabarica*	Ebenaceae
09.2.03/SUM	*Horsfieldia sp. 1*	Myristicaceae
09.2.04/SUM	*Eugenia sp. 1*	Myrtaceae
09.2.05/SUM	*Trigonopleura malayana*	Euphorbiaceae
09.2.06/SUM	*Eugenia sp. 1*	Myrtaceae
09.2.07/SUM	*Swintonia spicifera*	Anacardiaceae
09.2.08/SUM	*Eugenia sp. 1*	Myrtaceae
09.2.09/SUM	*Diospyros malabarica*	Ebenaceae
09.2.10/SUM	*Gluta renghas*	Anacardiaceae
09.2.11/SUM	*Dipterocarpus caudiferus*	Dipterocarpaceae
09.2.12/SUM	*Trigonopleura malayana*	Euphorbiaceae
09.2.13/SUM	*Barringtonia sp. 1*	Lecythidaceae
09.2.14/SUM	*Durio acutifolius*	Bombacaceae
09.2.15/SUM	*Santiria laevigata*	Burseraceae
09.2.16/SUM	*Persea macrophylla*	Lauraceae
09.2.17/SUM	*Aglaia tomentosa*	Meliaceae
09.3.01/SUM	*Canarium littorale*	Burseraceae
09.3.02/SUM	*Lithocarpus cyclophorus*	Fagaceae
09.3.03/SUM	*Palaquium dasyphyllum*	Sapotaceae
09.3.04/SUM	*Dipterocarpus caudiferus*	Dipterocarpaceae
09.3.05/SUM	*Dipterocarpus caudiferus*	Dipterocarpaceae
09.3.06/SUM	*Shorea sp. 1*	Dipterocarpaceae
09.3.08/SUM	*Memecylon sp. 1*	Melastomataceae
09.3.09/SUM	*Diospyros durionoides*	Ebenaceae
09.3.10/SUM	*Shorea sp. 1*	Dipterocarpaceae
09.3.12/SUM	*Terminalia belerica*	Combrotaceae
09.3.13/SUM	*Dipterocarpus caudiferus*	Dipterocarpaceae
09.3.14/SUM	*Hydnocarpus polypetalus*	Flacourtiaceae
09.3.15/SUM	*Dipterocarpus caudiferus*	Dipterocarpaceae
09.4.01/SUM	*Hopea mengarawan*	Dipterocarpaceae
09.4.02/SUM	*Aporusa sp. 1*	Euphorbiaceae
09.4.03/SUM	*Horsfieldia sp. 1*	Myristicaceae
09.4.04/SUM	*Garcinia sp. 1*	Gutteraceae
09.4.05/SUM	*Santiria rubiginosa*	Burseraceae
09.4.08/SUM	*Dipterocarpus caudiferus*	Dipterocarpaceae

FHM ID	Species Name	Family
09.4.09/SUM	*Persea macrophylla*	Lauraceae
09.4.10/SUM	*Aglaia sp. 1*	Meliaceae
09.4.11/SUM	*Terminalia citrina*	Combrotaceae
09.4.12/SUM	*Gluta wallichii*	Anacardiaceae
09.4.13/SUM	*Shorea johorensis*	Dipterocarpaceae
09.4.14/SUM	*Terminalia citrina*	Combrotaceae
09.4.15/SUM	*Pimelodendron macrocarpum*	Euphorbiaceae

Annex 4. List of Tree Species in FHM Cluster-plots 4, Jambi

FHM ID	Species Name	Family
04.1.01/JAM	*Macaranga pruinosa*	Euphorbiaceae
04.1.02/JAM	*Coelostegia griffithii*	Bombacaceae
04.1.03/JAM	*Aglaia ganggo*	Meliaceae
04.1.04/JAM	*Shorea acuminata*	Dipterocarpaceae
04.1.05/JAM	*Rhodamnia cinerea*	Myrtaceae
04.1.06/JAM	*Santiria laevigata*	Burseraceae
04.1.07/JAM	*Pimelodendron griffithianum*	Euphorbiaceae
04.1.08/JAM	*Durio oxleyanus*	Bombacaceae
04.1.09/JAM	*Koompassia malaccensis*	Caesalpiniaceae
04.1.10/JAM	*Radermachera gigantea*	Bignoniaceae
04.1.11/JAM	*Beilschmiedia kuntsleri*	Lauraceae
04.1.12/JAM	*Gynotroches axillaris*	Rhizoporaceae
04.1.13/JAM	*Radermachera gigantea*	Bignoniaceae
04.1.14/JAM	*Radermachera gigantea*	Bignoniaceae
04.1.15/JAM	*Coelostegia griffithii*	Bombacaceae
04.1.16/JAM	*Pellacalyx axillaris*	Rhizoporaceae
04.1.17/JAM	*Horsfieldia wallichii*	Myristicaceae
04.1.18/JAM	*Rhodamnia cinerea*	Myrtaceae
04.1.19/JAM	*Blumeodendron tokbrai*	Euphorbiaceae
04.1.20/JAM	*Alstonia scholaris*	Apocynaceae
04.1.21/JAM	*Horsfieldia wallichii*	Myristicaceae
04.1.22/JAM	*Sterculia macrophylla*	Sterculiaceae
04.1.23/JAM	*Horsfieldia wallichii*	Myristicaceae
04.1.24/JAM	*Radermachera gigantea*	Bignoniaceae
04.1.25/JAM	*Aglaia ganggo*	Meliaceae
04.1.26/JAM	*Dracontomelon dao*	Anacardiaceae
04.1.27/JAM	*Dracontomelon dao*	Anacardiaceae
04.1.28/JAM	*Gynotroches axillaris*	Rhizoporaceae
04.1.30/JAM	*Santiria laevigata*	Burseraceae
04.1.31/JAM	*Santiria oblongifolia*	Burseraceae

FHM ID	Species Name	Family
04.1.32/JAM	*Alangium javanicum*	Alangiaceae
04.1.33/JAM	*Aglaia ganggo*	Meliaceae
04.2.01/JAM	*Xanthophyllum sp. 4*	Polygalaceae
04.2.02/JAM	*Nephelium lappaceum*	Sapindaceae
04.2.03/JAM	*Knema latifolia*	Myristicaceae
04.2.04/JAM	*Eugenia sp. 8*	Myrtaceae
04.2.05/JAM	*Xanthophyllum sp. 4*	Polygalaceae
04.2.06/JAM	*Actinodaphne sp. 1*	Lauraceae
04.2.07/JAM	*Hydnocarpus woodii*	Flacourtiaceae
04.2.08/JAM	*Dacryodes rostrata*	Burseraceae
04.2.10/JAM	*Parinari glaberrima*	Rosaceae
04.2.11/JAM	*Polyalthia hypoleuca*	Annonaceae
04.2.12/JAM	*Dialium platycepalum*	Caesalpiniaceae
04.2.13/JAM	*Polyalthia hypoleuca*	Annonaceae
04.2.14/JAM	*Shorea parvifolia*	Dipterocarpaceae
04.2.15/JAM	*Shorea parvifolia*	Dipterocarpaceae
04.2.16/JAM	*Dacryodes rostrata*	Burseraceae
04.2.17/JAM	*Shorea ovalis*	Dipterocarpaceae
04.2.18/JAM	*Artocarpus elasticus*	Moraceae
04.2.19/JAM	*Gymnacranthera bancana*	Myristicaceae
04.2.20/JAM	*Rhodamnia cinerea*	Myrtaceae
04.2.22/JAM	*Aquilaria malaccensis*	Thymelaeaceae
04.2.23/JAM	*Artocarpus dadah*	Moraceae
04.2.25/JAM	*Koompassia malaccensis*	Caesalpiniaceae
04.2.26/JAM	*Engelhardtia serrata*	Juglandaceae
04.3.01/JAM	*Ervatamia sphaerocarpa*	Apocynaceae
04.3.02/JAM	*Alstonia scholaris*	Apocynaceae
04.3.03/JAM	*Macaranga populifolia*	Euphorbiaceae
04.3.04/JAM	*Coelostegia griffithii*	Bombacaceae
04.3.05/JAM	*Gymnacranthera forbesii*	Myristicaceae
04.3.06/JAM	*Litsea ferruginea*	Lauraceae
04.3.07/JAM	*Blumeodendron tokbrai*	Euphorbiaceae
04.3.08/JAM	*Horsfieldia wallichii*	Myristicaceae
04.3.09/JAM	*Knema latifolia*	Myristicaceae
04.3.10/JAM	*Koompassia malaccensis*	Caesalpiniaceae
04.3.11/JAM	*Shorea parvifolia*	Dipterocarpaceae
04.3.12/JAM	*Mangifera foetida*	Anacardiaceae
04.3.13/JAM	*Myristica maxima*	Myristicaceae
04.3.14/JAM	*Mangifera caesia*	Anacardiaceae
04.3.15/JAM	*Gymnacranthera forbesii*	Myristicaceae
04.3.16/JAM	*Durio oxleyanus*	Bombacaceae
04.3.17/JAM	*Nauclea subdita*	Rubiaceae

FHM ID	Species Name	Family
04.3.18/JAM	*Pterospermum javanicum*	Sterculiaceae
04.3.19/JAM	*Dracontomelon dao*	Anacardiaceae
04.3.20/JAM	*Horsfieldia wallichii*	Myristicaceae
04.3.21/JAM	*Radermachera gigantea*	Bignoniaceae
04.3.22/JAM	*Horsfieldia wallichii*	Myristicaceae
04.3.23/JAM	*Eugenia sp. 8*	Myrtaceae
04.3.24/JAM	*Palaquium rostratum*	Sapotaceae
04.3.26/JAM	*Neolitsea javanica*	Lauraceae
04.4.02/JAM	*Radermachera gigantea*	Bignoniaceae
04.4.03/JAM	*Lithocarpus bennetti*	Fagaceae
04.4.04/JAM	*Lithocarpus bennetti*	Fagaceae
04.4.05/JAM	*Sandoricum koetjope*	Meliaceae
04.4.06/JAM	*Xylopia malayana*	Annonaceae
04.4.07/JAM	*Dacryodes rostrata*	Burseraceae
04.4.08/JAM	*Gardenia sp. 3*	Rubiaceae
04.4.09/JAM	*Artocarpus fulvicortex*	Moraceae
04.4.10/JAM	*Gymnacranthera forbesii*	Myristicaceae
04.4.11/JAM	*Pellacalyx axillaris*	Rhizoporaceae
04.4.12/JAM	*Nauclea orientalis*	Rubiaceae
04.4.13/JAM	*Gymnacranthera forbesii*	Myristicaceae
04.4.14/JAM	*Macaranga pruinosa*	Euphorbiaceae
04.4.15/JAM	*Vernonia arborea*	Compositae
04.4.16/JAM	*Artocarpus fulvicortex*	Moraceae
04.4.17/JAM	*Radermachera gigantea*	Bignoniaceae
04.4.20/JAM	*Gymnacranthera bancana*	Myristicaceae
04.4.21/JAM	*Dacryodes rostrata*	Burseraceae
04.4.22/JAM	*Koompassia malaccensis*	Caesalpiniaceae
04.4.23/JAM	*Eugenia sp. 2*	Myrtaceae
04.4.24/JAM	*Palaquium rostratum*	Sapotaceae
04.4.25/JAM	*Prunus acuminata*	Rosaceae
04.4.26/JAM	*Sapium baccatum*	Euphorbiaceae
04.4.27/JAM	*Endospermum diadenum*	Euphorbiaceae
04.4.28/JAM	*Nauclea subdita*	Rubiaceae
04.4.29/JAM	*Nephelium sp. 1*	Sapindaceae
04.4.30/JAM	*Gardenia anisophyllea*	Rubiaceae
04.4.31/JAM	*Timonius borneensis*	Rubiaceae

Annex 5. List of Tree Species in NFI plot grid no. 483209760, Jambi

KEY	Species Name	KEY	Species Name
4832097609815140	*Alstonia angustifolia*	4832097609815100	*Dialium* sp.
4832097609815120	*Anisoptera marginata*	4832097609815010	*Dialium* sp.
4832097609815030	*Artocarpus elasticus*	4832097609815150	*Dialium* sp.
4832097609815030	damar hitam	4832097609815070	*Dialium* sp.
4832097609815040	damar hitam	4832097609815070	*Dialium* sp.
4832097609815080	damar hitam	4832097609815150	*Dialium* sp.
4832097609815090	damar hitam	4832097609815070	*Dialium* sp.
4832097609815040	damar hitam	4832097609815070	*Dialium* sp.
4832097609815030	damar hitam	4832097609815140	*Dialium* sp.
4832097609815030	damar hitam	4832097609815010	*Dialium* sp.
4832097609815040	damar hitam	4832097609815130	*Dillenia indica*
4832097609815070	damar hitam	4832097609815020	*Dyera costulata*
4832097609815100	damar hitam	4832097609815060	*Endiandra rubescens*
4832097609815050	damar hitam	4832097609815110	*Endiandra rubescens*
4832097609815050	damar hitam	4832097609815060	*Endiandra rubescens*
4832097609815030	damar hitam	4832097609815100	*Endiandra rubescens*
4832097609815110	damar hitam	4832097609815050	*Endiandra rubescens*
4832097609815050	*Dialium* sp.	4832097609815060	*Endiandra rubescens*
4832097609815100	*Dialium* sp.	4832097609815100	*Endiandra rubescens*
4832097609815050	*Dialium* sp.	4832097609815010	*Endiandra rubescens*
4832097609815050	*Dialium* sp.	4832097609815060	*Endiandra rubescens*
4832097609815100	*Dialium* sp.	4832097609815060	*Endiandra rubescens*
4832097609815070	*Endiandra rubescens*	4832097609815020	*Endiandra rubescens*
4832097609815090	*Endiandra rubescens*	4832097609815010	*Endiandra rubescens*
4832097609815060	*Endiandra rubescens*	4832097609815130	*Endiandra rubescens*
4832097609815040	*Endiandra rubescens*	4832097609815020	*Endiandra rubescens*
4832097609815040	*Endiandra rubescens*	4832097609815140	*Endiandra rubescens*
4832097609815090	*Endiandra rubescens*	4832097609815050	*Endiandra rubescens*
4832097609815090	*Endiandra rubescens*	4832097609815050	*Endiandra rubescens*
4832097609815060	*Endiandra rubescens*	4832097609815050	*Endiandra rubescens*
4832097609815060	*Endiandra rubescens*	4832097609815050	*Endiandra rubescens*
4832097609815030	*Endiandra rubescens*	4832097609815050	*Endiandra rubescens*
4832097609815040	*Endiandra rubescens*	4832097609815110	*Endiandra rubescens*

KEY	Species Name	KEY	Species Name
4832097609815080 4832097609815010	*Endiandra rubescens* *Endiandra rubescens*	4832097609815120 4832097609815120	*Endiandra rubescens* *Endiandra rubescens*
4832097609815040	*Endiandra rubescens*	4832097609815120	*Endiandra rubescens*
4832097609815120	*Endiandra rubescens*	4832097609815110	*Endiandra rubescens*
4832097609815050	*Endiandra rubescens*	4832097609815050	*Endiandra rubescens*
4832097609815050	*Endiandra rubescens*	4832097609815020	*Endiandra rubescens*
4832097609815160	*Endiandra rubescens*	4832097609815010	*Endiandra rubescens*
4832097609815150	*Endiandra rubescens*	4832097609815080	*Eugenia* sp.
4832097609815160	*Endiandra rubescens*	4832097609815080	*Eugenia* sp.
4832097609815120	*Endiandra rubescens*	4832097609815080	*Eugenia* sp.
4832097609815160	*Endiandra rubescens*	4832097609815120	*Eugenia* sp.
4832097609815120	*Endiandra rubescens*	4832097609815040	*Ixonanthes petiolaris*
4832097609815100	*Endiandra rubescens*	4832097609815120	*Koompassia malaccensis*
4832097609815060	*Endiandra rubescens*	4832097609815160	*Koompassia malaccensis*
4832097609815160	*Engelhardtia spicata*	4832097609815110	*Koompassia malaccensis*
4832097609815040	*Engelhardtia spicata*	4832097609815110	*Koompassia malaccensis*
4832097609815160	*Engelhardtia spicata*	4832097609815090	*Koompassia malaccensis*
4832097609815010	*Engelhardtia spicata*	4832097609815010	*Koompassia malaccensis*
4832097609815020	*Engelhardtia spicata*	4832097609815010	*Koompassia malaccensis*
4832097609815130	*Koompassia malaccensis*	4832097609815090	*Koompassia malaccensis*
4832097609815140	*Koompassia malaccensis*	4832097609815080	*Koompassia malaccensis*
4832097609815140	*Koompassia malaccensis*	4832097609815130	*Koompassia malaccensis*
4832097609815130	*Koompassia malaccensis*	4832097609815110	*Koompassia malaccensis*
4832097609815130	*Koompassia malaccensis*	4832097609815110	*Koompassia malaccensis*
4832097609815140	*Koompassia malaccensis*	4832097609815130	*Macaranga* sp.
4832097609815050	medang putih	4832097609815160	*Macaranga* sp.
4832097609815060	medang putih	4832097609815030	medang putih
4832097609815130	medang putih	4832097609815120	medang putih
4832097609815020	medang putih	4832097609815090	medang putih
4832097609815020	medang putih	4832097609815020	medang putih
4832097609815100	medang putih	4832097609815070	medang putih
4832097609815060	medang putih	4832097609815150	medang putih
4832097609815060	medang putih	4832097609815060	medang putih
4832097609815060	medang putih	4832097609815060	*Palaquium* sp.
4832097609815130	*Palaquium* sp.	4832097609815090	*Palaquium* sp.

KEY	Species Name	KEY	Species Name
4832097609815160	*Palaquium* sp.	4832097609815070	*Palaquium* sp.
4832097609815130	*Palaquium* sp.	4832097609815070	*Palaquium* sp.
4832097609815130	*Palaquium* sp.	4832097609815070	*Palaquium* sp.
4832097609815130	*Palaquium* sp.	4832097609815060	*Palaquium* sp.
4832097609815030	*Palaquium* sp.	4832097609815110	*Palaquium* sp.
4832097609815030	*Palaquium* sp.	4832097609815020	*Ryparosa micromera*
4832097609815010	*Santiria nervosa*	4832097609815080	*Scaphium macropodum*
4832097609815150	*Santiria nervosa*	4832097609815100	*Scaphium macropodum*
4832097609815140	*Santiria nervosa*	4832097609815030	*Scaphium macropodum*
4832097609815050	*Santiria nervosa*	4832097609815140	*Scaphium macropodum*
4832097609815050	*Santiria nervosa*	4832097609815080	*Scaphium macropodum*
4832097609815050	*Santiria nervosa*	4832097609815070	*Scaphium macropodum*
4832097609815110	*Santiria nervosa*	4832097609815060	*Scaphium macropodum*
4832097609815080	*Santiria nervosa*	4832097609815050	*Scaphium macropodum*
4832097609815090	*Santiria nervosa*	4832097609815030	*Scaphium macropodum*
4832097609815140	*Santiria nervosa*	4832097609815110	*Shorea* sp.
4832097609815150	*Santiria nervosa*	4832097609815130	*Shorea* sp.
4832097609815150	*Shorea* sp.	4832097609815080	*Shorea* sp.
4832097609815010	*Shorea* sp.	4832097609815090	*Shorea* sp.
4832097609815010	*Shorea* sp.	4832097609815090	*Shorea* sp.
4832097609815140	*Shorea* sp.	4832097609815120	*Shorea* sp.
4832097609815160	*Shorea* sp.	4832097609815100	*Shorea* sp.
4832097609815160	*Shorea* sp.	4832097609815100	*Shorea* sp.
4832097609815020	*Shorea* sp.	4832097609815110	*Shorea* sp.
4832097609815140	*Shorea* sp.	4832097609815110	*Shorea* sp.
4832097609815090	*Shorea* sp.	4832097609815110	*Shorea* sp.
4832097609815040	*Shorea* sp.	4832097609815120	*Shorea* sp.
4832097609815080	*Shorea* sp.	4832097609815090	*Shorea* sp.
4832097609815080	*Shorea* sp.	4832097609815110	*Sindora wallichii*
4832097609815150	*Sindora wallichii*	4832097609815130	*Sindora wallichii*
4832097609815150	*Sindora wallichii*		

Annex 6. List of Tree Species in NFI plot grid no. 503209620, South Kalimantan

Grid No	Record Unit	Local Name	Grid No	Record Unit	Local Name
503209620	1	Mahalayaan	503209620	2	Mahalayaan
503209620	1	Mahalayaan	503209620	2	Durian
503209620	1	Meranti	503209620	2	Sinampar
503209620	1	Sumpung	503209620	2	Paning-paning
503209620	1	Kelapaan	503209620	2	Kelapaan
503209620	1	Kelapaan	503209620	2	Mahalayaan
503209620	1	Bintangur	503209620	2	Rambutan Hutan
503209620	1	Bilayang	503209620	2	Mahalayaan
503209620	1	Keruing	503209620	2	Keruing
503209620	1	Meranti	503209620	2	Keruing
503209620	1	Sinampar	503209620	2	Meranti
503209620	1	Keruing	503209620	2	Keruing
503209620	1	Mahalayaan	503209620	2	Meranti
503209620	1	Bilayang	503209620	2	Duku-duku
503209620	1	Meranti	503209620	2	Mahalayaan
503209620	1	Meranti	503209620	4	Keruing
503209620	1	Keruing	503209620	4	Bintangur
503209620	3	Kelapaan	503209620	4	Kopi-kopi
503209620	3	Mendarahan	503209620	4	Sinampar
503209620	3	Mendarahan	503209620	4	Kopi-kopi
503209620	3	Jambu-	503209620	4	Kelapaan
503209620	3	Nyatoh	503209620	4	Bintangur
503209620	3	Sumpung	503209620	4	Sumpung
503209620	3	Kayu Buluh	503209620	4	Mahalayaan
503209620	3	Meranti	503209620	4	Kelapaan
503209620	3	Kayu Asam	503209620	4	Bintangur
503209620	3	Bilayang	503209620	4	Durian
503209620	3	Sumpung	503209620	4	Kayu Buluh
503209620	3	Sarangan Batu	503209620	4	Sumpung
503209620	3	Meranti	503209620	4	Meranti
503209620	3	Sarangan Batu	503209620	4	Bintangur
503209620	3	Meranti	503209620	4	Meranti
503209620	3	Kelapaan	503209620	4	Kopi-kopi
503209620	5	Margatahan	503209620	6	Jambu-jambuan
503209620	5	Pakan	503209620	6	Meranti
503209620	5	Margatahan	503209620	6	Jambu-jambuan
503209620	5	Jambu-jambuan	503209620	6	Mahalayaan
503209620	5	Anglai	503209620	6	Jambu-jambuan
503209620	5	Batu Begalang	503209620	6	Keruing

Grid No	Record Unit	Local Name	Grid No	Record Unit	Local Name
503209620	5	Sarangan Batu	503209620	6	Keruing
503209620	5	Keruing	503209620	6	Sarangan Batu
503209620	5	Sarangan Batu	503209620	6	Paning-paning
503209620	5	Meranti	503209620	6	Paning-paning
503209620	5	Meranti	503209620	6	Jambu-jambuan
503209620	5	Pakan	503209620	8	Mendarahan
503209620	5	Margatahan	503209620	8	Mahalayaan
503209620	7	Sumpung	503209620	8	Mahalayaan
503209620	7	Rambutan Hutan	503209620	8	Medang
503209620	7	Mahalayaan	503209620	8	Salam Hutan
503209620	7	Keruing	503209620	8	Medang
503209620	7	Keruing	503209620	8	Meranti
503209620	7	Keranji	503209620	8	Keruing
503209620	7	Keruing	503209620	8	Keruing
503209620	7	Sumpung	503209620	8	Jambu-jambuan
503209620	7	Sumpung	503209620	8	Mentawa
503209620	7	Mahalayaan	503209620	10	Bilayang
503209620	7	Keruing	503209620	10	Jambu-
503209620	7	Sumpung	503209620	10	Meranti
503209620	7	Keranji	503209620	10	Jambu-
503209620	9	Mahirangan	503209620	10	Kayu Buluh
503209620	9	Kungkuni	503209620	10	Meranti
503209620	9	Kayu Buluh	503209620	10	Nyatoh
503209620	9	Keruing	503209620	10	Bilayang
503209620	9	Keladan	503209620	10	Kemanjing
503209620	9	Geronggang	503209620	10	Kayu Buluh
503209620	9	Sumpung	503209620	10	Jambu-jambuan
503209620	9	Keruing	503209620	10	Kacang-kacangan
503209620	9	Meranti	503209620	10	Keruing
503209620	9	Jambu-jambuan	503209620	10	Simpur
503209620	9	Meranti	503209620	10	Keruing
503209620	9	Medang	503209620	10	Kacang-kacangan
503209620	9	Mahirangan	503209620	10	Keruing
503209620	9	Mendarahan	503209620	10	Keruing
503209620	9	Jambu-jambuan	503209620	10	Medang
503209620	9	Kemanjing	503209620	10	Keruing
503209620	6	Bilayang	503209620	10	Sumpung
503209620	6	Perupuk	503209620	10	Putat
503209620	6	Sarangan Batu	503209620	10	Jambu-jambuan
503209620	11	Paning-paning	503209620	10	Kemanjing
503209620	11	Medang	503209620	12	Jambu-jambuan

Grid No	Record Unit	Local Name	Grid No	Record Unit	Local Name
503209620	11	Meranti	503209620	12	Jambu-jambuan
503209620	11	Duku-duku	503209620	12	Kopi-kopi
503209620	11	Meranti	503209620	12	Kopi-kopi
503209620	11	Meranti	503209620	15	Bilayang
503209620	11	Bintangur	503209620	15	Medang
503209620	11	Keruing	503209620	15	Belanti
503209620	11	Anglai	503209620	12	Marlapang
503209620	11	Simpur	503209620	12	Damak-damak
503209620	13	Sumpung	503209620	12	Salam Hutan
503209620	13	Sindur	503209620	12	Meranti
503209620	13	Keruing	503209620	12	Meranti
503209620	13	Kopi-kopi	503209620	12	Keruing
503209620	13	Galam Tikus	503209620	12	Kanigara
503209620	13	Kopi-kopi	503209620	12	Keruing
503209620	13	Damak-damak	503209620	12	Jingat
503209620	13	Galam Tikus	503209620	14	Kayu Buluh
503209620	13	Keladan	503209620	14	Mahalayaan
503209620	13	Meranti	503209620	14	Banitan
503209620	13	Medang	503209620	14	Margatahan
503209620	13	Meranti	503209620	14	Kayu Buluh
503209620	15	Sumpung	503209620	14	Meranti
503209620	15	Sumpung	503209620	14	Galam Tikus
503209620	15	Keruing	503209620	14	Jambu-jambuan
503209620	15	Mahalayaan	503209620	14	Durian
503209620	15	Jambu-jambuan	503209620	14	Meranti
503209620	15	Bilayang	503209620	14	Medang
503209620	15	Kacang-kacangan	503209620	16	Meranti
503209620	15	Kopi-kopi	503209620	16	Mahirangan
503209620	15	Geronggang	503209620	16	Paning-paning
503209620	15	Keruing	503209620	16	Jingat
503209620	15	Belanti	503209620	16	Keruing
503209620	15	Paning-paning	503209620	16	Bilayang
503209620	15	Meranti	503209620	16	Paning-paning
503209620	15	Kempas	503209620	16	Kopi-kopi
503209620	15	Keladan			

ASSESSMENT OF DAMAGE INDICATOR IN FOREST HEALTH MONITORING TO MONITOR THE SUSTAINABILITY OF INDONESIAN TROPICAL RAIN FOREST

Technical Report No. 17

Simon Taka Nuhamara
Kasno
Ujang Susep Irawan

ABSTRACT

The measure of damage indicator using the US-FHM technology has been tested in two ecologically different natural tropical rain forest ecosystems: one in PT. INHUTANI II, South Kalimantan, and the other in PT. Asialog, Jambi, Sumatra. Seven and four clusters, respectively, were established in Pulau Laut and Jambi in 1996. Assessment of the damage indicator was made from 1996 through 2000. It was found that the US-FHM technology is easily adopted for tropical rain forest condition in field data recording. The common damage types encountered in the two study areas are loss of apical dominance, broken branches, open wounds, and other decay indicators such fruiting body, conk and advanced decay. Two other damage types found during the study period both in Pulau Laut and Jambi have been suggested for inclusion in the 1999 INDO-FHM issue. These are stem damage due to termite attack, and stem disorder due to woody-vines, excluding cracks and seams and crown damage due to liana which have been included in the 1999 INDO-FHM mentioned. Three level indices have been established based on the severity threshold defined in the 1999 INDO-FHM. These are three-level index, i.e. species-wise index, plot-level index and area-level index (Pulau Laut and Jambi, in this case). Since both of the study sites are of natural productive forest, it is clearly indicates an evidence for a tendency to develop serious heat-rot problem for the next cutting cycle to come. The information obtained will undoubtedly be of high significance for possible future reorientation of sustainable management of the tropical natural productive forest. It is believed that such a method will also be applicable to plantation forest. Furthermore, the data collected suggest that the residual stands in both study areas are getting worse and worse due to uncontrolled logging activities, coupled with its inherent ecological consequences. Therefore, this report is considered very timely for Indonesian forest condition to propose to authorized agencies to develop the next step of Forest Health Monitoring, the Intensive Site Ecosystem Monitoring (ISEM). Several related indicators seem to compliment each other. Therefore, adopting the method of field data recording for damage indicator as an instrument to assess other forest functions, such as protection forest, anticipative and creative analyses need to be developed wisely and accordingly.

***Key words**: Tropical rainforest, sustainable, forest health, forest damage*

I. INTRODUCTION

The Indo-Malayan rain forest is the second most extensive group of forest in the world (Pringle, 1969). Today, this rain forest has been more extensively disturbed by timber exploitation. As a consequence, drastic ecological changes will in turn influence the future of both individual tree vitality and the forest health as well.

Forest trees are shaped by a multitude of abiotic and biotic influences (Cline, 1995). There are various plant damages caused by mechanical, physical, chemical and biological factors. Improper logging activity may injure or kill the logged trees seedlings, saplings, poles and other economic plant species. Such unintended logging damages are examples of mechanical factors produced by human activities. Therefore, an accurate record of damages is critical for overall assessment of the trees health on Forest Health Monitoring (FHM) plots. Damages caused by pathogens, insects, air pollution, other natural and artificial activities affect the growth and survival of trees. Damages caused by any of these agents, either singly or in combination, can significantly affect forest health.

Damage symptoms may be persistent or ephemeral. Identifying the signs and symptoms of damages provides valuable information concerning the forest's condition and indicates possible causes of deviation from expected conditions. The damage indicator acts as an early warning, providing information on sustainability, resiliency, productivity, and aesthetics (Cline, 1995).

All damages are manifested by reduced growth, loss of biomass, poor crown condition, and ultimately, mortality. Damage to locations of lower priority must occur repeatedly, or must be of sufficient severity before survivability is threatened. In most cases, when damage to lower priority locations does occur, it generally predisposes the higher priority location to damage and these damages then ultimately reduce tree survivability. This tendency goes more or less toward declining trees (Figures 1 and 2) (Manion, 1981).

This quantitative assessment presents specific damage categories, estimate the status of the damage indicator on tree health and the possible causes of mortality. The collected information will better understanding and provide basis for observing changes and eventually, the tendency of the tropical rain forest health in the future.

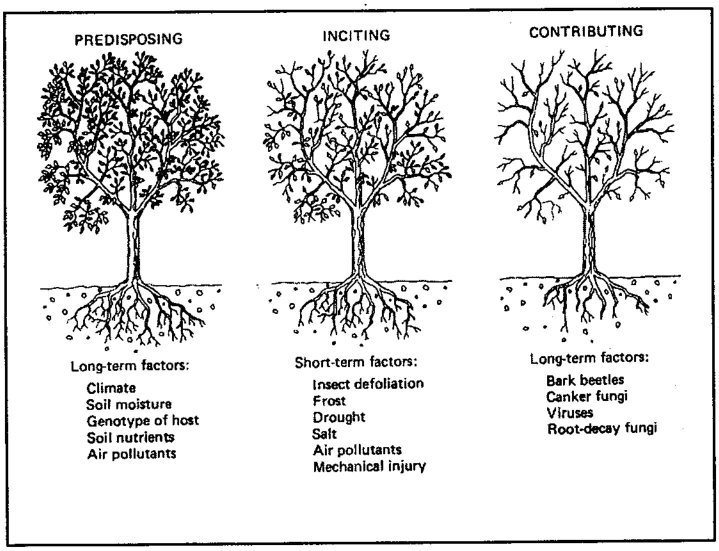

Figure 1. Categories of Factors Influencing Declines (After Manion,1981)

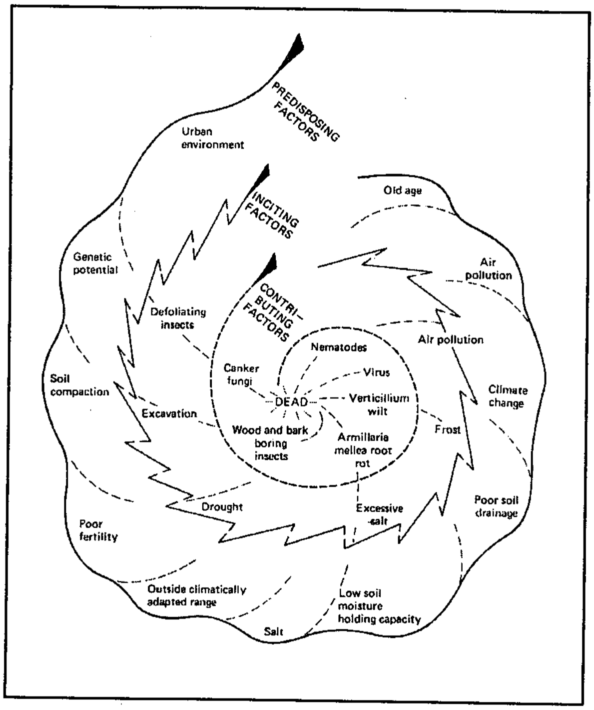

Figure 2. Decline Diseases Spiral (After Manion,1981)

II. MATERIALS AND METHODS

The plots used for this study were the same plots used for other indicators studied and established in Pulau Laut, South Kalimantan (7 clusters), and at PT. Asialog in Jambi (4 clusters). The mentioned clusters had a standard design as presented in Figure 3.

Damage signs and symptoms were recorded on all live trees at 20 cm DBH and larger on each 1/60 hectare subplot that was classified as forest. Damage signs and symptoms were prioritized according to location on the tree in the following order : roots, roots and lower bole, lower bole, lower and upper bole, upper bole, crown stem, branches, buds and shoots, and foliage (Table 1 and Figure 4).

Only those damage categories that could kill the trees or decrease the long-term survival of the trees were recorded on FHM plots. Minimum thresholds and severity classes exist for appropriate damage categories.

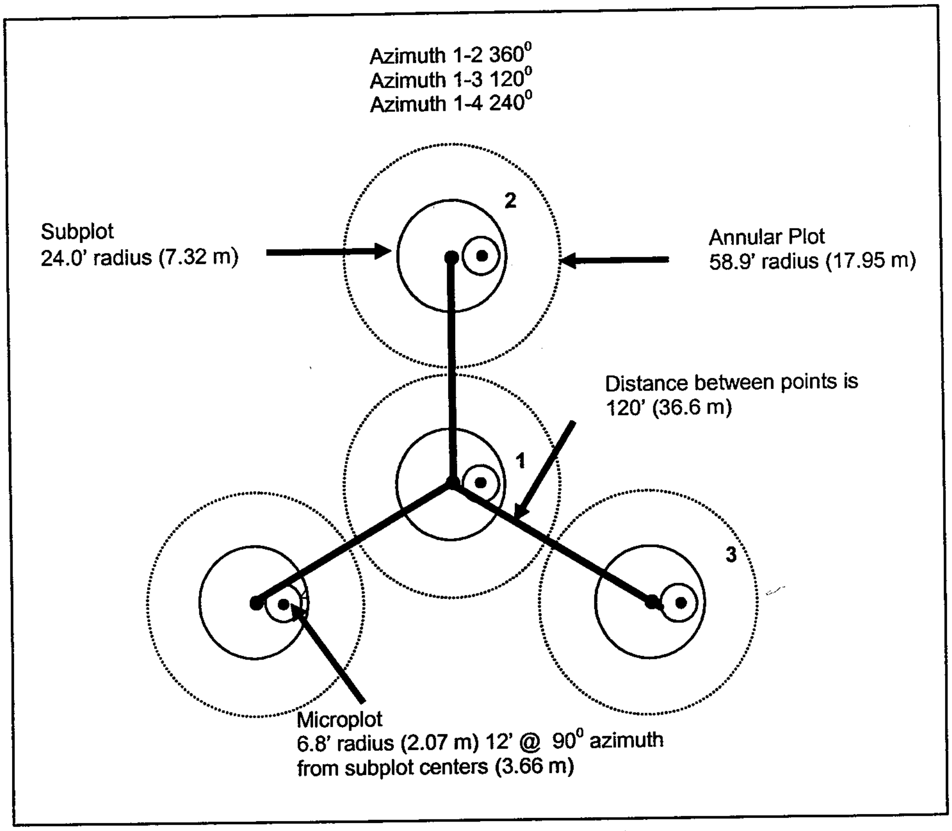

Figure 3. National FHM plot layout consists four points (subplot centers) (After USDA Forest Service, 1997)

Table 1. Location Codes and Descriptions in the Order of Highest to Lowest Priority or Tree Survivability

Code	Definition
0	No damage
1	Exposed roots and "stump" (12 inch (30 cm) in height from ground level)
2	Roots and lower bole
3	Lower bole (lower half on the trunk between the "stump" and base of the live crown)
4	Lower and upper boles
5	Upper bole (upper half on the trunk between "stump" and base of the live crown)
6	Crown stem (main stem within the live crown area, above the base of the live crown)
7	Branches (woody stems other than main stem)
8	Buds and shoots (the most recent year's growth)
9	Foliage

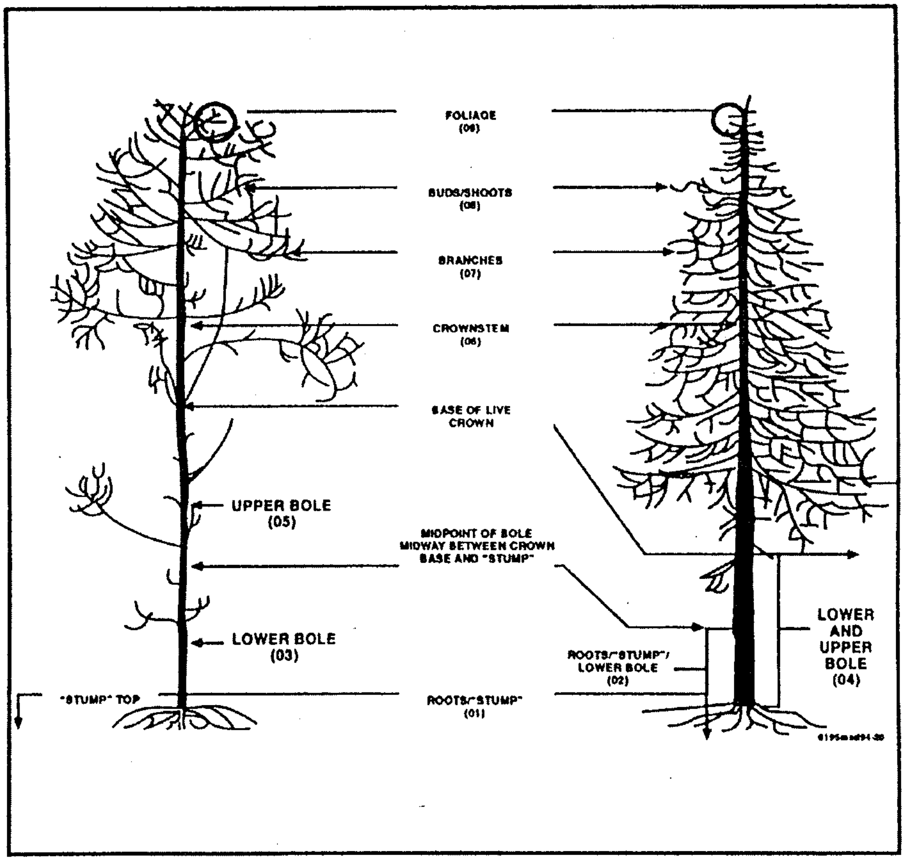

Figure 4. Location Codes for the Damage Indicator (After USDA Forest Service, 1997)

Within any given location, the hierarchy of damages follows the numeric order of damage types possible for that location (Johnson and Lyon, 1988; Sinclair et al., 1987). The numeric order denotes decreasing significance as the code number goes up, i.e. damage 01 is more significant to the tree health than damage 31 (Table 2). Trees in a plot which have already been logged over were recorded based on the appropriate catastrophic causal agent - the code is 700 (see Table 3). Subsequently, this level of evaluation is not repeatable - no tree-level index is computed. A maximum of three damages were recorded for each tree, beginning at the lowest location (highest priority). If a tree has more than three damages that meet the threshold levels, the first three that are observed starting at the roots are recorded. For damages that have a severity threshold, the severity is recorded in 10 percent classes up to 99 percent, beginning with the threshold value. All damages with no severity threshold are recorded as "0" severity.

Table 2. Damage Codes, Descriptions, and Threshold in the order from Highest to Lowest Significance to the Tree Health

Code	Description	Severity Threshold (in 10 % Classes to 99%)
01	Canker	≥ 20% of circumference at the point of occurrence
02	Conks, fruiting bodies, and other indicators of advanced decay	none, except for ≥ 20% for roots > 3 feet (0.91 m) from bole
03	Open wounds	≥ 20% of circumference at the point of occurrence
04	Resinosis/gummosis	≥ 20% of circumference at the point of occurrence
05 *	Cracks and seams	> 5', 1.52 m in length and on at least 20% of branches
11	Broken bole or roots (< 3 feet (0.91 m) from bole	none
12	Brooms on roots or bole	≥ 20% of roots
13	Broken or dead roots (> 3 feet (0.91 m) from bole	≥ 20% of roots
20 *	Vines in the crown	≥ 20% of live crown affected
21	Loss of apical dominance, dead terminal	≥ 1% of crown stem
22	Broken or dead	≥ 20% of branches or shoots
23	Excessive branching or brooms	≥ 20% of branches or brooms
24	Damaged foliage or shoots	≥ 30% of foliage
25	Discoloration of foliage	≥ 30% of foliage
31	Other	none

Note : *) Damage types newly introduced by USDA Forest Service, 1999. No record was made during the 1997 & 1998 assessment.

The number of measurements per plot is dependent on the number of trees 20 cm DBH present on each subplot (annular plot in Indonesia), up to a maximum of three measurements per tree.

Two personnel if possible are responsible for all measurements to adequately collect the data. In many cases, binoculars help identify damage in the upper bole and above. Linear tape assists in determining whether specific damage categories meet threshold and to assign a severity class.

Obvious signs of catastrophic events such as fire, bark beetles, wilts, beaver, wind, or logging may cause mortality to trees when no previous significant signs of damage were present or were unrelated to previous damage. Identification of these major agent groups has in fact helped to explain sudden and unexpected causes of mortality.

The cause of death has been recorded for all trees 20 cm DBH and larger on the subplot that were recorded as live trees during the previous inventory (Table 3). The causal agent group that most likely killed the tree is specified and the appropriate 3-digit code for each cut or dead tree is recorded.

Table 3. Cause of Death Codes and Descriptions *)

Code	Definition
001	Tree dead when first encountered
100	Insect
200	Disease
300	Fire
400	Animal
500	Weather
600	Suppression/Competition
700	Logging and related human damage
800	Unknown
999	Other then described above, needs explanation in notes

Note : *) Used if it is applicable. Source : Alexander, 1996

Formulation of the Damage Index

In computing the damage indexes, the authors have been trying to adopt the model proposed by Saltman and Lewis, 1994 with some modification following the single data sheet mode of computation (Dr. Mielke Manfred, personal communication).

The damage indicator comprised three separate components, namely : *type of damage, location of damage*, and *severity of damage*.

In other words,

Damage = f(type, location, severity)

For each individual tree, a maximum of three damages can be recorded. By assigning numerical values to each component, a cumulative numerical damage estimate for each tree can be developed using the following model :

damage = [xDamagetype*yLocation*zSeverity]

where : x, y and z = weighing values based on the relative effect of each component for the growth and survival of a tree.

For example, the highest value for damage type is 2 (two) and is given to the damage type with code 11 and the smallest for damage type is 1 (one) and is given to the damage type 22, 23, and so on. The highest value for the location is also 2 (two) and is given to location 1 and 2 (one and two). At the end of severity 1 (10%), the value is 1.1 until 1.9 (≥ 90%). Specifically for 0 (<20 %), the value is 1.5.

Tree Level Index = [Damage Type1*Location1*Severity1] +
(TLI) [Damage Type2*Location2*Severity2] +
[Damage Type3*Location3*Severity3]

Plot Level Index = Average damage [tree1, tree2, tree3, ...]
(PLI)

Area Level Index = Average damage [Cluster1, cluster2, cluster3...]
(ALI)

III. RESULTS AND DISCUSSIONS

3.1. Results

3.1.1 Natural Productive Forest

3.1.1.1 Damage Location

The most common damage location in both sites (Pulau Laut, South Kalimantan and Jambi, Sumatera are quite the same. Those are roots and stump (Location 1), roots, stump up to lower bole (Location 2), lower bole (Location 3), loss or dead of apical dominance (Location 6) and branch (Location 7) (Figure 5 and 6).

The average percentage of the different damage locations in Pulau Laut is shown in Figure 5 and 6. Lower bole = 10.6 %, apical dominance = 7.6 %, branch = 6.30 %, roots and stump = 2.8 % and roots, stump, and lower bole combination = 3.2 %. While in Jambi for lower bole is 5 %, apical dominance = 7.5 %, branch = 9 %, roots and stump = 1.4 %, and roots, stump and lower bole combination is 1.2 %.

3.1.1.2 Damage Type

The most common damage types recorded on trees in both study sites are also very similar. In Pulau Laut, those are : open wound (Figure 7A), conk (B) loss or dead of apical dominance (7C), broken or dead branch (7D), decay

(7E), gall (7F) broken or dead roots, damage of foliage or shoots etc. The example of these damage types are presented in Figure 8A.

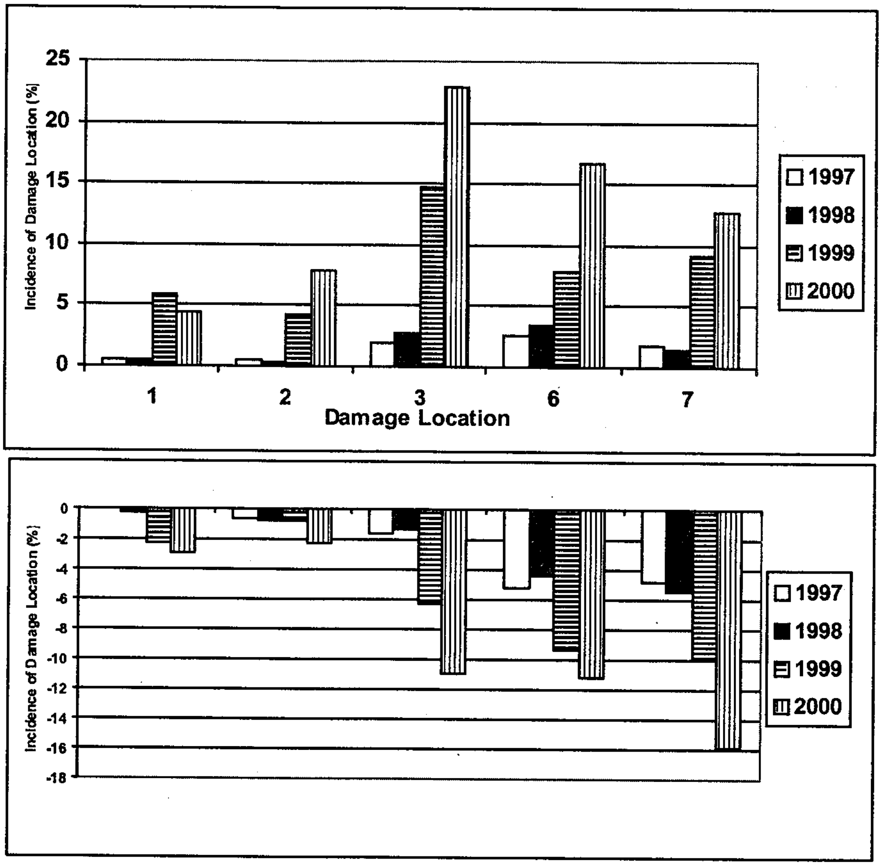

Figure 5. Histogram showing the incidence of damage location in Pulau Laut (A) and Jambi (B) from the first assessment in 1997 throughout the last one in 2000 consecutively

Similarly in Jambi, Sumatera, the common of damage types are broken branch, loss or dead of apical dominance, open wound, decay, broken and dead roots, etc. (Figure 8B).

In this study, another two damage types are proposed to be inserted as typical new important damage type found during the assessment period. These are termite gallery with code 06 and woody liana code 07. The severity threshold for these two damage types are also proposed below (Table 4).

Foliage damage type is also recorded, but this damage type is considered as the lowest in priority according the FHM technology. This damage type is again considered less important since most if not all of the trees in the tropics are broad leaves species which could easily be renewed by the tree itself.

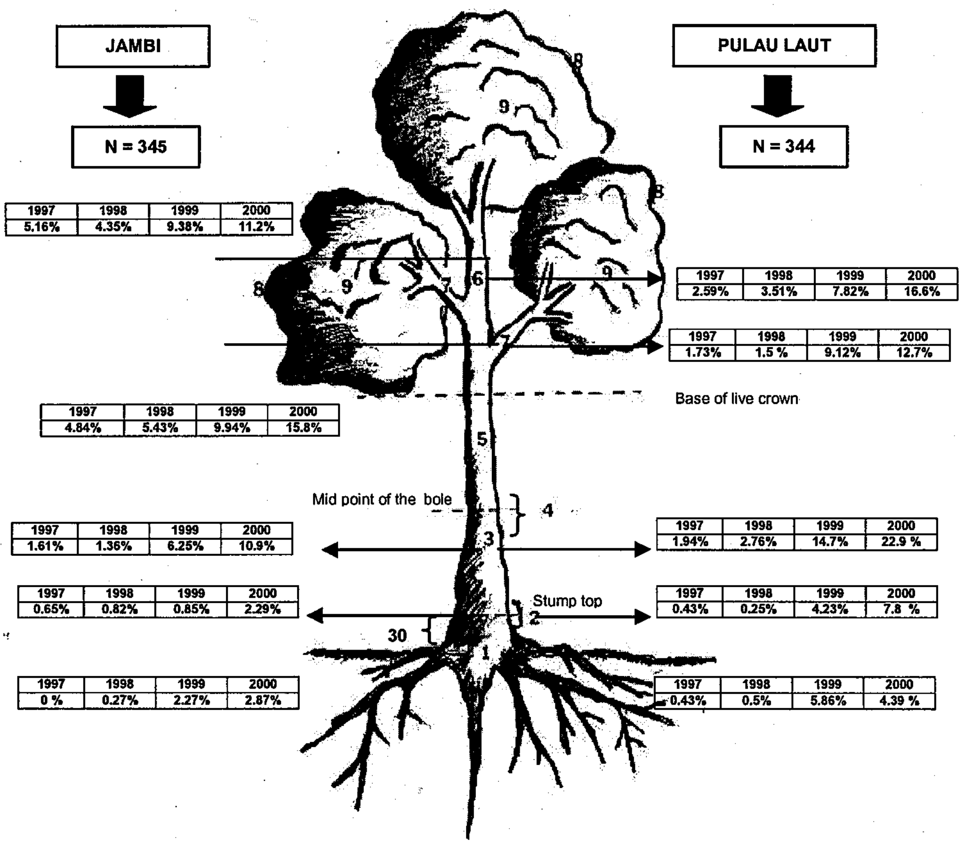

Figure 6. The Damage Location Recorded at Six Clusters in Pulau Laut, South Kalimantan and Four Clusters at PT Asialog in Jambi, Sumatera During the Detection Monitoring from 1997 through 2000

Table 4. Damage Codes, Descriptions, and Threshold in the Order from Highest to Lowest Significance to the Tree Health

Code	Description	Severity Threshold (in 10 % Classes to 99%)
06	Termite gallery	≥ 20% of circumference at the point of occurrence
07	Woody liana	≥ 20% of circumference at the point of occurrence

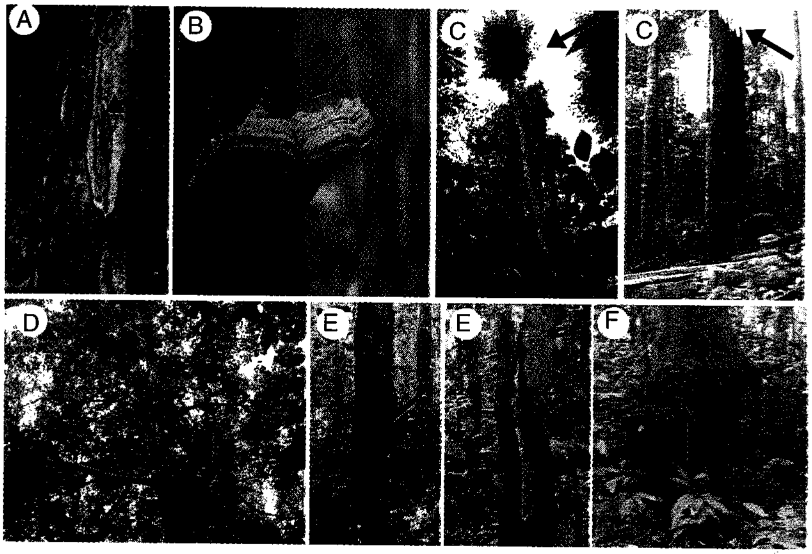

Figure 7. Different Damage Types

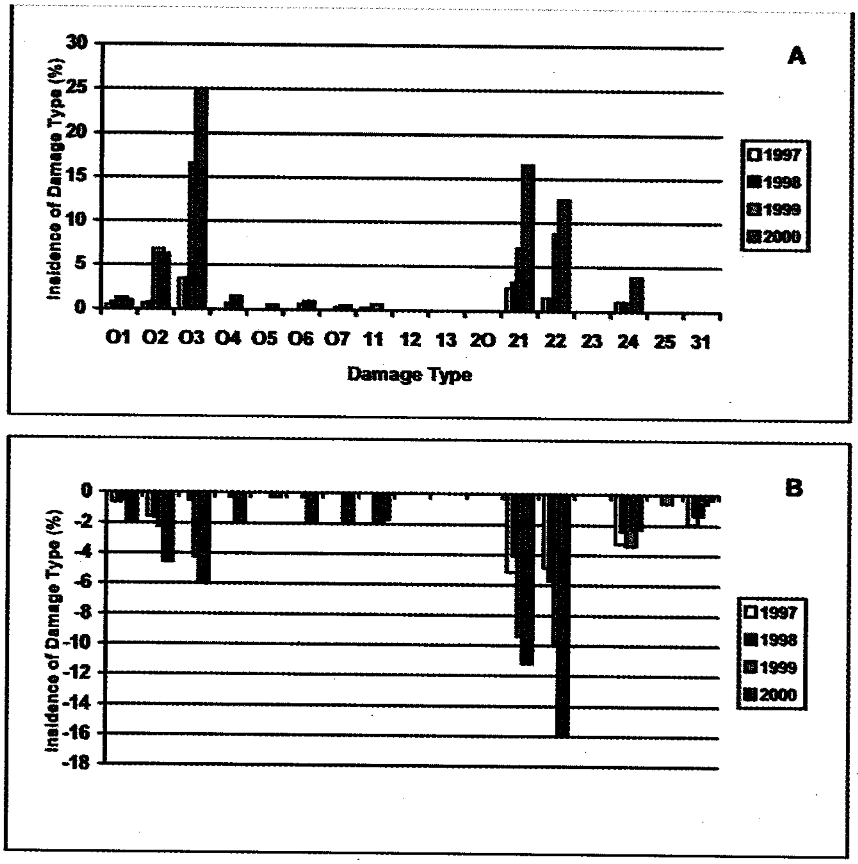

Figure 8. Histogram showing the incidence of different damage types recorded consecutively during the assessment periods (1997-2000), at Pulau Laut (A) and Jambi (B)

3.1.1.3. Damage Severity Index

The cumulative area level-index (CALI) of some important tree species obtained by means of summing up the tree-level index, plot level-index, and finally the whole area of Pulau laut and similarly in Jambi, Sumatera are presented in Figure 9 and 10 respectively.

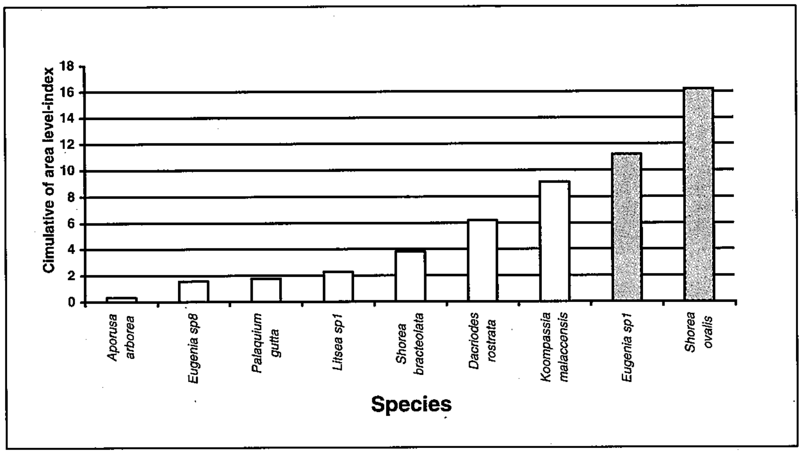

Figure 9. Histogram Showing the Cumulative Area Level Index of Some Important Trees Species in Pulau Laut, Year 2000

From Figure 9 it reveals that *S. polyandra*, followed by *D. caudiferus*, *S. johorensis*, *S. ovalis*, *S. parvifolia*, and *Eugenia* sp 1 have the most high CALI (cumulative area level-index). Ranging from heavily damage (*S. polyandra*) to slightly damage (*Eugenia* sp1). On the contrary, *S. leprosula*, *E. zwageri*, *Hopea nervosa*, *Drypetes sp*, *Gluta wallichii*, *Litsea roxburghii*, *D. accutifolius*, *D, curraniopsis* are the tree species categorized as healthy, at least externally during the assessment periods.

Following the similar way of thinking on the same case in Pulau Laut, Figure 10 indicates that *S. ovalis* in Jambi is categorized as lightly damage which is followed by *Eugenia* sp 1 with CALI of around 16 and 10 respectively. The other species in Jambi such as *A. arborea*, *Eugenia* sp 8, *P. gutta*, *Litsea* sp 1, *S. bracteolata*, *D. rostrata*, and *K. malacensis* are categorized healthy.

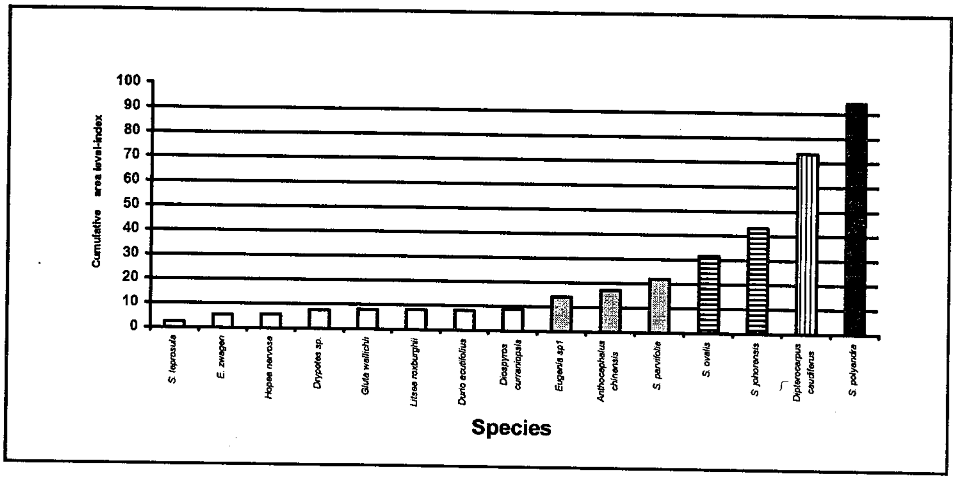

Figure 10. Histogram Showing the Cumulative of Area Level-Index of Some Important Trees Species in Jambi, Year 2000

3.1.1.4. Damage Status, Change, and Possible Tendency

3.1.1.4.1. Pulau Laut, South Kalimantan

To illustrate the status, change, and possible tendency, some commercially important tree species are selected as an example (Figure 11).

This figure clearly shows that *S. leprosula* during the assessment period has a CALI of less than 10. This indicates that the tree species is categorized as healthy and shows very little changes during the rest of the measurement. Next to *S. leprosula* are *Diospyros macrophylla* followed by *S. johorensis*, *Dipterocarpus caudiferus*, and the worst one is *S. polyandra* especially during the last assessment (2000). Categorically, the selected tree species have a tendency to become worst and worst.

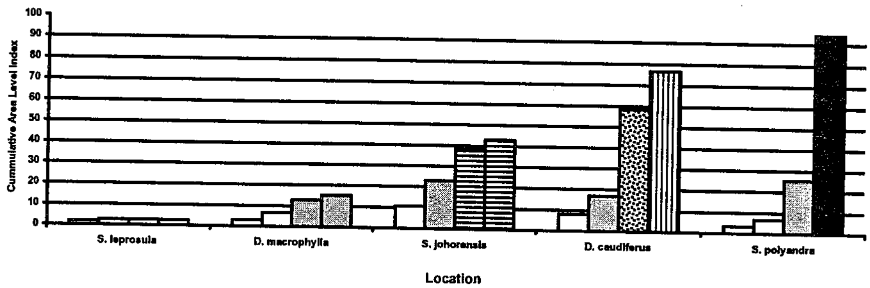

Figure 11. Histogram Showing the Status, Change, and Tendency of the Cumulative Area Level-Index of Some Important Tree Species in Pulau Laut During the Assessment Periods from 1997 through 2000 Consecutively from the Left to the Right

3.1.1.4.2. Jambi, Sumatera

In the case of Jambi (PT Asialog), there is also a tendency to become worst and worst (Figure 12).

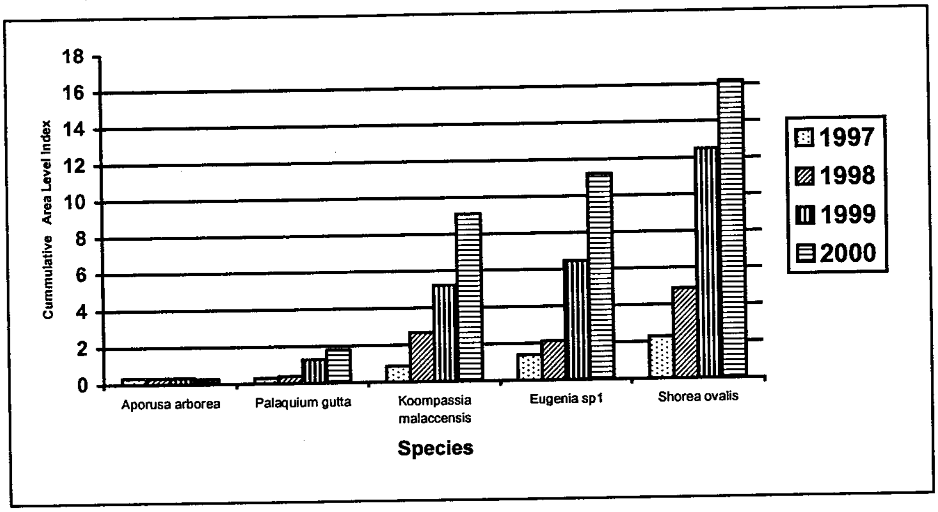

Figure 12. Histogram showing the status, change, and tendency of the cummulative area level-index of some important tree species in Jambi during the assessment periods from 1997 through 2000 consecutively from left to the right

3.1.1.4.3. Area Comparison

There are around five common tree species found in Pulau Laut, South Kalimantan and Jambi, Sumatera. Those tree species are : S. ovalis, Eugenia sp 1, D. rostrata, Aporusa sp 1, and Litsea sp 1.

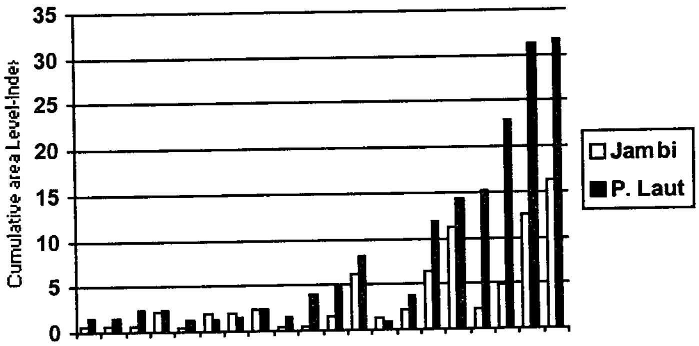

Figure 13. Comparative histogram of area level-index of some common species based on their area level-indeces found in Pulau Laut, South Kalimantan and Jambi, Sumatera during the assessment periods

Based on their CALI, the tree species in Pulau Laut have higher CALI as compared to the same trees species in Jambi. Yet, their CALI is ranging from below five up to around thirthy (Figure 17), except for *Aporusa* sp 1, especially on the second measurement (1998) and similarly for *Eugenia* sp 1 on the first measurement (1997).

3.1.2. Man-made Forest

3.1.2.1. Damage Location

Figure 14 indicates that only damage occurring on lower bole (location 3) is recorded throughout the assessment period (1998 through 2000). The damage occurring on location 2 or roots, stump up to lower bole is only found during the second year of measurement (1999). In addition, branch (location 7) is also recorded since 1999 as for location 2. The other damage location is recorded only during the last assessment (2000, Figure 14).

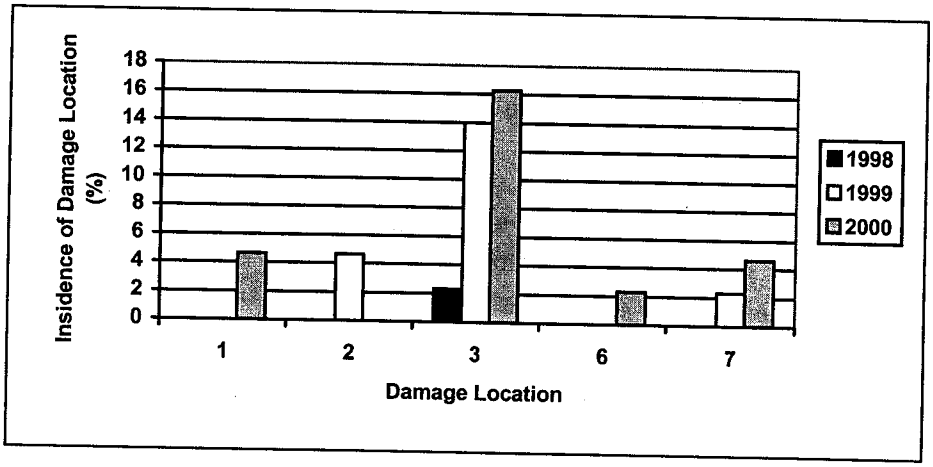

Figure 14. Histogram showing the occurrence of damage location at Cluster 3 Pulau Laut, South Kalimantan (1998-2000)

3.1.2.2 Damage Type

The most common damage types recorded during the assessment periods are: decay, open wound, broken or dead of branch, gumosis, loss or dead of apical dominance, and non-woody liana. Among these damage types only open wound has been recorded since the first year of assessment (1998) until the last year (2000). Loss and or dead of apical dominance was recorded only during the last year of assessment. The remaining damage types were recorded during 1999 and 2000 (Figure 15).

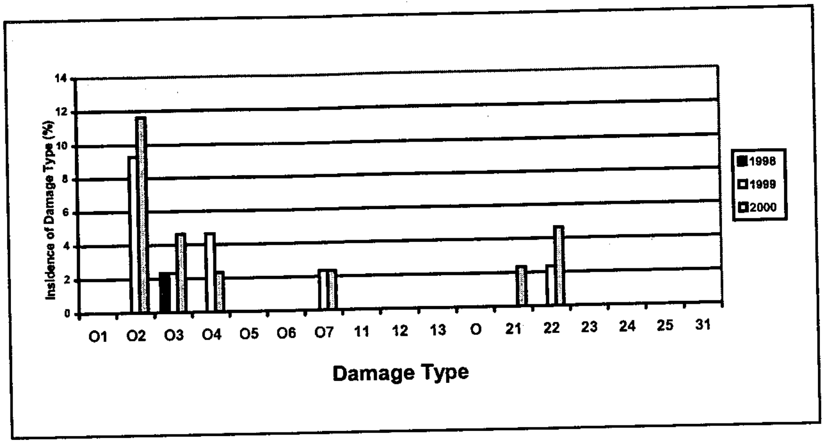

Figure 15. Histogram showing the occurrence of damage type at Cluster 3 Pulau Laut, South Kalimantan (1998-2000)

3.1.2.3 Damage Severity

The highest cumulative area level-index (CALI) recorded in 2000 is less than 10, it means that based on the scoring category established for this damage assessment, the *S. polyandra* stand at Cluster 3 Pulau Laut is belong to healthy category (Figure 16).

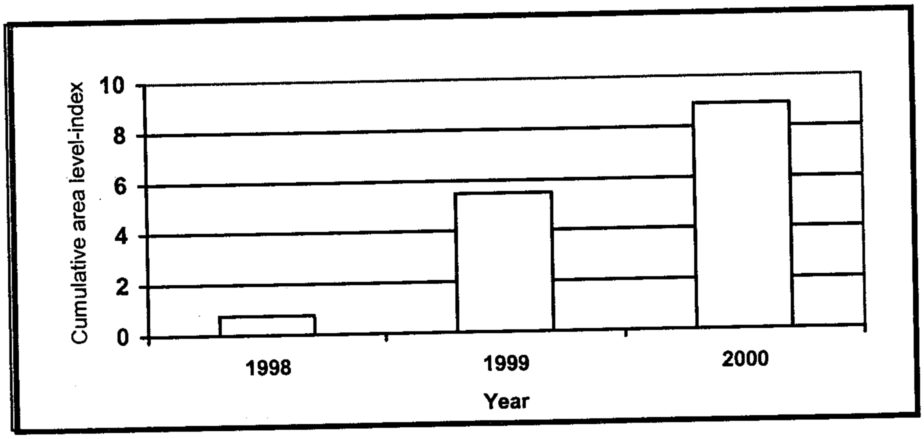

Figure 16. The area level-index (ALI) of *Shorea polyandra* at Cluster 3 (Man-made forest) in Pulau Laut, South Kalimantan

3.1.3. Natural Production Forest versus Man-made Forest

To give an idea on how is the damage condition on natural production forest compare to man-made forest, the ALI of *S. polyandra* in Cluster 3 is descriptively compared to average of the six clusters in Pulau Laut. Figure 15 clearly shown that the damage condition as reflected by their ALI in man-made forest is much lower as compare to the ALI of natural stand.

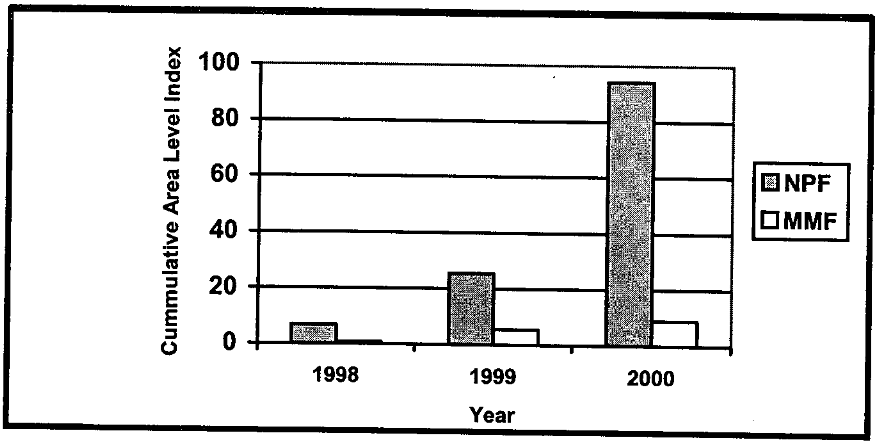

Figure 17. Area level-index (ALI) of *Shorea polyandra* in Natural Productive Forest (NPF) and in Man-made Forest (MMF)

3.2 Discussions

3.2.1 General (Overview)

In the first place, the two study sites were originally of natural productive forest. The first logging activities in Pulau Laut was in 1968 and Jambi in 1972. Being a natural production forest, mechanical injury is an unavoidable phenomenon. This mechanical injury, either in roots, stump, lower bole, branch or even in the apical dominance, could also be categorized under long term or predisposing factor besides genotype of the tree, soil compaction, poor fertility and others. Following predisposing factor, insect defoliator or stem borer will continue to cause damage as short-term factor or inciting factor. Eventually, other biological factors such as decay fungi will finalize the damage as contributing factor which is also another long-term factor, called or specified as contributing factor (Figure 1 and 2).

The US-FHM technology was established and / or issued by or in a country where environmental awareness of the people is very high. Indonesia in these days also appreciates environmental condition. In line with this, the paradigm is changing from forest as wood producers into forest as an ecosystem. Therefore, in Indo-FHM – forest is considered as an ecosystem or simply a system. Being a system, it consists of at least two elements, interacting each other, holistic, and clearly defined. It is a collection of communicating materials and process that together perform some set of functions (Grant *at al*, 1997).

FHM is conceptualized to answer particular assessment questions. The main concern of FHM is related to the sustainable forest management – this is a **principle**. To be sustainable, a forest should be healthy – this healthy concept comes under category **criteria**. How to argue that a forest is healthy? To answer this question, an **indicator** is needed. Indicator could be qualitative or quantitative.

In FHM, the damage indicator is translated into three components. The damage location and type (qualitative) and the severity (quantitative). These damage components are easy to detect, and the severity performed is measurable – this is called **verifier(s)** or **parameters**.

By organizing the collected data, a single information would help to explain whether the indicator tested (in this case the damage indicator) is reliable or not and so, by organizing different indicators, it is again expected to obtain good and valid information needed to explain that the criterion(s) in question (in this case the forest health criterion) is useful or ready to explain that the forest in study is sustainably managed or not.

The strength of the FHM technology, among others is that it is already dealing with or working on the verifier / or measurable level . To give a simple but comphrehensip idea on how the trees are recorded, and what is the condition of each individual tree during the whole assessment period (Figures 18, 19, 20).

3.2.2 Damage Location

Figure 5 and 6 indicate that — lower bole, apical dominance, and branch are the most susceptible location in trees following the Indonesian Selective Felling and Planting System adopted. Yet, according to the US-FHM Field Methods Guide (National 1997 & 1999), the highest priority is on the roots and stump (location 1), then followed by roots stump and lower bole (location 2) and so until the lowest, that is foliage (location 9). This means that all the damage locations either in Pulau Laut or Jambi (Figure 5) is of very similar at least during this study.

The damage locations found, are very harmful for the long-term survival of the trees, although the percentage shown in Figure 6 seems to be relatively very low. The reason is that, the physiological function of root, stem and branch supporting the foliage and the apical dominance are all susceptible for damage. This is particularly true in production forest.

Even the percentage of damage location 1 (roots and stump) is very low, its role in long term survival of the tree and its wood in particular is very important (high priority), (see Figure 5).

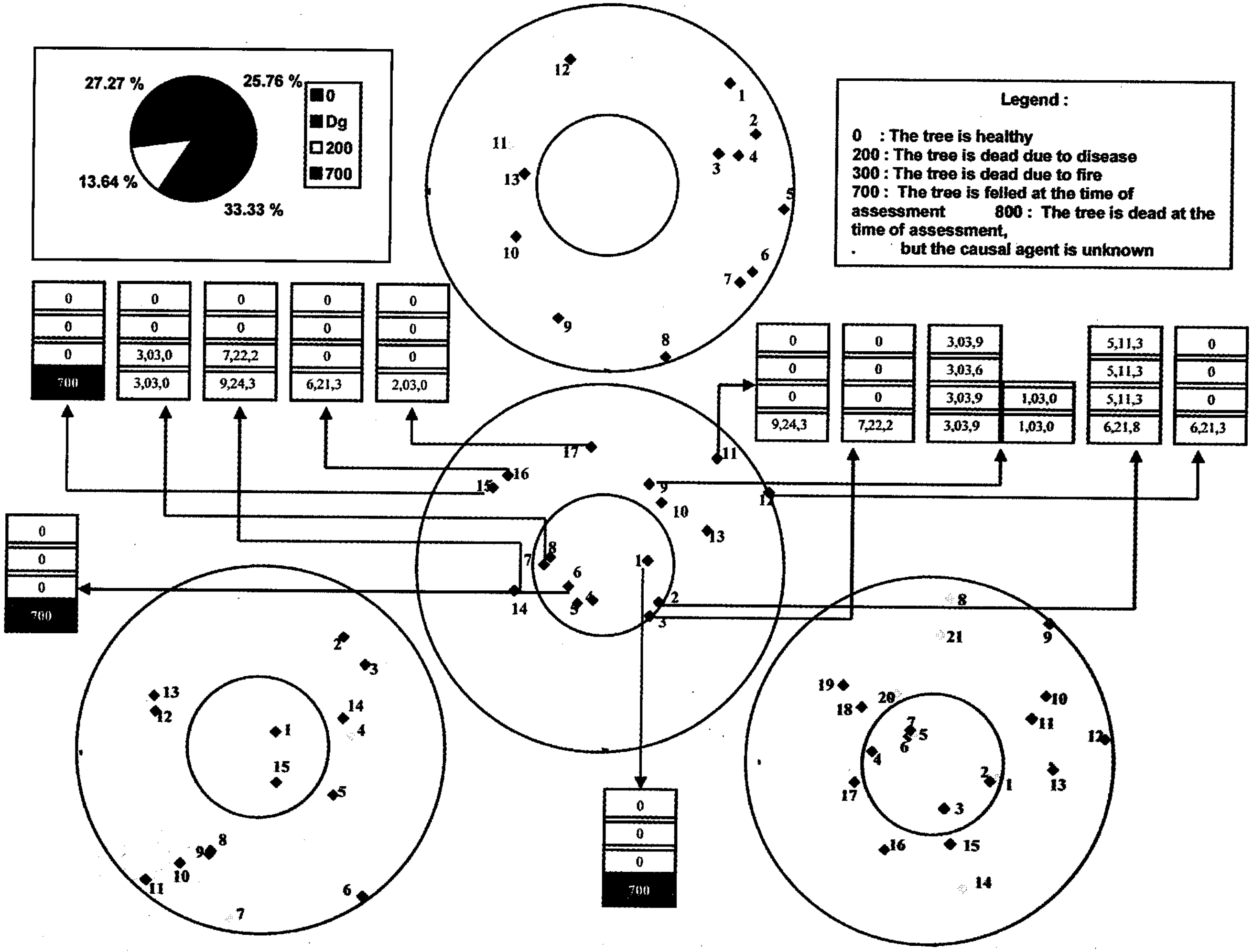

Figure18. Diagram representation of trees condition assessed in cluster 1 sub-plot 1, Pulau Laut (South Kalimantan) periods (1997-2000). The assessment year are arranged in the box consecutively from the top(1997) until the last one (2000). The figure in the box indicates the damage code for location, type, and severity

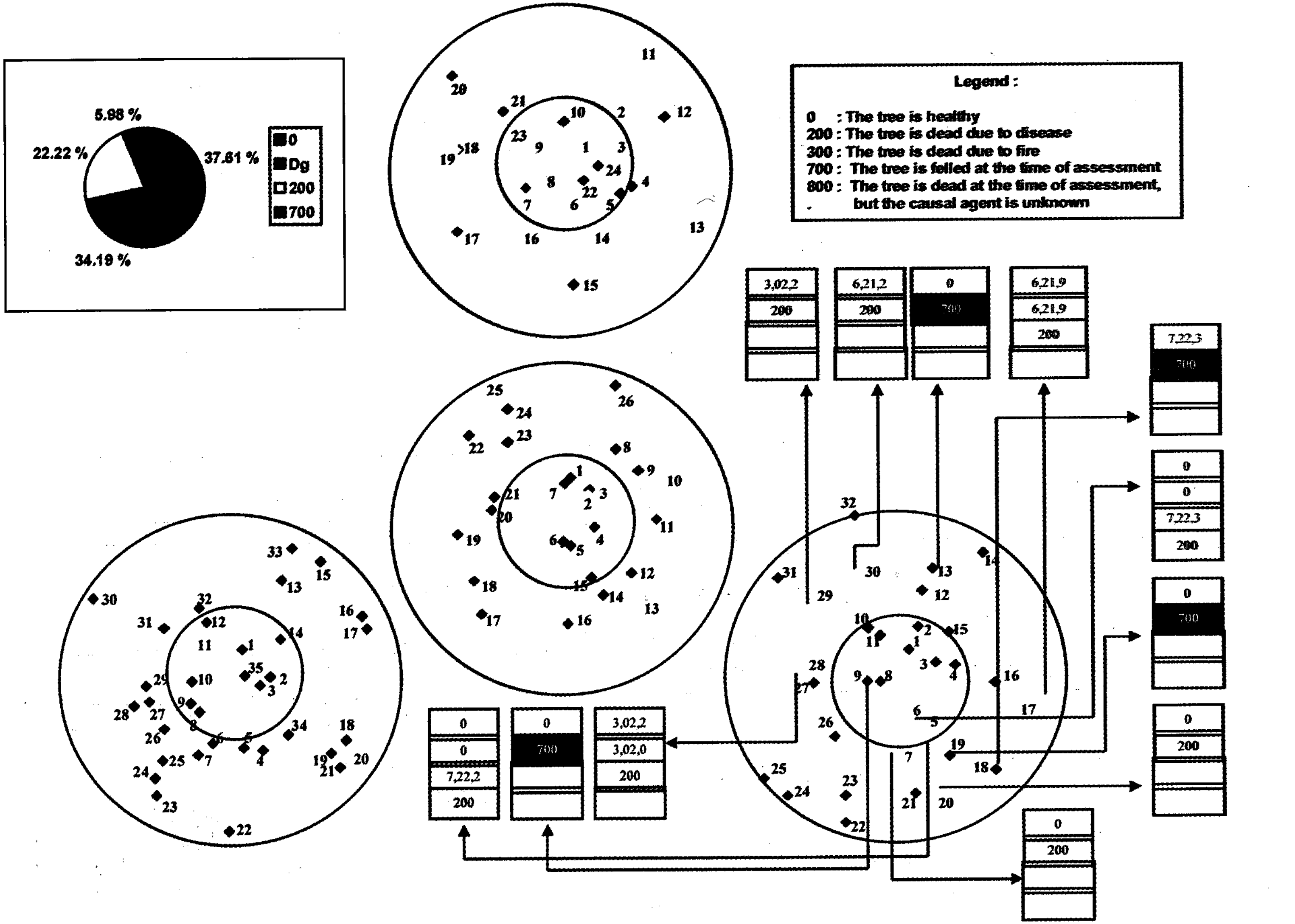

Figure 19. Diagram representation of trees condition assessed in cluster 1 sub-plot 3, Jambi periods (1997-2000). The assessment year are arranged in the box consecutively from the top(1997) until the last one (2000). The figure in the box indicates the damage code for location, type, and severity

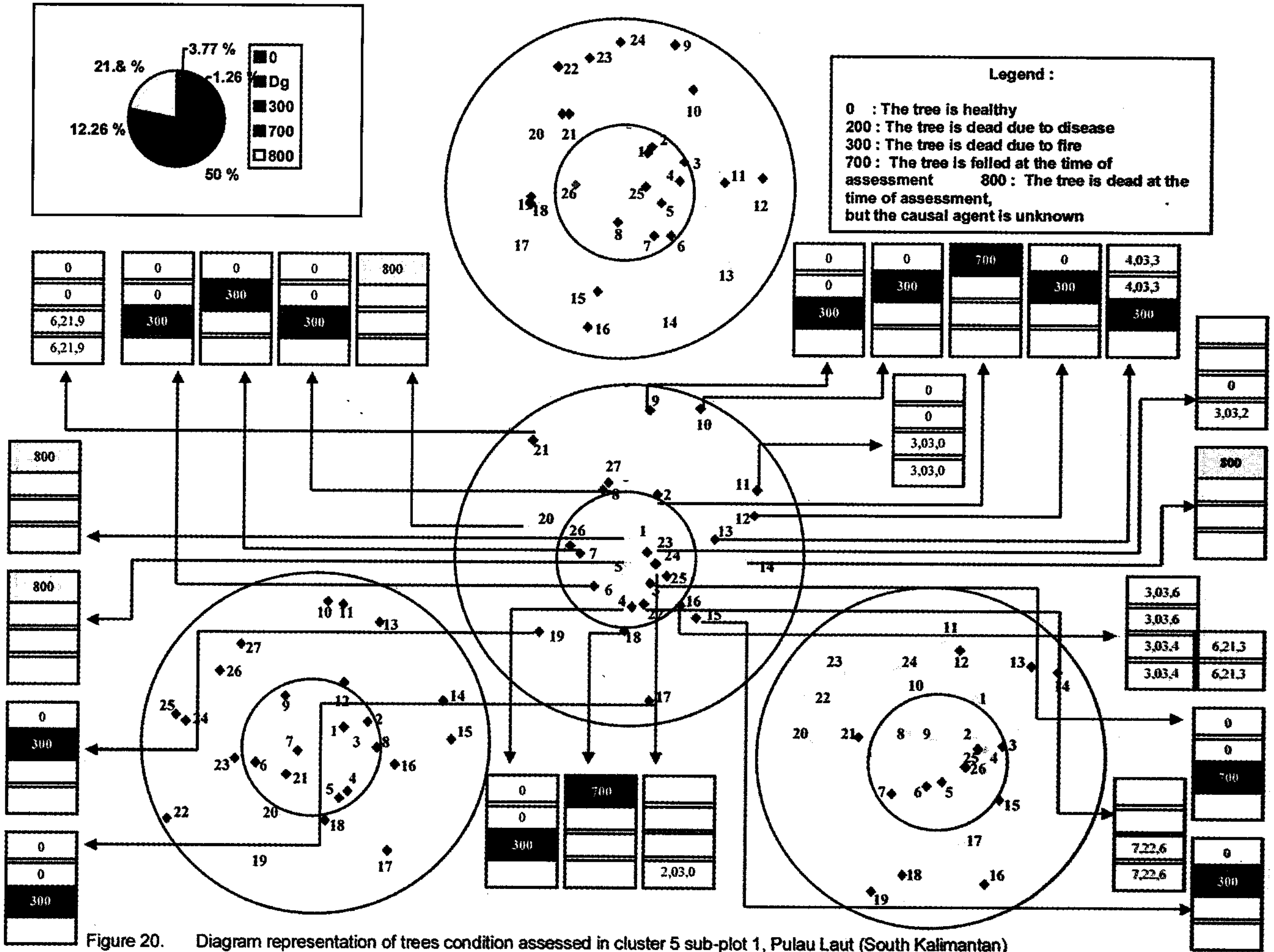

Figure 20. Diagram representation of trees condition assessed in cluster 5 sub-plot 1, Pulau Laut (South Kalimantan) (South Kalimantan) periods (1997-2000). The assessment year are arranged in the box consecutively from the top(1997) until the last one (2000). The figure in the box indicates the damage code for location, type, and severity

3.2.3 Damage Type

Figure 7 indicates that the most common damage types in both study areas are of quite the same. In Pulau Laut, open wound, loss or dead of apical dominance followed by broken or dead branch seems to be the highest in percentage. As in the case of damage location, the priority is given to the lowest damage type code number. In this case damage type that is assigned for canker and or gall, code 01 is given the highest priority to be recorded. It is interesting to note that in these two study areas, no canker is found even on the cluster 3 in Pulau Laut which is a plantation stand. Usually canker is always a common damage type in many if not all man-made forest. A similar case occur in Jambi natural production forest .

Nevertheless, broken or dead branches and loss or dead of apical dominance showed the highest in percentage. As shown in Figure 7, open wound seems to have damage type incidence of only around six percents compared to twenty percents of the same case in Pulau Laut. This phenomenon clearly indicates human interference or activities especially those related to logging. The high percentage in open wound in Pulau Laut clearly explained that the logging is being carried out very recently prior to and / or even during the assessment. While in Jambi, at least at the study sites, logging has been carried out long time before assessment and so, the wound might have been healed up.

Decay (damage type 02) seems to be quite low in percentage, but the actual deteriorating wood has never been precisely measured in this detection monitoring. By the time the decay development will become obvious when the tree is felled following the next cutting cycle. Figure 21 clearly shows this phenomenon. Similarly, the roots and or roots and stump damage is only around two percents in both the study areas. But, according to the FHM method this damage type is the highest in priority.

In this report two new damages types that are quite typical to tropical forest e.q. the termite gallery (Figure 22) and the woody liana (Figure 23) are proposed in addition to the US-FHM (1997/1999).

3.2.4 Damage Severity

To give an idea on how far is the damage severity of the tree species in clusters studied, some economically important tree species are selected and their cumulative area level-index (CALI) are compared especially based on the last year assessment.

3.2.4.1. Pulau Laut

Based on Figure 10, the highest CALI is represented by *S. polyandra* (> 90). Next to *S. polyandra* is *D. caudiferus* and the lowest CALI is represented by *S. leprosula*. The scoring of the CALI revealed that *S. polyandra* is the tree species categorized as very heavily damaged (CALI > 90). This figure, does not necessarily means that the tree species is severely damaging from the wood quality point of view. The figure is high during the assessment, the tree species is being logged. It means that at the time, the tree species has an economical value, regardless that the felling activity is against the rule or in line with the felling rotation schedule or not. The question raised in this context : Is such forest condition healthy or sustainably managed?

This question is particularly important for cluster 1 and 7 in Pulau Laut. Since 1970, actually the forest parts where cluster 1 and 7 were established, has been assigned for buffer zone area. The forest in these clusters are no longer as a production forest. But unfortunately, during the last year assessment (in 2000), felling or logging is being carried out officially or semi-officially. In this context, the forest could easily be categorized as unhealthy or not sustainably managed.

One may question on how and / or what is the parameter to be measured for protection forest beside measuring the damage of individual trees that is a very powerful tool in the production forest. The authors propose for canopy opening (See TR No 20).

3.2.4.2 Jambi

Figure 11 reveals that among the economically important tree species selected, *S. ovalis* gave the highest CALI (> 16), follows by *Eugenia* sp 1 and the lowest level is represented by *A. arborea*. This condition was based on the data of the last year assessment (2000). Our comparison is merely based on the CALI / ALI obtained during the detection monitoring, misleading information will certainly cover up the actual forest health condition. This is because during the detection monitoring phase, we are only dealing with the external measurement. In this phase, neither sample or damag e part of the tree is allowed to be taken or removed, nor section on the deteriorating heartwood is measured. As a result, no data on internal measurement of the damaging or decaying wood was available.

In natural production forest, the major usage of thewood is related to the strength and durable class. Consequently, long rotation cycle is required for this kind of forest management. As mentioned earlier, the mechanical injury serves as an infection court of the fungi, particularly the heart-rot decaying fungi. The number of logs or part of logs that are rejected or deducted in measurement made from gross timber volume because of defects is called cull. In standing tree, the cull expressed as a percent of the trees' gross volume is termed the cull factor (The Society of American Foresters (1998)). See also Figure 23 as an example of rejected logs.

The development of heart-rot is determined by the genotype of the tree, the strain of the heart rot fungi, the site and last but not least is the time. In Indonesian Selective Felling and Planting System adopted so far, the rotation cycle is 35 years. If the nucleus trees are mechanically injured during the felling or logging activities, either on the root, stump, bole, branch and / or apical dominance, the infection court is being facilitated. By that time, as the sapwood is changing into heartwood, one of the most prerequisite conditions for the germination and further development of heart rot decaying fungi is attained. The condition aimed for heartwood is the low moisture content. Heart-wood is a dead tissue. Being a dead tissue, the moisture content is much lower as compared to the sapwood moisture content (Bakshi, 1976; Manion, 1981).

In addition to the low moisture content, high extractive components is also attributed to the heartwood. This extractive could be toxic or non toxic to the heart rot decaying fungi. If the extractive is toxic then the heartwood of the particular tree species is mitigated or protected from being digested enzymatically by the heart rot fungi readily established following the mechanical injury during the felling or logging activities. If this is the case, then the wood is of durable class one. On the other hand, it may happen that a wood is of less durable or even may be very susceptible to the heart-rot fungi. In this case the development of the heart rot is simply a function of time.

According to the US-FHM Guide Method (1999), the deterioration of the heart wood is about 2 cm to 15 cm in 8 - 10 years. This means that the deterioration rate of the heart wood is about 0.25 cm to 0.66 cm per year. This figure suggests that in 35 year felling cycles, the heartwood might be rotten ranging from 8.75 cm up to 23.10 cm. But this figure is adopted from American tree species and site condition. No such information has been available for Indonesian or tropical tree species condition.

Figure 21. Typical heart-rot development on *S. polyandra* in Cluster 7, Pulau Laut

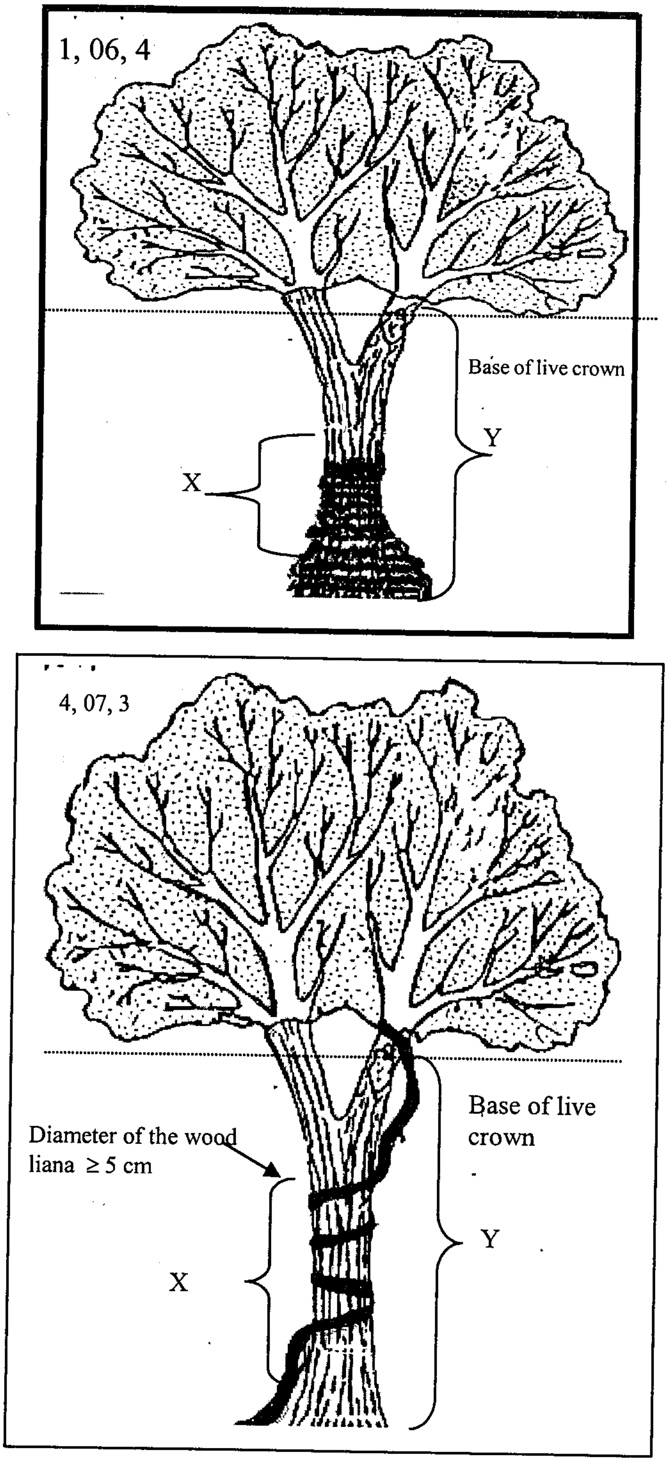

Figure 22. Procedure for measuring the percentage / severity of damage type 06 (termite gallery)

Note : X = Distance between two points on the bole, completely covered by the gallery if the bole is partly covered

Y = The height of the bole,

It is for such a situation or condition that the CALI of some important tree species selected for discussion is of no use as regard to the development of the heart-rot. In other words, the CALI of the selected tree species in Jambi which are mostly much lower as compared to the CALI of the different species in Pulau Laut are not of a better wood quality than that of Pulau Laut. This phenomenon has been mentioned earlier, that the logging activities in Jambi at least at the clusters studied have been carried out since long time ago compared to Pulau Laut. During that time some open wounds might have been healed up externally, but the wood continued to develop. This means that the diameter of the tree or new sapwood is increasing and at the same time, the already transformed heartwood is also decaying. This is the most critical and interesting point in natural production forest particularly in relation to the Indonesian Selective Felling and Planting System. For that reason, obtaining the information through the detection monitoring, the next step of FHM need to be initiated that is the intensive site environmental monitoring or ISEM.

The information expected through ISEM are among others : the deterioration rate of the heartwood of different economically important species. This is very fundamental in the sustainable management of the natural production forest, particularly in these days the forests are damaged.

3.2.5. Damage Status, Change, and Possible Tendency

From the Figure 12 (Pulau Laut) and Figure 13 (Jambi), an interesting information is presented that most of the tree species selected (Pulau laut and Jambi) have CALI with a tendency to increase year after year during the four-year assessment (1997-2000). *S. leprosula* in Pulau Laut and *A. arborea* in Jambi are showing relatively stable and low CALI during the whole assessment periods.

Another interesting thing is that the CALI increment is mostly or seem to be proportional except for *D. cauduferus* and *S. polyandra* in particular. This situation suggests that those trees being felled (in Pulau Laut) seem to have high value according to the loggers compared to the other trees species at the same time. This happens during the last year of assessment (2000). The CALI in this context as has been mentioned somewhere in this report, need to be interpreted critically.

3.2.6. Area Comparison

Using some common economically important tree species, Figure 14 reveals that mostly the trees in Jambi have lower CALI as compared to those of Pulau Laut tree species. This difference nevertheless, is believed more due to different in felling activities rezim rather then ecologically (see report TR No. 22 on Soil).

3.2.7. Man-made Forest

3.2.7.1. Damage Location and Type Combination

The damage occurring in cluster 3 (plantation) has nothing to do with felling activities. The damage is due to people activities during forage collection for their buffalos. In additions, most of the trees planted were used for *Piper* sp cultivated by the local people. During their activities, some body may hit the trees with their knife or chapping-knife. That is why the incidence of damage location is higher in location 3 or lower bole, root, root stump and lower bole (location 2).

This information is also in accordance with damage types mostly recorded during the assessment period (Figure 16). In this figure, decay, open wound, gumosis, liana (*Piper* sp), branch and apical dominance are damage type observed on a 25-years old *Shorea polyandra* plantation. This means, the many open wounds since the trees were young have changed to be decayed. That is why more decay is recorded compared to open wound.

As regard to the dead branches, it is also easy to explain because the tree's crown of 6 to 7 m in diameter have touched each other with the consequence the lower branch obtained less light. This is particularly due to spacing which is 3 by 3 meters and no thinning has been carried out so far.

3.2.7.2. Damage Severity

As has been indicated previously, following the health category established in terms of CALI, *S. polyandra* stand is a healthy stand. In general, there is also a tendency of the CALI to increase from the first year assessment throughout the last year assessment. One thing to emphasize is that dipterocarp planted in their natural habitat are still healthy at the age of ± 25 years.

This is very much different with many fast growing species planted elsewhere in Indonesia. Usually, at the age of 4 or 5 to 8 years, especially in many fast growing tree species, damage / diseases have been commonly caused by either biotic factor or in combination with abiotic factors (USDA-FHM, 1997; Nuhamara, 1996).

3.2.7.3. Natural Production Forest Versus Man-made Forest

As shown in Figure 18, the CALI of natural productive forest is much higher than the man-made forest. This is because of the high and strongly uncontrolled felling and / or logging activities in natural forest. The most important and critical point is that in man-made forest, no cutting has been carried out except one single tree in the whole cluster. While in natural production forest it was the trees having very high value were felled. In the context of growing tree, especially in terms of stem diameter, they are healthy, but in terms of wood quality, such a natural production forest is still questionable.

3.3. Data Interpretation

The FHM Field Method Guide (1996, 1997 and 1999) is a very powerful instrument of the data collection phase. In using this instrument, another indispensable document is needed i.e. the Quality Assurance Project Plant for Detection Monitoring (1995) issued by Environmental Monitoring and Assessment Program. In order to interpret the collected data critical and comprehenship knowledge is needed.

That is why, an easy, interpretable and applicable definition on forest health as a dynamic concept need to be refreshed / redefined accordingly. A dynamic concept is limited by time and space. Nuhamara (1997) proposed that " A forest is healthy, if it is in a condition able to perform its assigned function normally (or at least to the best of its main function expected).

This definition is constructed as a response to the statement of Dr. Manfred Mielke, Damage and Crown Indicator Leader of USDA Forest Service (pers. com.) and the suggestion of Dr. Supriyanto as the chairman of the executing agency program. He stated that the US – FHM Methods Guide is a tool for "recording". The interpretation is another thing that has to be developed further and very much depend on where the cluster is established and assessment questions.

Data obtained in this study clearly indicates the index level of a particular tree species (*S. polyandra*) recorded in a production forest (Cluster 6, Pulau Laut), but the same tree species is also recorded in buffer zone area (Cluster 1 or 7, also in Pulau laut).

The tree-level index (TLI) of *S. polyandra* recorded in different forest function and measured in the same period might have about the same TLI, but the interpretation should be different. As an example, *S. polyandra* tree number 11 at subplot 1 in cluster 2 (natural productive forest) has a tree-level index (TIL) of 2.18 and the same species recorded in plantation forest with TIL = 4.05 and in buffer zone, TIL = 4.05 (Table 5).

Table 5. The Tree-level Index of *S. polyandra* in Different Forest Function

No.	Tree Code	Forest Function	Index (TLI)
1.	01.3.12/ PUL	Buffer Zone	4.05
2.	07.1.06/ PUL	Buffer Zone	5.89
3.	02.1.11/ PUL	Natural Productive Forest	2.18
4.	03.2.08/ PUL	Plantation Forest	4.05

It seems that their TIL are about the same, but the reading interpretation should be different. The TIL of the tree species in natural production forest as well as in plantation forest shows an information related to the future wood quality of the tree species. On the other hand the TIL of the same tree species in buffer zone is showing an information of future quality of the protective function (hydro-orological function) of the forest area. In this context, the difference is determined by the assessment question needed by the people living surrounding the forest at a certain time. Originally the forest part where cluster 1 and 7 established, were treated as natural production forest (cutting was carried out in 1968 and in 1970 it was assigned as buffer zone).

The fact that the tree species found in cluster 1 and 7 were felled clearly shows that the forest function in that area is unproperly managed. In other words, such a forest is not sustainably managed.

In FHM, the damage indicator in particular, remeasurement should not be necessarily scheduled for every year. But due to unpredicted socio-economical circumstances and the funding support regulation, this study was conducted yearly. This situation certainly gave an opportunity to the team to embrace the necessary non-technical aspect related to sustainable forest management.

IV. CONCLUSIONS

Damage indicator established by the US-Forest Health Monitoring, Field Guide Method is technically suitable for the health of tropical forest ecosystem (Indonesian forestry) with some minor modifications and/or addition. The damage recorded in all clusters studied is typically of mechanical damage, reflecting clearly as a result of human activities such as logging (legal and illegal), and fire. These mechanical injuries either found in roots, stump, lower bole, branch or apical dominance serve as an infection court for different microorganisms to get into the wood. By the time, ecophysiologically, the quality of the heartwood which is the main product expected to be harvested in the coming cutting cycle will get loss due to decay. So far, no readable information is available on deterioration rate of the heartwood by different heart-rot fungi.

This kind of damage is typically very important for the future of the residual trees following the Indonesian Cutting and Replanting System. Therefore, an intensive site ecosystem monitoring (ISEM) which is the next step of FHM Detection Monitoring that can provide more detailed data / information related to the specific causal agent, interaction among factors including the damage development rate is strongly recommended. Such condition will be met if the forest is managed in sustainable way.

From this study, two new damage types quite typical to tropical forest, e.g. the termite gallery and the strangling woody liana are proposed for the improvement of the US-FHM Field Method (1997 &1999).

The tree-level index which is extended to plot level-index and finally into area-level index obtained from different forest functions studied, gave an invaluable information so that the index need to be interpreted critically. From this experience, there is an indispensable need to keep refreshing or redefining our understanding on forest health as the criteria for sustainable forest management, criterion 3 of ITTO Policy Development Series No. 7.

From this study, it is believed that political, and/or socio-economic aspects are other prerequisite factors for sustainable forest management. This suggests that both technical and non technical aspects in forest management need to be considered appropriately.

A forest is healthy, if it is in a condition able to perform its assigned function normally (or at least to the best of its main function expected).

ACKNOWLEDGEMENT

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The authors would like to thank ITTO, Ministry of Forestry (GOI), PT. INHUTANI II and PT. Asialog Concession Holder for their support. Appreciation also goes to the Project Steering Committee members for their suggestions.

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STEM DAMAGE DUE TO LOGGING IN FOREST HEALTH MONITORING

Technical Report No. 18

Simon Taka Nuhamara
Kasno

ABSTRACT

Studies on the impact of the Indonesian Selective Cutting and Replanting System to the residual stand have been carried out in Block Number 751 at PT Asialog Concession Holder in the year of 2000. Damage location, type and severity were recorded as well as the direction and position of the cut trees. Nineteen economically important trees have been assessed. It was found that the cutting of 19 trees affected about 194 trees of economic value, as well as lesser-known species were damaged. The damage types identified were: open wound, broken bole or roots, lost or dead terminal, and broken or dead branches. These mechanical damages due to logging activities are really unavoidable, but efforts to minimize such kinds of damage are compulsory.

Key words : *Logging, forest damage, dead terminal, broken bole*

I. INTRODUCTION

The Indonesian Selective Cutting and Replanting System is always presumed to inflict potential mechanical damage to the residual stand. Such kind of mechanical damage or injury could happen during tree felling, tractor operation or skidding during the log extraction process.

The type of mechanical damage could be broken apical dominance, broken branch, open wound on the crown stem and / or trunk, open wound at the base of the trunk or buttresses, open wound on the stem, or broken roots.

Most, if not all, of these types of mechanical injuries could readily be recovered through callus formation, depending on the ability of the different tree species, the width and the depth of the wound. Yet, the wound itself has become an important infection source for decaying microorganism in different woods sooner or later, the wood decaying microorganism start to develop as the tree forms the heartwood.

The tree damage could affect the quality and quantity of logs in the long-term period. It is for such reason that forest managers are interested in how to reduce the impact of logging activities. To be able to do this, first we need to have quite reliable empirical data on how to detect and what is the nature and extent of the damage, how far is it deviating from the normal available harvesting procedures.

II. MATERIALS AND METHODS

In order to assess a logging damage to the residual stand, an observation of an on- going logging was carried out in Block Number 751, in Southern latitude 2 ° 15' 12" and Eastern longitude 103 ° 25" 30". A plot was established in natural forest stand that will be felled for the annual cutting plan of 1999/ 2000. A tree distribution map produced by PT Asialog was used for plot establishment. Three rectangular plots measuring 10.000 m^2 were established (see figures 2, 3, 4, 5 and 6).

The trees with diameter of 20 – 59 cm were marked with yellow paint while trees that will be felled (60 cm up) were marked using red paint.

The data collected before felling included expected felling direction, crown size, number of main branches, stand density in the plots, and tree diameter breast height. The collected data after felling were actual felling direction, length of clear bole, position of damage trees to the Stem of felled tree, and damage to the stem and crown (location, type, and severity).

Damage causing agent is particularly interesting to be covered in this assessment, since our ultimate goal is also to have better understanding on felling procedures subject to improvement (damage caused by felled trees, skidding and / or tractor).

The damage classification used in this assessment is adopted from the Forest Health Monitoring Field Method Guide (International – Indonesia), 1997. Damages were assessed on trees with diameter of ≥ 10 cm.

The methods in observing the effect of skidding are as follows:

1. Observe the extent of the damage (location, type, and severity) reflected on the prospective residual trees.
2. Measure the direction and the position of the felled trees in relation to the skidding road.

The damage which severely affects the wood quality are those located at the root and bole. Their classifications are as follows:

Code	Definition
0	No damage
1	Roots (exposed) and "Stem" (12 inches [30 cm] in height from ground level on uphill side)
2	Roots and lower bole
3	Lower bole (lower half of the trunk between the "Stem" and base of the live crown)
4	Lower and upper bole
5	Upper bole (upper half of the trunk between "Stem" and base of the live crown
6	Crown-stem (main stem within the live crown area, above the base of the live crown)

The classification of severity threshold of the root and stem damages are as follows:

Code	Description	Severity Threshold (in 10 % classes to 99 %)
01	Canker, gall	20 %
02	Conks, fruiting bodies, and sign of advanced decay	none
03	Open wounds	20 %
04	Resinous or gummosis	20 %
05	Cracks and stems (> 5', 1.52 m in length)	None
11	Broken bole or roots less than 3 ft (0.91 m) from bole.	none
12	Brooms on roots or bole.	None
13	Broken or dead roots (> 3 feet from bole)	20 %
20	Vines in crown	20 %

III. RESULTS AND DISCUSSIONS

Nineteen (19) economically-importance trees have been felled down in the three established plots during logging damage assessment. These trees include: Jelutung (Dyera costulata), Medang (Lauraceae), Kempas (Koompassia malacensis), Meranti (Dipterocarpaceae), Balam (Palaquium sp), Sindur (Sindora sindur), and Embacang (Mangifera sp) (Table 1).

Table 1. Data on Felled Trees, Felling Direction, and Damaging Trees due to Felling in Block Number 751, Asialog Jambi

Plot/ Strip	Tree Species Felled Name/ Number	Felling Direction		Tree Damage due to Felling			
		Planned	Actual	Type	Location	No	Number of Trees
I/ 25	Jelutung (1745)	316	330 (+14)	03 22	2,3,4,7	3 2	5
26	Medang (1849)	310	308 (-2)	03 11 22	3,3,3,3 1,1,1 7	4 4 1	9
26	Kempas (1850)	332	288 (-44)	No Damage			
22	Meranti (1557)	268	280 (+12)	03 11 21 22	3,4 3,3,5 6 7	2 3 2 2	9
34	Meranti (2410)	249	278 (+29)	03 11 22	2,3,3 1,1,1 7,7,7	3 3 3	9
35	Meranti (2500)	93	204 (+111)	11 21 22	1,3 6 7	15 1 2	18
22	Medang (1156)	88	94 (+6)	03 11	3 1	1 3	4
31	Balam (2240)	88	94 (+8)	03 11 21 22	1,4,6 1 6 7	4 5 2 5	16

Table 1. (Continuation)

Plot/ Strip	Tree Species Felled Name/ Number	Felling Direction		Tree Damage due to Felling			
		Planned	Actual	Type	Location	No	Number of Trees
31	Meranti (2239)	246	255 (+9)	03 11 22	3,4 3 7	2 1 3	6
35	Medang (2502)	262	202 (-60)	11	1	3	3
34	Jelutung (2406)	257	271 (+14)	11 22	1,3,5 7	5 1	6
32	Sindur (2268)	231	228 (-3)	03 11 21 22	2,3,4 1,3,,5 6 7	3 10 2 1	15
33	Balam (2375)	275	320 (+45)	03 11 21 22	3,4 1,5 6 7	5 4 2 3	14
28	Embacang (2000)	212	240 (+28)	03 11 21 22	2,5 1,3 6 7	1 11 3 1	15
30	Kempas (2154)	240	250 (+10)	03 11 21 22	3 1,5 6 7	2 7 1 2	12
32	Meranti (2292)	50	31 (-19)	03 11	3 1,3	1 7	8
30	Medang (2155)	253	260 (+7)	03 11 21 22	2,4 1,3 6 7	2 6 4 8	18
31	Kempas (2223)	275	320 (+45)	03 11 21 22	3,6 1,3,5 6 7	2 13 12 2	18
32	Meranti (2290)	245	283 (+38)	03 11 21 22	4 1 6 7	1 2 1 1	5

Deviation of felling direction from the planned direction revealed that in many cases it is relatively not significant. But this descriptive judgment still has to be further examined in detail. This is because the contour, presence of liana / vines, and stand density will also determine the risk of felling activities in natural forest.

Nineteen (19) trees were felled down; as a consequence, 194 trees of economical value as well as lesser-known species were damaged. The damage types identified in this assessment are:

1. Open wound, code (03) of 36 trees,
2. Broken bole or roots, code (11) of 106 (the highest)
3. Loss of apical dominance or dead terminal, code 21 of 19 trees, and
4. Broken or dead branches, code (22) of 37 trees, Table 2.

Table 2. Number of Trees Damaged in Different Plots in Block Number 751, Asialog Jambi

Damage Type	I	II	III	Total
Open wound (03)	13	14	9	36
Broken bole/ roots (11)	28	28	46	106
Loss of apical dominance/ dead terminate (21)	3	6	10	19
Broken or dead branches (22)	10	13	14	37
Total	54	61	79	194

The most common type and location of damage for the different damage types described above are presented in Table 3. All these damage types and damage location combination were very clear to the field data collector even with those newly trained during the assessment. This is again an indication that the damage indicator is quite applicable and proved to be the strength of the FHM as a tool for assessing sustainable forest management.

Table 3. Types of Wound, Location of Wound, and Number of Trees Damaged in Asialog Jambi, Block Number 751

Plot/ Strip	**I Types of wound**	**II Location of wound**	**Number of trees**	**Total Number**
I	03	2,3,4,5	13	
	11	1,3,5	28	
	21	6	3	
	22	7	10	54
II	03	1,2,3,4,5	14	
	11	1,3,5	28	
	21	6	6	
	22	7	13	61
III	03	2,3,4,5	9	
	11	1,3,5	46	
	21	6	10	
	22	7	14	79
				134

In this assessment, the emphasis is laid on gathering information on the type of the damage and the location of the damage resulting from felling activities. It is confined on the damages directly related to the falling down of the felled trees instead of skidding but felling activities is needed to be evaluated in order to have better knowledge on the impact of logging activities to the residual stand. Although the extent of damage inflected by both tree-felling and skidding activities are deemed important, this report shows only that of tree felling. It is therefore necessary to have careful and well-planned felling activities.

Although the severity indices is also computed and presented in Table 4, they are not well emphasized for this assessment.

Table 4. Severity of Damage and Number of Trees Damaged in Asialog Jambi, Block Number 751

Plot/ Strip	I Severity	Number of Trees	Total Number
I	0	10	
	2	13	
	3	2	
	4	3	
	5	3	
	7	2	27
II	0	46	
	2	24	
	3	8	
	4	2	
	5	4	
	6	7	
	8	3	87
III	0	48	
	2	15	
	3	6	
	4	2	
	5	5	
	6	1	
	7	2	
	8	5	78
			192

To give an idea as to how a tree is being felled down and how it could produce damage to the surrounding trees, Figure 1 is presented. As shown in Figure 1, the victim trees are mapped based on their azimuth and its horizontal distance relative to the felled trees. From Figure 1 it could be concluded that the main bole of quite a number of felled trees caused damage in different ways. It is noticed that the role of liana should be considered in doing such kind of assessment.

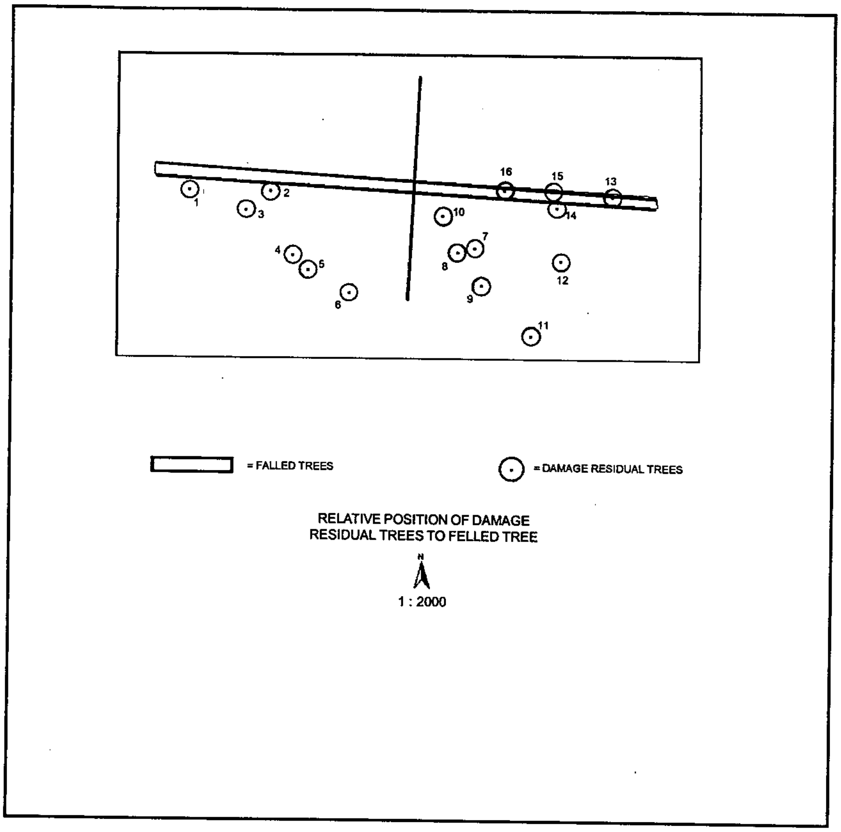

Figure 1. A tree model showing probable damages inflicted to trees in its surroundings

Table 5. Number of Damaged Trees and Damage Types due to Logging Activities in Block Number 751, Asialog Jambi

Plot	Tree Number	Damaged Species	Damage 1	Damage 2	Damage 3
II	2240	1	1;03;2	6;21;8	
	(Balam)	2	7;22;4		
		3	7;22;2		
		4	7;22;6		
		5	7;22;3		
		6	7;22;3		
		7	1;03;2	6;21;6	
		8	6;21;6		
		9	6;21;6		
		10	1;11;9		
		11	4;03;2		

Table 5. (Continuation)

Plot	Tree Number	Damaged Species	Damage 1	Damage 2	Damage 3
		12	6;03;2		
		13	1;11;9		
		14	1;11;9		
		15	1;11;9		
		16	1;11;9		

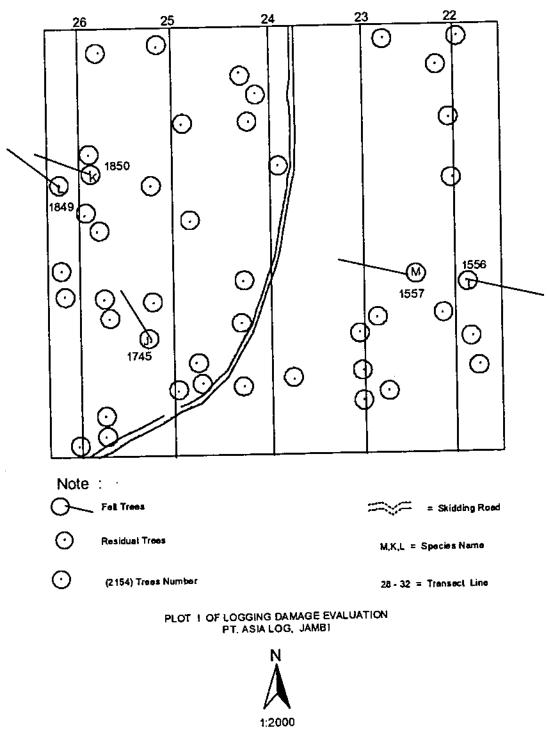

Figure 2. The Actual Felling Direction in Plot I of Block Number 751, Asialog, Jambi, 1999-2000

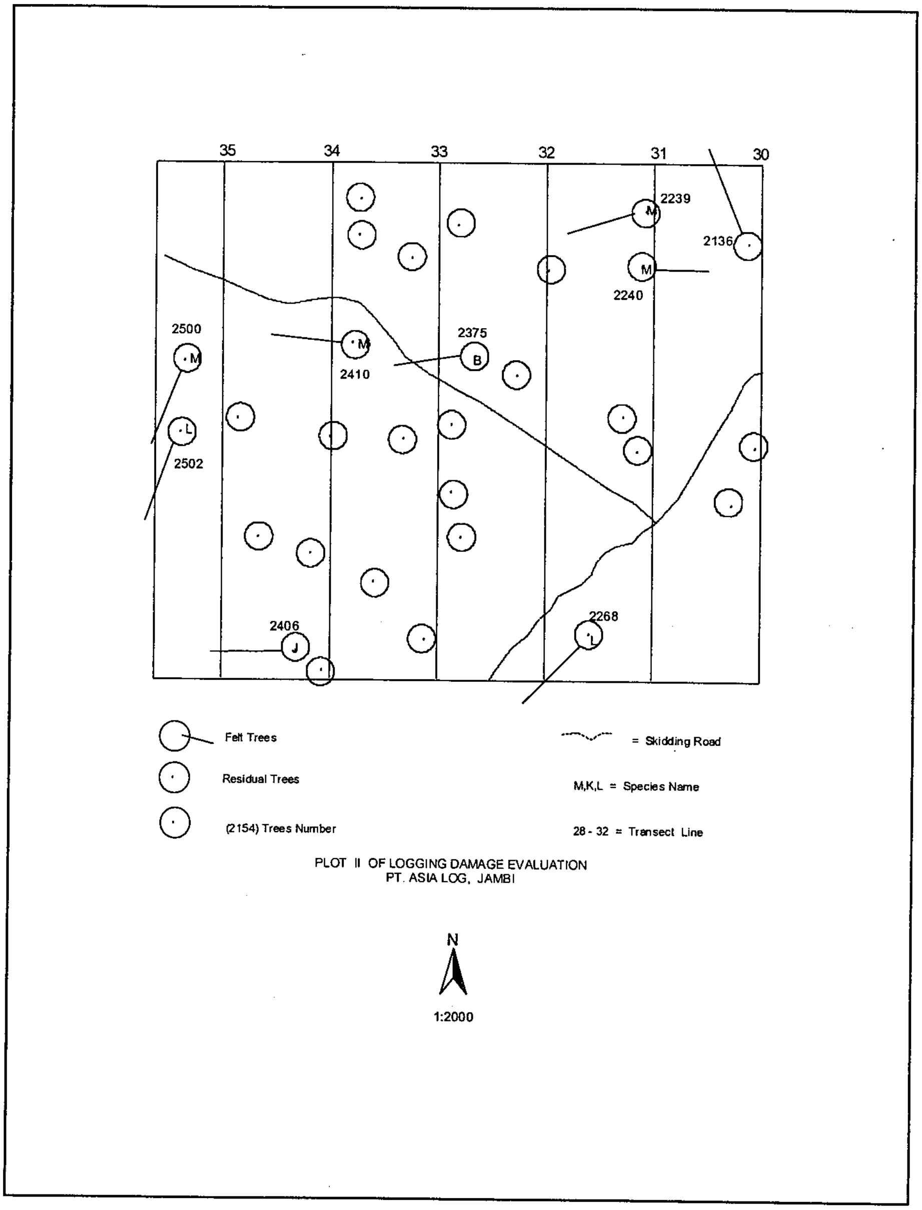

Figure 3. The Actual Felling Direction in Plot II of Block Number 751, Asialog, Jambi, 1999-2000

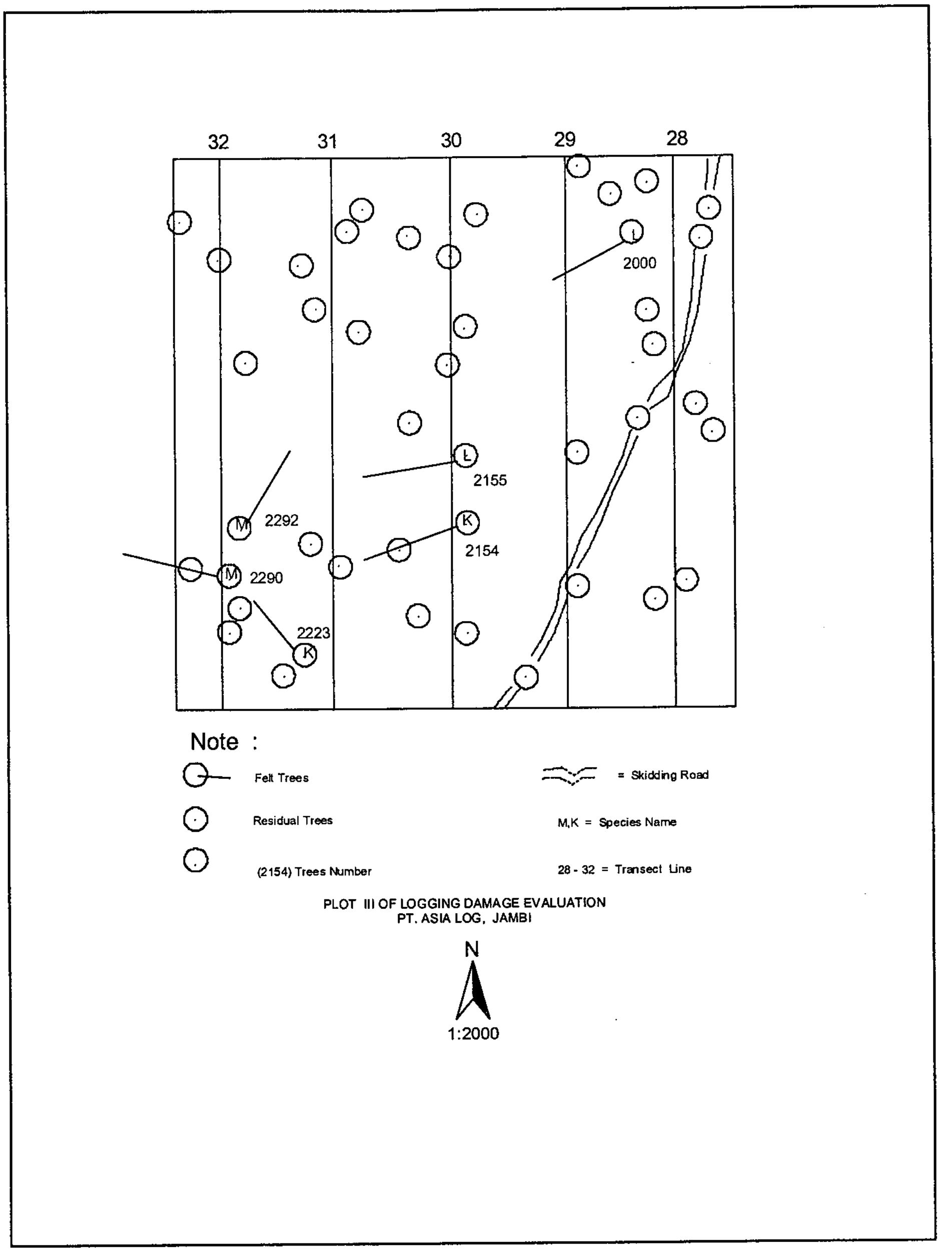

Figure 4. The Actual Felling Direction in Plot III of Block Number 751, Asialog, Jambi, 1999-2000

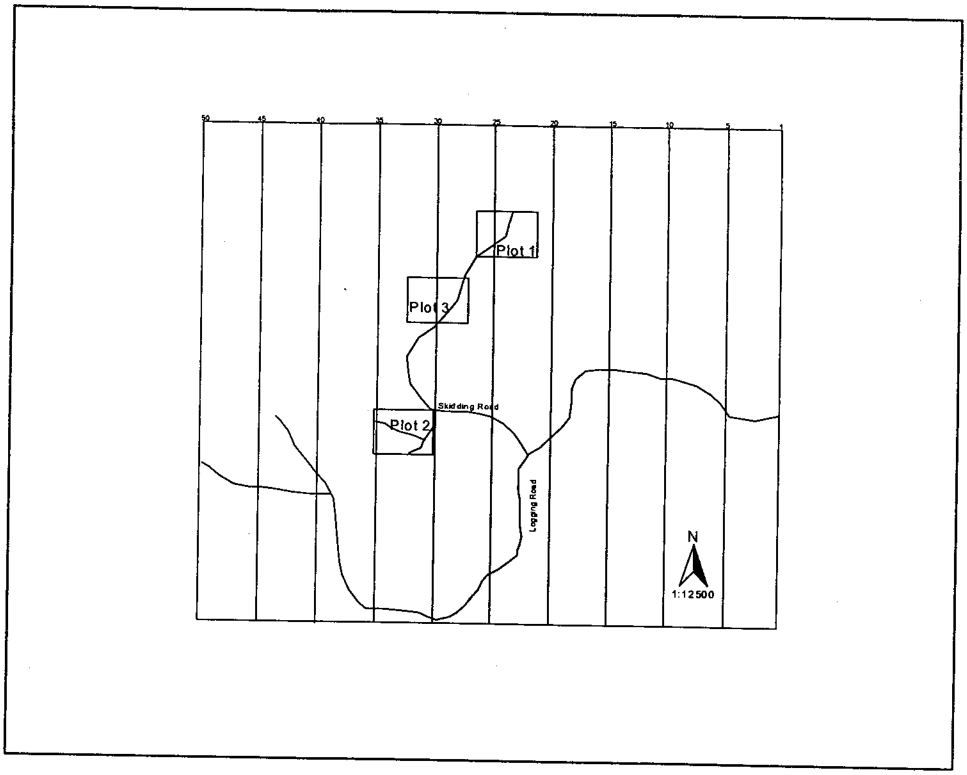

Figure 5. Block number 751 of Asialog Concession where the three plots were established, Annual Cutting Plan, 1999-2000 scale 1 : 6667

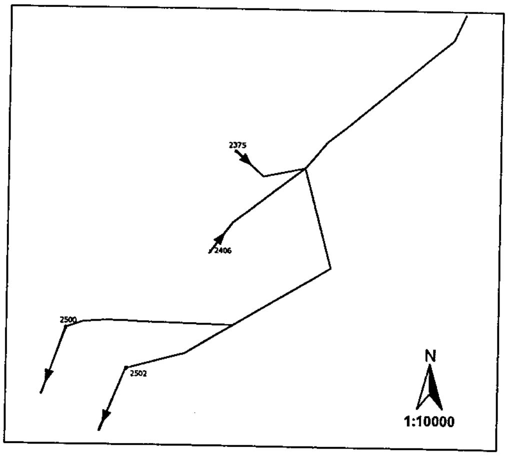

Figure 6. The position and the felling direction of the trees to the skidding road
P = witness point

IV. CONCLUSIONS

Mechanical damage caused by logging activities is something unavoidable. Efforts to minimize such kind of damage are compulsory if one has to attain sustainable forest management.

Mechanical injury plays a role as a source of infection for heart-rot decaying fungi in the long- run. It will be a big problem after 35 years, when the next cutting cycle of the Indonesian selective cutting and replanting system will be carried out.

More detailed empirical data are needed on the development rate of the decaying fungi since the tree is being injured, resulting to deteriorate quality in the long run.

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The authors would like to thank ITTO, Ministry of Forestry (GOI) and PT. Asialog Forest Concession Holder for their support. Appreciation also goes to the Project Steering Committee members for their suggestions.

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ASSESSMENT OF THE CANOPY DENSITY INDICATOR USING THE SPHERICAL DENSIOMETER IN FOREST HEALTH MONITORING

Technical Report No. 19

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Kasno

ABSTRACT

The assessment of canopy density was measured using spherical densiometer, a handy instrument. The results showed that light intensity reaching the forest floor affect very much the forest regeneration and survival rate of seedlings and saplings. The light being blocked heavily from reaching the forest floor affects the natural pruning of seedlings, saplings, and pole stages. Canopy density is complementary to crown parameter, especially crown diameter.

Key words: *Canopy density, spherical densiometer*

I. INTRODUCTION

The intensity of light reaching the forest floor affects much the regeneration of forest, and the survival rate of seedlings and saplings. The photosynthetic capacity of seedlings and saplings depends on the quantity and quality of light penetrating into the forest floor through the tree crowns.

Some lights are blocked by the tree or stand canopy in the forest, and some of them penetrate through the canopy to the forest floor. Heavy light blocking affects the natural pruning of seedlings, saplings and pole stages. This condition is often manifested in their live-crown ratio. The live-crown ratio is the ratio between the live-crown length and the total live-crown top. The live-crown length is the distance between the top live foliage and the lowest live twig (Barnard 1997, Dunn, 1999). The live-crown ratio tends to decrease when the light is blocked by the canopy. Insufficient light for photosynthetic activity could cause the seedling to die and the diameter growth to decrease, too. The number of poles or trees depends on the number of seedlings and saplings. Saplings and poles eventually become the future trees. Their mortality and growth affect the forest structure and sustainability. A relatively cheap equipment, the spherical densiometer, can be used to measure the canopy density.

From the practical point of view and for data accuracy, a relatively cheap equipment is urgently needed as an alternative to some expensive ones. The Spherical Densiometer (SD), either concave or convex type, may meet the requirements. Under a forest canopy, if SD is placed in the correct position, the projection of a unit area of the crown could be seen on the surface of the equipment. Crowns and their gaps are clearly differentiated by observing the silhouette of the crown on the spherical surface. The shadows represent the crown mass and the light represents the spaces and gaps.

The Spherical Densiometer is specifically used to measure the estimation of density of a unit area (0.1 ha) of tree crowns in relation to the ability of light to penetrate the ground through the crown spaces and gaps. By knowing the percentage of light below the crown, the percentage of the canopy could be determined. The percentage of light penetrating into the ground indicates the crown's efficiency catch the much-needed light for photosynthesis activity.

The objective of the study is to assess the canopy density indicator in Forest Health Monitoring to monitor the sustainability of Indonesian tropical rain forest.

II. MATERIALS AND METHODS

To assess the canopy density indicator, three FHM cluster-plots were established in Pulau Laut and four cluster-plots in Jambi. The plot establishment followed the Forest Health Monitoring procedures published by the USDA Forest Service (1997). The method was adapted to the Indonesian forest conditions.

To measure the canopy density, the spherical densiometer was used. The observation points to determine the canopy density is shown in Figure 1.

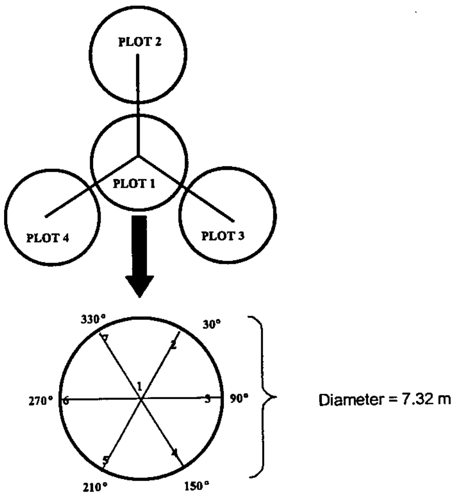

Figure 1. The observation points for canopy density

The procedures of operation are as follows :

1. Place the SD on a horizontal position about 30-40 cm away from your navel, assuming that you are the operator, to make your vision into the mirror most comfortable but with no silhouette of your head in the mirror. Such position may form about 45^0 angle if an imaginary straight line runs from your eyes to the mirror and crosses a horizontal line.
2. If the SD has been placed in the correct position, the observation is then ready to start. The sky light and dark view are visible in the mirror. Before computing the real canopy opening, it must be remembered that each rectangle has four parts represented by four spots (dots). Each dot represents one percent of canopy opening. As an example, suppose a rectangle showing sky light in one part, it means the rectangle has score 1. If the rectangle has about two parts showing sky light, it means the rectangle has score 2. If the rectangle has about three parts showing sky light, it means the rectangle has score 3. If most parts of the rectangle show sky light, it means the rectangle has score 4. Suppose the result of the observation showing total sky light from all rectangles is 40, it means that the score is 40.
3. Compute the canopy opening by multiplying the score of rectangle with the correction factor. The correction factor of SD is 1.04%. As an example, suppose the result of an observation has the score of 40 (sky light), the canopy opening (CO) is 40x1.04% = 41.6 %. When you use the SD with 25 rectangles, you don't need to multiply with the correction factor, you will have the CO = 41 or 42.
4. Compute the canopy density (CD) by subtracting 100% - CO%. As an example, CO = 41.6 %, then the CD = 100% - 41.6% = 60.4 %.
5. To have a more accurate data of measuring a unit canopy opening or canopy density, it is suggested to measure some sites with different positions (PAR points). The number of PAR points in the operational practice of the Forest Health Monitoring Program is 7 sites. The first is a site called the center of circular plot with radius of 7.32 m. The other 6 sites are on the position with the following azimuths: 30^0, 90^0, 150^0, 210^0, 270^0, and 330^0, respectively. On each site, CO or CD is recorded on four positions, e.g. north, east, south, and west. Therefore, there are four data on each site. The final data of CO or CD is the average of 28 data.
6. Referring to the example in point no. 5, the following is a more detailed example of computing the Canopy Opening and Canopy Density :

   CD = 100 % - CO (%)

   CO = Total sky-light spots x Cf.

   Cf = 1.04

The collected data consisted of canopy density, live-crown ratio of sapling, diameter growth, and number of saplings. The mortality rate was also calculated. The saplings found in the plot were counted. The criteria of the sapling's Live-Crown Ratio (LCR) are as follows:

0 - 20% LCR	= vigor 3 (poor growth)
20 -35% LCR	= vigor 2 (moderate growth)
> 35% LCR	= vigor 1 (healthy, good growth)

The tally sheet of the data recorded for canopy density is shown in Annex 1.

III. RESULTS AND DISCUSSIONS

Table 1 shows that the average canopy density in the cluster-plots in Jambi was 77.2 - 84.6 % in 1998 and changed to 92.6 – 95.0 % in 1999, while the CD in Pulau Laut was 82.0 – 92.3% in 1998 and changed to 83.92 – 92.87 %. The canopy density blocked the light penetrating into the forest floor.

Such condition affects the live-crown ratio of the sapling. The live-crown ratio in the FHM Plots at Jambi and Pulau Laut decreased, but their live-crown ratio is still more than 30 %. It means that their sapling vigor is still in vigor class 2 (moderate growth) and class 3 (good growth).

The coefficient correlation between the change of canopy density and the live-crown ratio is generally negative. It means that every increment of canopy density will decrease the live-crown ratio (Table 2). The photosynthetic capacity could decrease and the diameter growth is not so significant (Hipkins and Baker). The pattern of sapling indicator growth is not clearly influenced by the canopy density. In Pulau Laut, the number of saplings is influenced by the increment of canopy density. The sapling in Pulau Laut is dominated by *Shorea polyandra*. It means that dipterocarp saplings need higher shadings.

The data collection of canopy density using the spherical densiometer is relatively easy. The effect of canopy density is also easy to interpret. The observation points should be modified to five points. The live-crown ratio can be measured easily in the sapling stage. Technically, the use of the spherical densiometer for canopy density is very important for assessing the canopy density indicator.

Table 1. Data on canopy density, live-crown ratio, number of saplings and its diameter in 1998-1999

Loc.	Cl. No.	Plot	Canopy Density (%)		Number of Saplings (n/plot)		Live Crown Ratio (%)		DBH (1,30 cm)		ΔCD 99-98	ΔNS 99-98	ΔLCR 99-98	ΔDBH 99-98
			98	99	98	99	98	99	98	99	(%)	(n/plot)	(%)	(cm)
JAMBI	1	1	77.38	97.07	39	38	39.5	36.8	3.91	4.13	19.69	-1	-2.6	0.22
		2	70.32	89.53	43	33	46.4	34.2	3.96	4.39	19.21	-10	-12.2	0.43
		3	68.99	96.17	14	14	46.1	33.0	4.3	4.67	27.18	0	-12.99	0.37
		4	92.24	97.4	34	34	25.6	32.7	3.34	3.55	5.16	0	7.2	0.21
		Avg.	77.23	95.04	32.5	29.8	39.4	34.2	3.87	4.185	17.81	-2.75	-5.15	0.31
	2	1	89.34	96.92	11	13	30.4	40.1	4.11	4.52	7.58	2	9.55	0.41
		2	80.2	97.96	35	34	44.8	33.6	4.85	5.12	17.76	-1	-11.17	0.27
		3	89.41	90.64	7	23	21.4	38.0	6.84	5.52	1.23	16	16.61	-1.32
		4	91.05	84.99	32	37	37.5	48.3	3.64	3.91	-6.06	5	10.88	0.27
		Avg.	87.5	92.63	21.25	26.8	33.5	40.02	4.86	4.77	5.13	5.5	6.47	-0.092
	3	1	88.63	94.84	40	48	39.5	26.49	4.77	5.23	6.21	8	-13.01	0.46
		2	74.85	95.17	68	68	42.7	34.63	3.83	4.18	20.32	0	-8.09	0.35
		3	86.29	88.89	29	17	44.8	36.47	4.44	4.7	2.6	-12	-8.36	0.26
		4	90.16	93.2	35	36	36.4	26.39	3.55	4.03	3.04	1	-10.04	0.48
		Avg.	84.98	93.02	43	42.3	40.8	30.99	4.15	4.53	8.04	-0.75	-9.87	0.387
													0	0
	4	1	86	91.94	10	10	49.4	36	5.57	4.95	5.94	0	-13.44	-0.62
		2	87.22	97.29	43	41	37.2	25.61	3.79	3.99	10.07	-2	-11.63	0.2
		3	78.12	89.04	17	15	45.8	46.67	4.94	5.29	10.92	-2	0.79	0.35
		4	87.33	98.32	33	31	38.1	32.26	3.96	4.05	10.99	-2	-5.92	0.09
		Avg.	84.67	94.15	25.75	24.25	42.6	35.13	4.56	4.57	9.48	-1.5	-7.55	0.005
P. Laut	1	1	83.06	85.63	1	1	82.4	80	2.1	2.2	2.57	0	-2.48	0.1
		2	87.56	89.75	8	7	64.4	62.86	2.94	3.43	2.19	-1	-1.57	0.49
		3	79.42	84.25	6	6	49.5	46.67	7	7.15	4.83	0	-2.84	0.15
		4	86.44	87.78	2	2	43.1	42.5	2.15	2.45	1.34	0	-0.66	0.3
		Avg.	84.12	86.852	4.25	4	59.8	58.00	3.54	3.80	2.73	-0.25	-1.88	0.26
	2	1	93.2	93.43	3	7	47.2	47.14	2.8	5.92	0.23	4	-0.13	3.12
		2	92.16	90.9	1	4	46.8	47.5	5.47	6.24	-1.26	3	0.65	0.77
		3	93.09	92.05	7	8	55.6	56.25	5.01	4.85	-1.04	1	0.63	-0.16
		4	90.9	95.1	0	3	27.9	26.67	0	6.9	4.2	3	-1.23	6.9
		Avg.	92.337	92.87	2.75	5.5	44.4	44.39	3.32	5.98	0.53	2.75	-0.02	2.66
	7	1	85.03	90.2	17	16	58.6	55.31	3.34	3.76	5.17	-1	-3.36	0.42
		2	78.23	72.4	5	4	39.3	42.5	3.04	3.48	-5.83	-1	3.17	0.44
		3	84.51	85.81	17	15	47.0	46.33	4.56	4.79	1.3	-2	-0.71	0.23
		4	80.31	87.26	8	8	60.4	55.63	3.7	4.06	6.95	0	-4.81	0.36
		Avg.	82.02	83.917	11.75	10.75	51.3	49.94	3.66	4.02	1.89	-1	-1.43	0.36

Table 2. Correlation between the change of canopy density and the change of live-crown ratio, number of saplings and diameter growth rate

No.	Location	Parameters	Coefficient Correlation (1999-1998)	Probability (1999-1998)
1.	Jambi Cluster 1	Number of saplings DBH growth rate Live crown ratio	-0.12 0.60 -0.90	0.88 0.40 0.10
2.	Cluster 2	Number of saplings DBH growth rate Live crown ratio	-0.56 0.26 -0.83	0.44 0.74 0.17

Table 2. (Continuation)

No.	Location	Parameters	Coefficient Correlation (1999-1998)	Probability (1999-1998)
3.	Cluster 3	Number of saplings DBH growth rate Live crown ratio	0.14 0.12 0.36	0.86 0.88 0.64
4.	Cluster 4	Number of saplings DBH growth rate Live crown ratio	-0.98 0.95 0.71	0.02 0.05 0.29
5.	Pulau Laut Cluster 1	Number of saplings DBH growth rate Live crown ratio	0.24 -0.49 -0.87	0.76 0.51 0.13
6.	Cluster 2	Number of saplings DBH growth rate Live crown ratio	0.41 0.97 -0.99	0.56 0.03 0.01
7.	Cluster 7	Number of saplings DBH growth rate Live crown ratio	0.41 -0.21 -1.00	0.59 0.79 0.00

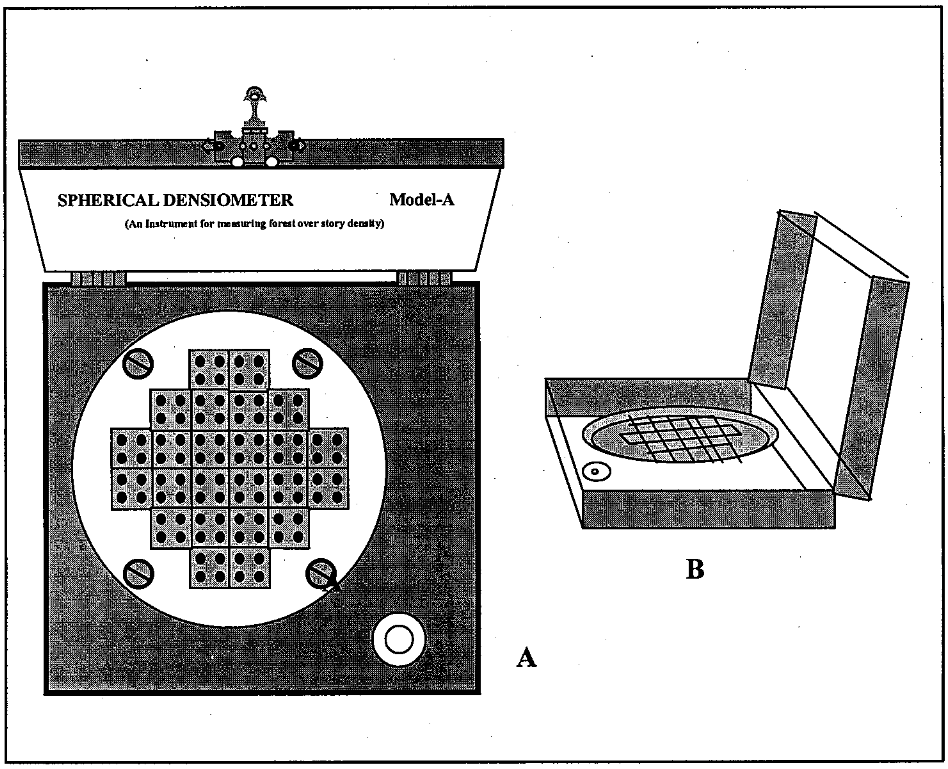

Figure 1. The Shape of Spherical Densiometer: Upper-View (A), Side View (B)

IV. CONCLUSIONS

Canopy density is one of the FHM indicator to monitor the sustainability of Indonesian tropical rain forest. It can be used to assess vigor (live crown ratio) as a criteria for forest health, specially for saplings. One economical but reliable way of measuring the canopy density is the use of spherical densiometer. The spherical densiometer is a handy instrument and its use is described in prescribed procedures.

ACKNOWLEDGEMENT

This Technical Report No. 19 on the **Assessment of Canopy Density Indicator Using Spherical Densiometer in Forest Health Monitoring** has been prepared to fulfill Objective 1 point 2.2 of the Work-plan of ITTO Project PD 16/95 Rev. 2 (F): Forest Health Monitoring to Monitor the Sustainability of Indonesian Tropical Rain Forest.

The authors would like to thank ITTO, Ministry of Forestry (GOI), PT. INHUTANI II and PT. Asialog Forest Concession Holder for their support. Appreciation also goes to the Project Steering Committee members for their suggestions.

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Annex 1.

INDO-FHM TALLY SHEET
Spherical Densiometer Tally Sheet

Cluster/ Plot	PAR Points	Number of Sky-Light Spots				
		North	East	South	West	Average
/1	Center					
	30 ^{0}					
	90 ^{0}					
	150 ^{0}					
	210 ^{0}					
	270 ^{0}					
	330 ^{0}					
/2	Center					
	30 ^{0}					
	90 ^{0}					
	150 ^{0}					
	210 ^{0}					
	270 ^{0}					
	330 ^{0}					
/3	Center					
	30 ^{0}					
	90 ^{0}					
	150 ^{0}					
	210 ^{0}					
	270 ^{0}					
	330 ^{0}					
/4	Center					
	30 ^{0}					
	90 ^{0}					
	150 ^{0}					
	210 ^{0}					
	270 ^{0}					
	330 ^{0}					

CROWN DAMAGE DUE TO LOGGING IN FOREST HEALTH MONITORING

Technical Report No. 20

Kasno
Supriyanto

ABSTRACT

An investigation on crown damage due to logging was carried out in PT. Asialog, Jambi Province, in 1999. The objectives of the investigation were to identify types of crown damage and to assess the severity of crown damage of the residual stand due to tree felling activities. Three rectangular plots of 10.000 m^2 were established in the logging area (block No. 751) of limited natural production forest. Data on identified trees that would be felled, tree diameter at breast height (dbh), crown size, number of primer branches, expected direction of felling of each tree to be felled, and tree density (dbh 10 cm up) were recorded prior to the felling execution. After felling, data collection was made on the actual felling direction, number of trees killed and injured, and types and severity of crown damage due to felling activity. Crown damage classification developed by the USDA Forest Service was followed. The results showed that aside from killing some residual stands, felling activities may cause crown damages. Two types of crown damage were found: loss of apical dominance and broken branches. The deviation of felling direction from expected direction was varied from 0 – 111 with the average of 23; number of trees killed was varied from 2.6 – 9.9% with the average of 6.9%; number of injured trees varied from 4.4 to 15% with the average of 9.4%. The crown damage severity varied from 2-5 of the 0-9 severity classes. There was an indication that higher dbh and bigger crown size has caused more residual stand damage due to felling activities. The broken crown damage type is probably easy to recover, but the loss of apical dominance is believed to cause a lower quality of timber in the long run.

Key words: *Crown damage types, severity, felling activity*

I. INTRODUCTION

The Indonesian selective cutting and planting system always has in itself a potential mechanical damage to the residual trees in stand. Such kind of mechanical damage or injury could happen to trees being felled, or tractor's wheels used during log extraction or simply through the logs skidding itself.

The types of mechanical damage include broken apical dominance, broken branch, open wound on the crown stem and / or trunk, open wound at the base of trunk or buttresses, open wound on the stump and broken roots.

Most, if not all, of these types of mechanical injuries could be healed by the trees through callus formation, depending on the ability of the different tree species, the width and the depth of the wound. Yet, the wound itself has become an important infection source of decaying microorganisms in different woods. Sooner or later, the wood decaying microorganisms start to develop as the heartwood is formed by the trees.

It is for these reasons that forest managers are interested to know how to reduce the impact of logging activities. To be able to do this, first we need reliable empirical data regarding the nature of damage, how it was acquired and how seriously inflicted, deviating from the normal available harvesting procedures. This study is specifically directed towards answering such basic but important assessment questions.

The objective of the study is to assess the crown indicator in Indonesian Selective Cutting System.

II. MATERIALS AND METHODS

To assess a logging damage in the crown of the residual stand, observation on an on going logging was carried out in Block Number 751, Southern latitude 2°15'12", and Eastern longitude 103°26'30". The plot was established in a natural forest stand that will be felled according to the annual cutting plan of 1999/ 2000. The tree distribution map produced by PT Asialog was used for plot establishment. Three rectangular plots of 10,000 m^2 were established (Annexes 1, 2, 3, and 4).

Trees with the diameter of 20 – 59 cm were marked with yellow paint while trees that will be felled (60 cm up) were marked using red paint. The data collected before felling included: expected felling direction, crown size, number of main branches, stand density in the plots, and tree diameter at breast height. The data collected after felling were actual felling direction, length of clear bole, position of damage trees to the stump of felled tree, and damage to the crown (location, type, and severity), Annex 5.

The crown damage classification used in this assessment was adopted from the Forest Health Monitoring Field Method Guide (Barnard, 1997). Those damages were assessed on the trees with diameter of ≥ 10 cm. Location of crown damage is recorded in location 7 (branches > 1" at the point of attachment to the main crown stem within the live crown area). The damage type of crown is recorded as *code 21* (loss of apical dominance, determinal) and *code 22* (broken or dead).

Table 1. Severity classes of *code 21* (loss of apical dominance)

Code	Severity Classes
0	01 – 9
1	10 – 19
2	20 – 29
3	30 – 39
4	40 – 49
5	50 – 59
6	60 – 69
7	70 – 79
8	80 – 89
9	90 – 99

Table 2. Severity classes of *code 22* (percent of branches affected)

Code	Severity Classes
2	20 – 29
3	30 – 39
4	40 – 49
5	50 – 59
6	60 – 69
7	70 – 79
8	80 – 89
9	90 – 99

III. RESULTS AND DISCUSSIONS

The tree inventory shows that the area is mostly dominated by trees with the diameter 10 – 20 cm (Table 3). The TPTI (Indonesian Selective Cutting and Replanting) system regulates the minimum diameter cutting of the area which is 60 cm up. It means that the average number of allowable trees to be cut is 6 trees per hectare, because the forest is classified as limited production area.

Table 3. Number of trees per hectare in experiment plots

Plot number	Tree diameter (cm)			Total trees > 10 cm
	10 – 20 cm	20 - 59 cm	60 cm up	
I. (n/ Ha)	340	40	5	385
II. (n/ Ha)	320	24	9	353
III. (n/ Ha)	420	36	6	462
Total	**1080**	**100**	**20**	**1200**
Average (n/ Ha)	**360**	**33.3**	**6.2**	**400**

Table 4. The damaged trees of the residual stands

Plot	Total trees	Damaged trees/ Ha		Total damaged trees
		Dead trees	Live and damaged trees	
I	385	10 (2.6 %)	17 (4.4 %)	27 (7 %)
II	353	35 (9.9 %)	53 (15.0 %)	88 (24.9 %)
III	462	35 (7.6 %)	43 (9.3 %)	78 (16.9 %)
Total	**1200**	**80**	**113**	**193**
Average	**400**	**26.7**	**37.7**	**64.3 (16.3 %)**

Table 5. Effect of tree felling on crown damage of residual stands (20 – 59 cm)

Plot No.	Damaged Trees	Damage Location 7	Type of damage		Damage severity
			21	22	
I. (trees)	27	5	2	5	3
II (trees)	88	20	7	20	2 and 3
III (trees)	78	17	10	17	2 and 5
Average (trees)	**64.3**	**14**	**6.3**	**14**	
%/ha	**16.7**	**3.6**	**1.6**	**3.6**	

Table 5 shows the forest tree felling operation caused two types of damage namely terminal death of the stem within live crown / loss of apical dominance (type 21) and broken branch (type 22). If the concerned tree survives till the cutting stage, terminal death may bring about a worse adverse effect than broken branch in the long run. However, since most of the crown damage severity is low (level 2 of the 1 – 9 levels). Such level of damage severity probably will not cause a significant economic loss in the future. It is realized in such natural forest where tree position is randomly distributed, crown damage due to logging is technically unavoidable.

It was suspected that larger tree, if it is felt, will always cause higher damage severity on crown of the residual stand. It was proven, in this study, only damage severity of broken branch showing a significant correlation to the size of stem and crown of tree that will be felt (Table 6). The damage severity of terminal death is not significantly correlated to the size of stem and crown of tree that will be felt. Such fact is logically acceptable because branch grows horizontally while stem grows vertically. Such growing direction may cause branch has higher chance to suffer damage due to tree felling than terminal death. The longer branch has higher chance to suffer damage from tree felling operation. However, broken branches probably will easier to recover than loss of apical dominance.

Table 6. The correlation between damage type and crown diameter wide (CdWd) and tree diameter (Dbh) due to logging

No.	Damage Type	Parameters	Coeficient Correlation
1.	Type 21	Dbh CdWd	- 0.269 - 0.121
2.	Type 22	Dbh CdWd	0.418 0.446

IV. CONCLUSIONS

1. Logging, specifically mechanical logging, may cause minor damage on the crown of trees in some residual stands
2. The type of damage on crown due to logging could be in terms of :
   a. broken branches (code 22)
   b. broken stems in the living crown (code 21).
3. Broken branches are probably easy to recover but broken stems may reduce significantly the quality of timber in the long term.

ACKNOWLEDGEMENT

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The authors would like to thank ITTO, Ministry of Forestry (GOI), PT. INHUTANI II and PT. Asialog Forest Concession Holder for their support. Appreciation also goes to the Project Steering Committee members for their suggestions.

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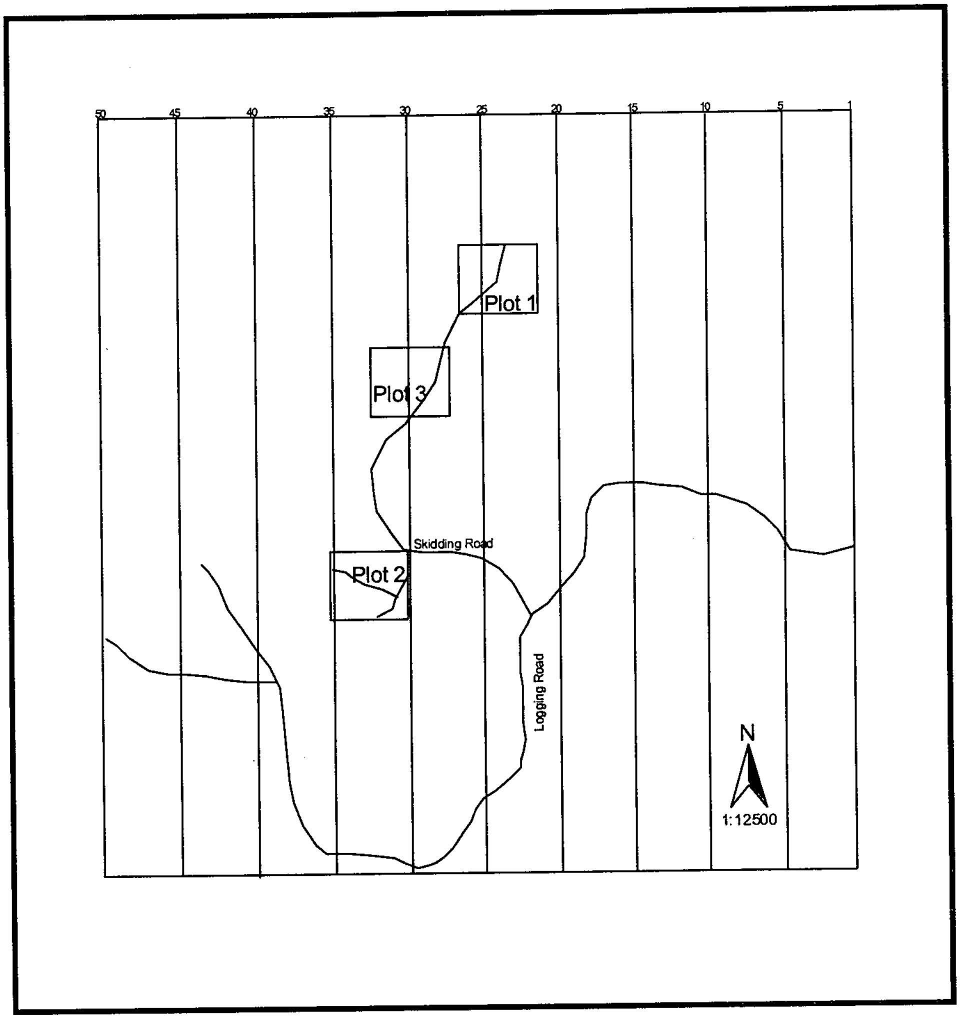
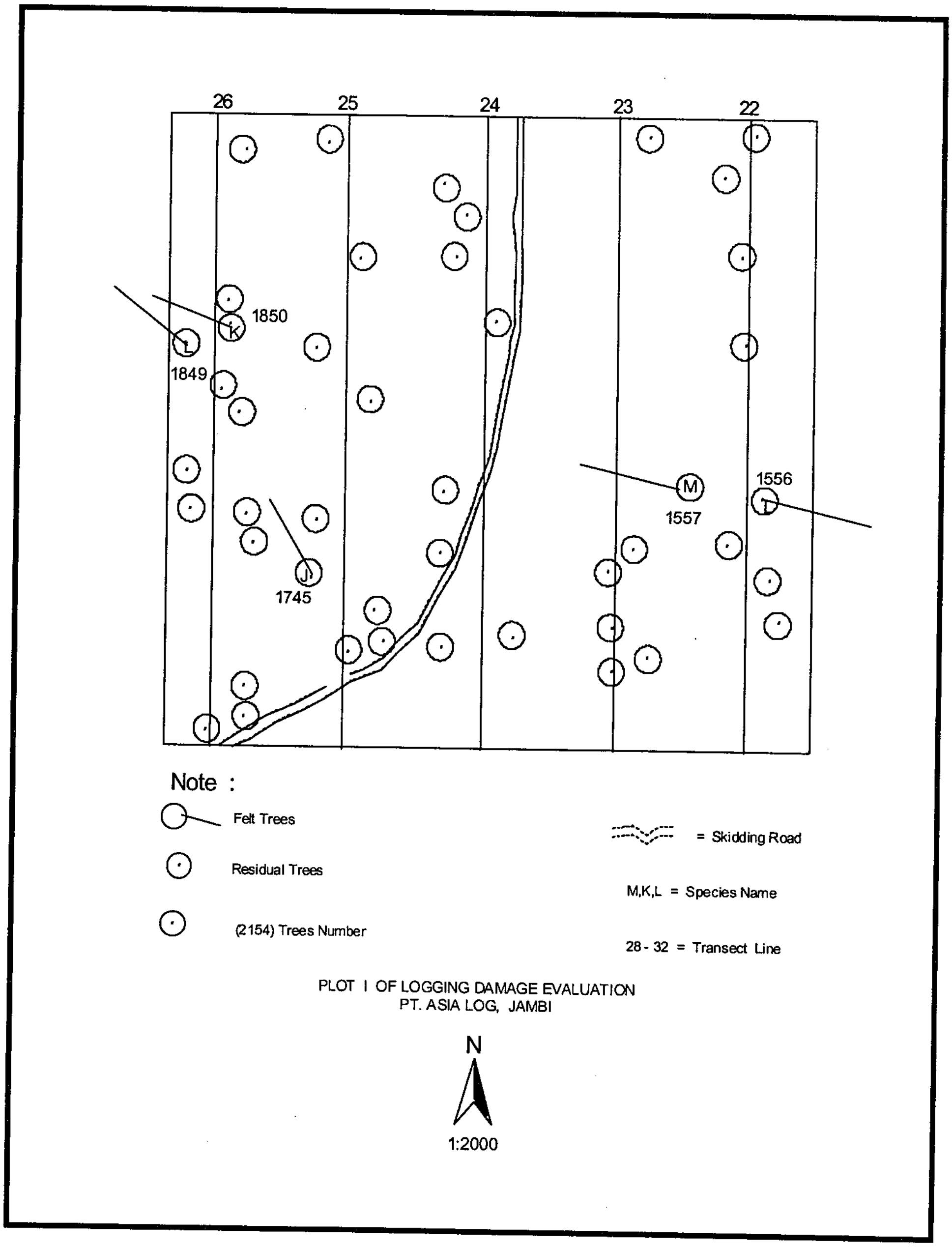
Annex 2. Actual felling direction in Plot I of Block Number 751, Asialog, Jambi, 1999-2000

Annex 3. Actual felling direction in Plot II of Block Number 751, Asialog, Jambi, 1999-2000

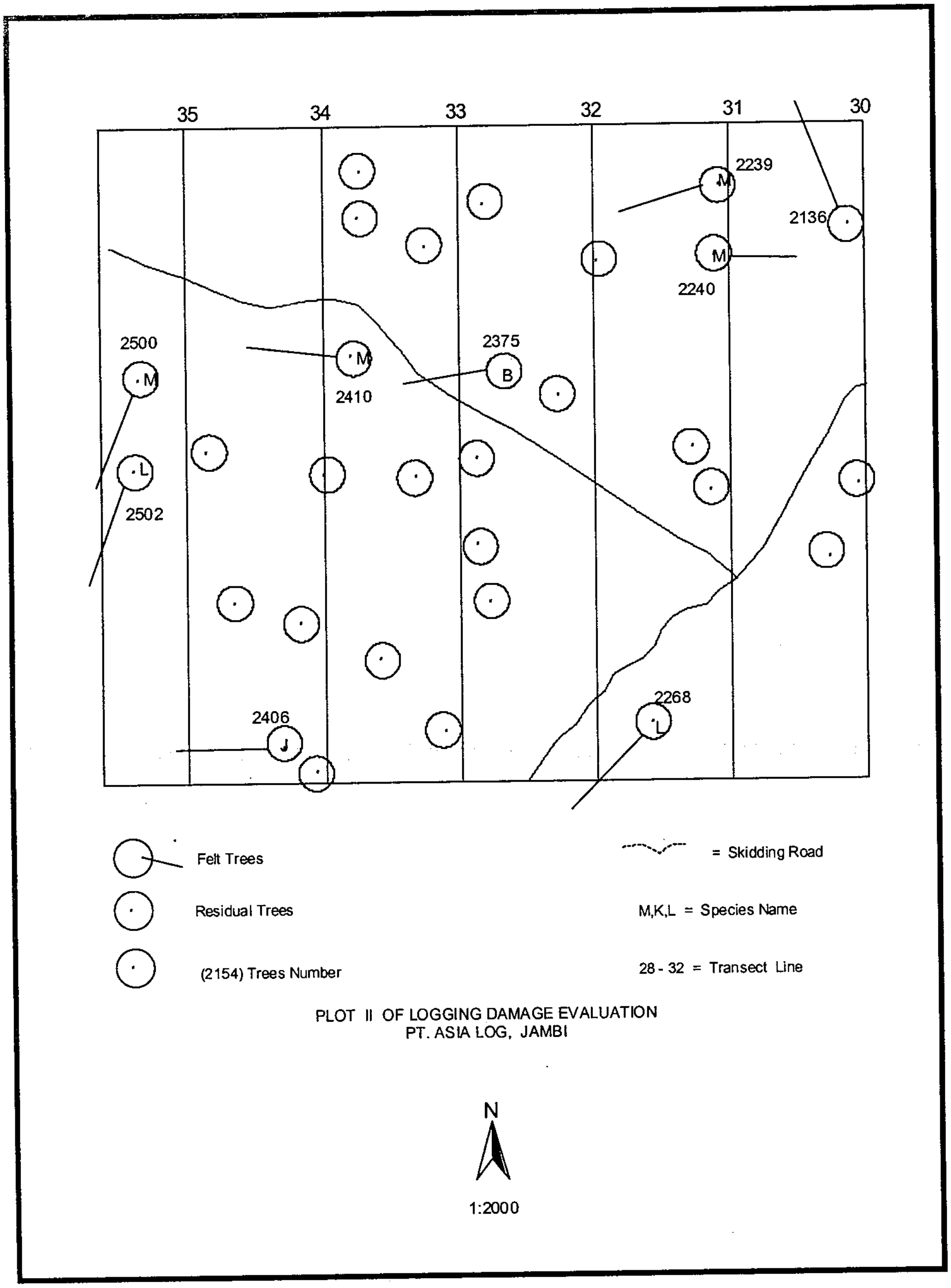
Annex 1. Block number 751 of Asialog Concession where the three plots were established, Annual Cutting Plan, 1999-2000



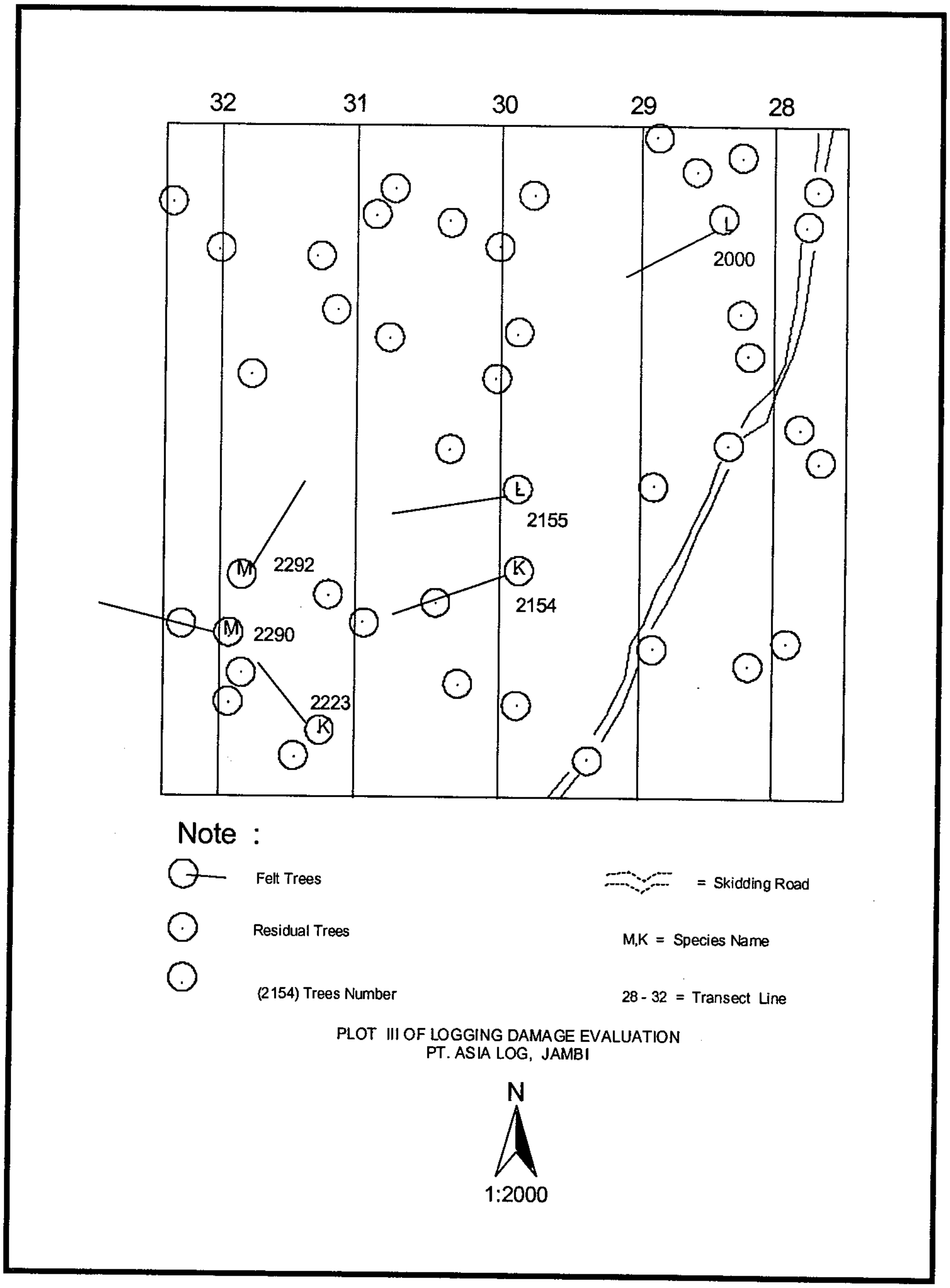
Annex 2. Actual Felling Direction in Plot I of Block Number 751, Asialog, Jambi, 1999-2000



Annex 3. Actual Felling Direction in Plot II of Block Number 751, Asialog, Jambi, 1999-2000



Annex 4. Actual felling direction in Plot III of Block Number 751, Asialog, Jambi, 1999-2000



TREND OF SOIL CHEMICAL PROPERTY CHANGES ON FOREST HEALTH MONITORING ACTIVITIES CONDUCTED IN SOUTH KALIMANTAN, JAMBI, AND EAST JAVA

Technical Report No. 21

Chairil Anwar Siregar
Supriyanto

ABSTRACT

Bearing physical, chemical and biological characteristics, the forest soils are typically stable and resilient bodies that are temporarily altered by natural driving forces like fire and flood. However, the effects of perturbations associated with intensive forest management on the soil physical, chemical, and biological properties and long term sustainability are relatively recent problems that have become a global issue. This study is aimed at examining the possible changes in soil chemical properties on selected study areas namely P.T. Sumpol, and P.T. INHUTANI II in South Kalimantan, P.T. Asialog in Jambi, and Perum Perhutani Unit II in Kediri, to monitor the forest health condition within a 4-year period. The decrease in soil organic matter should be viewed vis-à-vis the increase in tree growth indicated by an increase in basal area with time. Changes in soil reaction with time should be examined very carefully because the process may be induced by soil erosion, basic cations leached or absorbed by tree, and the presence of decomposed organic matters. Significant and high correlation between soil organic carbon and other soil chemical properties indicated that all soil chemical properties examined to judge forest health are of the same importance. Examining the soil pH and soil organic matter changes with time in FHM activity should be related to the changes in basal area representing the tree growth in order to reach better understanding on the status of forest health.

Key words: *Soil fertility, forest health monitoring*

I. INTRODUCTION

Soil is a natural entity of unconsolidated organic and inorganic constituents in dynamic equilibrium with its environment. Soil quality reflects the capacity of a soil to produce plant as determined by soil growth factors including water holding capacity, soil pH, soil fertility, soil depth and soil texture. National Research Council (1993) emphasized that protecting soil quality, like protecting air and water quality, should be the fundamental goal of national environmental policies. Soil plays three important roles in terrestrial ecosystems namely: productivity and biodiversity medium, hydrologic function, and environmental buffer.

As plant grows, available water and nutrients are absorbed from soils so that plant growth development process takes place in a living plant system. Within a given climatic zone, soils significantly determine the nature, productivity and spatial distribution of plant communities. By regulating the water movement on a landscape, soils have a pronounced influence on regional and local hydrology. Soils are extremely reactive chemically and biologically. As a result, they perform functions to degrade, decompose, or immobilize a large array of substances. These include phosphorus, nitrates, pesticides, solid wastes, and heavy metals.

It has been well understood that soils in natural forest ecosystems encounter few problems to the forest manager. Bearing physical, chemical and biological characteristics, the forest soils are typically stable and resilient bodies that are temporarily altered by natural driving force like fire and flood. However, the effects of perturbations associated with intensive forest management on the soil's physical, chemical, and biological properties and long term sustainability are relatively recent problems that have become a global issue. Many of the problems remain peculiar to the forest stakeholders and require special effort to clarify the adverse phenomenon.

Oldeman *et al.* (1990) stated that the main potential threats to soil stability in forest ecosystems are erosion by water, loss of nutrients, acidification, and compaction. With regard to the application of modern forest management techniques to fulfill the world demand for wood, the soil measurements used in Forest Health Monitoring (FHM) are designed to assess soil status in relation with these possible causes of instability and degradation. Accordingly, the FHM soil measurements have been developed to address important issues related to sustainable forest management. Some important factors are considered when developing the soil indicator including (Santiago Declaration, 1995):

1. The soil resource is a basic component of all terrestrial ecosystems. The loss of soil will influence the vitality and species composition of forest ecosystems.
2. Soil organic matter is important for water retention, carbon storage, and soil organisms development and is an indication of soil nutrient status. Changes in soil organic matter can affect the vitality of forest ecosystems through diminished regeneration capacity of trees, lower growth rates, and changes in species composition.
3. Nitrogen, phosphorus, potassium, calcium and magnesium are essential nutrients for forests.
4. Nutrient and water availability to forest vegetation is dependent on the physical ability of roots to grow and access nutrients, water and oxygen from the soil. This in turn is dependent on soil texture and structure and can be altered by soil compaction.
5. Air and water pollutants are suspected to have a significant cumulative impact on forest ecosystems by affecting regeneration, productivity, and species composition.

6. The accumulation of biomass as living vegetation, debris, peat and soil carbon is an important forest function in regulating atmospheric carbon and can be a factor in controlling the amount of carbon entering the world's atmosphere.

Based on the critical information mentioned above, several important monitoring questions have been selected for the FHM soils indicator, and the core question is directed to capture information on the current status and projected trend in the area and percent of land with forest cover (USDA Forest Service, 1999):

1. Having significant soil erosion;
2. Having significantly diminished soil organic matter and or changes in other soil chemical properties;
3. Having significant compaction or change in soil physical properties resulting from human activities;
4. Experiencing an accumulation of persistent toxic substances;
5. Contributing to the global carbon budget, including absorption and release of carbon; and
6. Having significant changes in the amount of moisture holding capacity, internal drainage and rooting depth of forested soil.

This study is aimed at examining the possible changes in soil chemical properties on selected study areas namely P.T. Sumpol, and P.T. INHUTANI II in South Kalimantan, and P.T. Asialog in Jambi and Perum Perhutani Unit II in Kediri in order to monitor forest health condition within a four year period.

II. MATERIALS AND METHODS

2.1. Location

The forest health monitoring associated with soil indicator was carried out in four study sites namely: P.T. INHUTANI II in South Kalimantan, and P.T. Asialog in Jambi, lasting from 1996 to 1999, and P.T. Sumpol in South Kalimantan and Perum Perhutani Unit II in Kediri, lasting in 1999. General information of each FHM study site is provided below.

2.1.1. P.T. INHUTANI II

P.T. INHUTANI II is located in Pulau Laut, a small island that belongs to South Kalimantan Province. The FHM plots were established according to Buffer Zone, which was logged in 1978 (clusters 1 and 7), Biodiversity Conservation Area (cluster 2), Dipterocarp Plantation (cluster 3) and Seed Production Areas (clusters 4, 5, and 6). The soil classification falls into Oxisols and Ultisols, topographical condition ranging from flat to hilly and dissected with slope greater than 50 %. Some important physical and chemical characteristics of the soil are moderately fine (topsoil) and fine (subsoil), shallow to very shallow, high exchangeable Ca and Mg, medium to high exchangeable K, low exchangeable Na, low to medium CEC, acid to slightly acid, and low Al saturation.

Based on the criteria of Schmidt and Ferguson, the climate in the project site is categorized into Type A with annual rainfall ranging from 2,429 to 2,492 mm. The rainy season occurs in December to June with monthly rainfall average of more than 250 mm. Meanwhile, the dry season occurs in July to November with monthly average rainfall of 150 mm.

2.1.2. P.T. Asialog

P.T. Asialog is located in Jambi and the FHM plots were established in Limited Production Forest (clusters 1, 2, 3 and 4). The soil classification falls into Oxisols and Ultisols, topographical condition is variable from flat to wavy with slope of 5-10 %. Some important physical and chemical characteristics of the soil are moderately coarse (topsoil) and moderately fine (subsoil), thick to very thick, very low to low exchangeable Ca, low to medium exchangeable Mg, low exchangeable K, low to medium exchangeable Na, low to medium CEC, very strong acid to strong acid in soil reaction, and low Al saturation.

Based on the criteria of Schmidt and Ferguson, the climate in the project site is categorized into Type A with average annual rainfall of 2,248 mm, and the average daily temperature is 26.5 °C with relative humidity of 84 %.

2.1.3. P.T. Sumpol

P.T. Sumpol is located in South Kalimantan, and the FHM plots were established in Limited Production Forest (clusters 8 and 9). The soil classification falls into Oxisols, topographical condition ranging from flat to hilly and dissected with slope greater than 50 %. Some important physical and chemical characteristics of the soil are moderately coarse (topsoil) and moderately fine (subsoil), thick to very thick, very low to medium exchangeable Ca, high exchangeable Mg, low exchangeable K, low exchangeable Na, low CEC, very strong acid to strong acid in soil reaction, and low Al saturation.

Based on the criteria of Schmidt and Ferguson, the climate in the project site is categorized into Type B with average annual rainfall of 2,485 mm. The average monthly rainfall during rainy season is 288 mm, meanwhile the average monthly rainfall during dry season is 177 mm. The wettest month occurs in January with 354 mm rainfall. Average daily temperature is 29 °C with relative humidity ranging from 72-95 %.

2.1.4. Perum Perhutani

Perum Perhutani Unit II is located in Kediri, and the FHM plots were established in P. falcataria plantation forest (clusters 1, 2, 3, 4, and 5). The soil classification falls into Ultisols, topographical condition is variable from flat to wavy with slope 5-10 %. Some important physical and chemical characteristics of the soil are moderately coarse (topsoil) and moderately fine (subsoil), thick to very thick, low exchangeable Ca, low exchangeable Mg, low to medium exchangeable K, low exchangeable Na, very low to low CEC, strong acid in soil reaction, and low Al saturation.

The study site is located at 200 m above sea level, and received average annual rainfall of 1500 mm with air temperature ranging from 22 ° – 32 ° C and relative humidity ranging from 50-70 %.

2.2. Location of sampling points

Plot establishment procedure, described by USDA Forest Service (1999), was applied on each cluster under investgation. Soil sampling sites are located on soil sampling lines adjacent to subplots 2,3, and 4 on the FHM plot (Figure 1). The location of a soil sampling site on the soil sampling line is determined by the number of times a plot has previously been sampled. The forest floor layers (litter layer and organic soil layer – if present) are sampled at only one soil sampling site on each plot. The primary location is the soil sampling site associated with subplot 2. If no litter layer is found at the sampling site on subplot 2, proceed to subplot 3. Proceed to subplot 4 if necessary.

Mineral soil samples are taken from three soil sampling sites and composite by depth layers into individual soil samples for analysis. Locate the three soil sampling sites using the following procedure:

- From the center of Subplot 2 of the FHM plot, measure 30 ft (9.2 m) on an azimuth of 180 degrees or due south. Mark the soil sampling site with flagging. This is soil sampling site for visit # 1 to the subplot 2 soil sampling line.
- From the center of Subplot 3 of the FHM plot, measure 30 ft (9.2 m) on an azimuth of 300 degrees (northwest). Mark the soil sampling site with flagging. This is soil sampling site for visit # 1 to the subplot 3 soil sampling line. Mineral soil samples are taken from three soil sampling sites and composite by depth layers into individual soil samples for analysis.
- From the center of Subplot 4 of the FHM plot, measure 30 ft (9.2 m) on an azimuth of 60 degrees(northeast). Mark the soil sampling site with flagging. This is soil sampling site for visit # 1 to the subplot 4 soil sampling line.

During the first visit to a plot for soil sampling, soil sampling site with visit #1 will be used for soil depth measurements and to collect soil samples. On subsequent visits to a plot, soil sampling sites labelled as number 2 or larger will be used (depending on the number of times a plot has previously been sampled).

Proceed to the location of the appropriate sampling site along a soil sampling line. If it appears that a soil sample can be taken, place a small plastic tarp on the ground beside the sampling point.

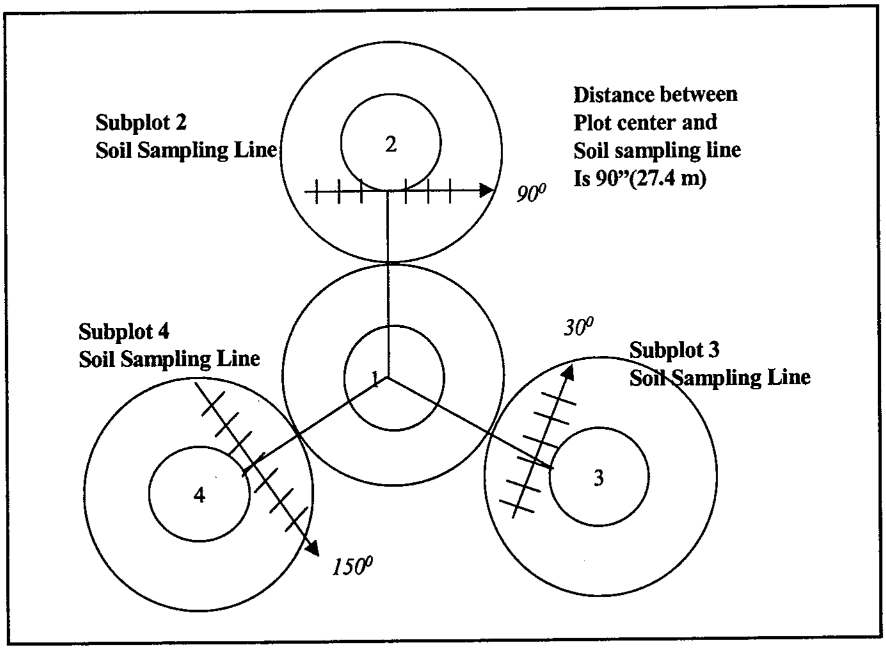


Figure 1. Location of soil sampling lines

2.3. Measuring and Sampling Procedures

2.3.1. Organic Layers

Proceed to sampling point 1. Place a plastic tarp on the ground beside the sampling point. Sample the organic surface material as follows: Place a sampling frame of a known area (e.g., 0.3 m^2) over the sampling point. Using a sharp knife, carefully cut through the organic soil surface along the inner surface on the frame to separate it from the surrounding soil. Carefully remove any live forbs, grasses or shrubs and all living above-ground vegetation from the sample area. Using inward scooping motions, carefully remove the entire volume of O horizon material from within the confines of the sampling frame. Working over the tarp, place the entire O horizon sample into a pre-labeled 8-L sample bag. In some areas, more than one bag might be required to hold the sample. If so, label the bags with identical information, then add "1 of 2" and "2 of 2" respectively. Make sure the bag is properly labeled and then seal it securely. The O horizon is sampled only at sampling point 1.

Measure the thickness of the O horizon to the nearest cm at four points on the outer perimeter of the sampled area. Locate these points due north, due east, due south and due west. Determine the mean of the four measurements and record it.

2.3.2. Mineral Surface Layers

After exposing the top of the mineral surface layer (A horizon) by removing the O horizon, use a tile spade or entrenching tool to excavate a soil pit approximately 30 cm on a side and deep enough to expose the boundary between the soil surface and the subsoil. Do not excavate deeper than 50 cm. Record the thickness of the A horizon (lighter texture; colored brownish from organic material leached in from O horizon) and the depth to the subsoil (usually the "B" horizon; generally heavier textured and brighter yellow or red color) to the nearest cm. Measure the A horizon thickness and the depth to the subsoil at the four points on the outer perimeter of the sampled area. Locate these points due north, due east, due south, and due west. Determine the mean of each set of four measurements and record them. If the subsoil is not encountered within a depth of 50 cm, record depth to the subsoil as "more than 50 cm."

Smooth and clean one face of the pit for sampling. Measure from the surface of the mineral soil to the bottom of the A horizon and mark the boundary with a knife. Then measure 10 cm below the bottom of the A horizon (often the "E" horizon; similar texture to A but without organic material leached in) and mark this boundary. Remove approximately 150 cc (about two handfuls) of soil from the A horizon and place it in a pre-labeled 2-L sample bag. Then remove approximately 150 cc of soil from the underlying 10 cm layer and place it in a second 2-L sample bag. Estimate the texture of the second layer and record it as loamy, clayey or sandy. If possible, discard rock fragments larger than approximately 20 mm (3/4 in) in diameter (coarse pebbles or larger) from all soil samples. Discard root fragments, too.

After sampling and measurements are completed, place the soil back in the pit in its original layer sequence. Try to restore the sample point as similar to its original condition as possible. Proceed to sampling point 2.

At sampling point 2, lay the tarp down beside the area to be sampled. Remove the organic surface layer and place it on the tarp, but do not sample it. Prepare a sampling pit as before. Sample the A horizon, placing approximately 150 cc of soil into the same 2-L bag containing the A horizon sample from point 1. Shake the bag to mix the samples. Then sample the underlying 10 cm layer as before, placing approximately 150 cc of soil in the same 2-L bag containing the second mineral sample from point number 1. Shake the bag to mix the samples. Estimate the texture of both the A horizon and the underlying 10 cm layer, recording texture as clayey, loamy or sandy. As before, record the thickness of the A horizon and the depth to the subsoil to the nearest cm. If the subsoil is not encountered within a depth of 50 cm, record depth to the subsoil as "more than 50 cm".

After restoring the site at sampling point 2, proceed to sampling point 3. Repeat the procedure followed at sampling point 2. Seal the sample bags and make sure they are properly labeled with the state, hexagon number, layer sampled, date, and crew identifiation.

2.4. Laboratory Analyses

Soil samples collected from the field are analyzed in the laboratory to determine the following:

- Mineral soil samples:
    - pH in water and in KCl
    - Total organic carbon
    - Exchangeable Ca, Mg, K, and Na
    - Bray I Phosphorus
    - CEC and BS
    - Texture (optional)
- Organic layers:
    - Total organic carbon
    - Total N
    - Percent organic matter (Loss on ignition, LOI)

III. RESULTS AND DISCUSSIONS

Soil chemical properties of Pulau Laut study site for both years (1996 and 1999) are presented in Table 1.There was a tendency toward lower soil pH over time. The decrease in soil organic carbon and total nitrogen was also evident. It was also noted that the depletion of soil organic matter was consistent with the significant decrease of exchangeable bases, particularly Ca, and Bray I extractable P. In most cases, the level of soil chemical properties decreased with soil depth; however, there were considerable random variations within the time of observation.

The soil chemical analyses of Jambi for both years (1996 and 1999) are presented in Table 2. There was no significant changes over time in soil pH, soil organic carbon, extractable basic cation and CEC. However, tremendous decrease in LOI with time was evident and this suggests that intensive decomposition of organic matter occurred in soil O horizon. The cause of higher BS in 1999 is not clear, but the increase in BS with time was consistently observed throughout all clusters 1 and 2 in Jambi. Moreover, there

The status of soil fertility level as reflected by soil chemical properties of Sumpol, Jambi, is presented in Table 3. Soil carbon organic and total nitrogen level were categorized into medium. Exchangeable Ca and Mg were classified as low and high, respectively. Eventhough the BS level ranged from medium to high, the CEC level was considerably low and hence, in general the soil was assessed as bearing poor soil fertility.

The degree of soil fertility of the study site in Kediri reflecting by soil chemical properties is shown in Table 4. Soil carbon organic, total nitrogen exchangeable basic cations and CEC were mostly low, but BS level was recorded as significantly high. As in the case of Sumpol, the soil of FHM plots in Kediri was also bearing poor soil fertility.

Soil organic matter , one of the important soil properties employed in the assessment of forest health condition, is expressed by total organic carbon and percent of organic matter (LOI). The decrease in soil organic matter at the expense of increase in tree growth is indicated by increase in basal area with time (Table 5) as has been observed in Pulau Laut and Jambi. It was noted that the lower basal area in 1999 compared to that of 1996 occurred at Clusters 4, 5, 6 (Pulau Laut), and at Cluster 2 (Jambi) due to the fact that corresponding sites were burnt causing tree mortality.

Decrease in soil organic matter may occur due to the removal of organic litter from on site and intensive decomposition resulting in net mineralization which in turn was absorbed by the tree in its growth and development process. Forest ecosystem dynamics have long been explained by changes in nutrient availability (Vitousek, 1984). Once the tree is firmly established , it increasingly influences its own environment, both above ground by shading and by intercepting rain , and below ground, by absorbing water and nutrient ions and by releasing other ions and organic chemicals. Ponge *et al.*(1998) suggested that both softwood and hardwood trees tend to acidify the soil because proton production due to nutrient uptake and storage exceeds proton consumption due to mineral weathering, mineralization of organic matter and nitrogen fixation in the soil. It was concluded that soil organic matter, the humus layer in forest, is a key factor influencing forest ecosystem dynamics.

Changes in the soil reaction with time should be examined very carefully simply because the process may be induced by soil erosion, basic cations leached or absorbed by the tree, and the presence of decomposed organic matter. Conflicting accounts of the effect of organic matter on soil pH exist. Soil pH has been reported to both increase and decrease due to the presence of organic matter (Pocknee and Summer, 1997) and was affected by basic cation and nitrogen contents. As a result, examining the soil pH and soil organic matter changes with time in FHM activity should be related at least to the changes in basal area representing the tree growth in order to reach better understanding on the status of forest health.

changes in basal area representing the tree growth in order to reach better understanding on the status of forest health.

Extractable basic cation, CEC, BS and Bray I extractable P are other important soil chemical properties that should be investigated precautiously when tree growth parameter is concerned. The correlation between these soil characteristics and tree growth parameter may not be important. Baillie *et al.* (1987) concluded that geological variables, especially Mg, appear to be the most influencing factor on forest composition; however, organic matter and exchangeable cations appear to be relatively unimportant.

Extractable soil Al or Al saturation level indicates the presence of possible toxic substance to plant growth which is an important soil parameter. In all cases no significant extractable Al was observed throughout the FHM plots in South Kalimantan , Jambi , and East Java.

The organic fraction of soil consists of living organisms and dead plant and animal residues. Per unit mass, the organic fraction is the most chemically active portion of the soil. It is a reservoir for various essential nutrients, promotes good soil structure, is a source of cation exchange capacity and soil pH buffering, promotes good air-water relations in soils, and is a large geochemical reservoir for carbon. Owing to the facts mentioned, correlation coefficients were examined between soil chemical properties and basal area (Tables 6, and 7), between soil organic carbon and other soil chemical properties (Tables 8, and 9), between basal area and soil chemical properties averaged across all clusters (Table 10), and between soil organic carbon and other soil chemical properties averaged across all clusters (Table 11). In most cases, basal area of clusters 1,2 and 7 (natural forest) of Pulau Laut correlated significantly with soil organic carbon in 1996, and correlated significantly with soil nitrogen, extractable K, P, LOI, CEC and BS in 1999. The low correlation between basal area of clusters 4, 5, and 6 with soil chemical properties was due, in part, to the poor tree growth as affected by harsh forest fire which occurred in the previous year. There was a better correlation between basal area and soil organic carbon in 1999 than that of 1996 in clusters 1, 2, 3, and 4, Jambi. It is interesting to note that, in most cases, there was significant correlation between basal area averaged across all clusters and almost all soil chemical properties for both years (Table 10). It was also noted that there was significant and high correlation between soil organic carbon and other soil chemical properties averaged across all clusters from South Kalimantan, Jambi and East Java for both years (Table 11). This suggests that all soil chemical properties examined as a tool to judge forest health are of the same importance.

IV. CONCLUSIONS

Soil organic matter, as one of the important soil properties employed in the assessment of forest health condition, is expressed by total organic carbon and percent of organic matter (LOI). The decrease in soil organic matter should be viewed at the expense of the increase in tree growth indicated by increase in basal area with time. Changes in soil reaction with time should be examined very carefully because the process may be induced by soil erosion, basic cations leached or absorbed by tree, and the presence of decomposed organic matter. Significantly, high correlation between soil organic carbon and other soil chemical properties indicated that all soil chemical properties examined as a tool to judge the forest health are of the same importance. In general, all soils in these studies bearing poor soil fertility indicated that the soils are strongly weathered or leached. High BS in most cases suggests that management regime should put into account any silvicultural technique so that soil productivity can be maintained before the basic cations available in the soils are leached.

ACKNOWLEDGEMENT

This Technical Report No. 21 on **Trend of Soil Chemical Property Changes on Forest Health Monitoring Activities Conducted in South Kalimantan, Jambi and East Java** has been prepared to fulfill Objective 1 point 2.2 of the Work-plan of ITTO Project PD 16/95 Rev. 2 (F) : Forest Health Monitoring to Monitor the Sustainability of Indonesian Tropical Rain Forest.

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Table 1. Soil chemical properties of Pulau Laut, 1996 and 1999

Location, Year	Cluster	Hor.	pH		C org	N tot	LOI	C / N	Ca	Mg	Na	K	P	CEC	BS	Al	H	Sand	Silt	Clay
			H_2O	KCl	%				me/100 gr				ppm	me/100 gr	%	me/100 gr		%		
P. Laut, 1996	1	A	7.1	6.9	4.70	0.69	-	6.81	24.83	9.98	-	0.89	31.11	-	-	-	-	-	-	-
P. Laut, 1996	1	B	7.0	6.1	4.10	0.61	-	6.72	12.69	5.17	-	0.98	7.34	-	-	-	-	-	-	-
P. Laut, 1996	2	A	7.4	7.1	5.40	0.82	-	6.59	34.69	7.81	-	0.93	44.68	-	-	-	-	-	-	-
P. Laut, 1996	2	B	7.0	6.4	3.50	0.50	-	7.00	20.95	3.28	-	0.54	28.12	-	-	-	-	-	-	-
P. Laut, 1996	3	A	6.5	5.0	4.45	0.67	-	6.64	20.19	6.58	-	0.96	24.60	-	-	-	-	-	-	-
P. Laut, 1996	3	B	5.2	5.6	1.70	0.25	-	6.80	3.26	1.54	-	0.24	25.42	-	-	-	-	-	-	-
P. Laut, 1996	4	A	6.7	4.0	2.00	0.30	-	6.67	9.19	2.59	-	0.42	20.40	-	-	-	-	-	-	-
P. Laut, 1996	4	B	5.3	5.4	1.15	0.16	-	7.19	1.84	1.03	-	0.14	2.47	-	-	-	-	-	-	-
P. Laut, 1996	5	A	6.5	5.4	4.35	0.77	-	5.65	9.80	5.68	-	1.17	12.65	-	-	-	-	-	-	-
P. Laut, 1996	5	B	4.5	3.5	1.05	0.16	-	6.56	0.92	0.93	-	0.40	20.61	-	-	-	-	-	-	-
P. Laut, 1996	6	A	6.9	5.8	3.40	0.52	-	6.54	6.18	3.64	-	0.66	10.99	-	-	-	-	-	-	-
P. Laut, 1996	6	B	4.6	3.6	1.00	0.14	-	7.14	1.37	0.65	-	0.16	18.80	-	-	-	-	-	-	-
P. Laut, 1996	7	A	7.3	6.4	3.85	0.67	-	5.75	28.19	10.09	-	1.07	42.96	-	-	-	-	-	-	-
P. Laut, 1996	7	B	6.3	5.1	1.15	0.18	-	6.39	7.80	4.21	-	0.60	24.04	-	-	-	-	-	-	-

Remark: - data not available

Table 1. (Continuation)

Location, Year	Cluster	Hor.	pH		C org	N tot	LOI	C / N	Ca	Mg	Na	K	P	CEC	BS	Al	H	Sand	Silt	Clay
			H_2O	KCl	%				me/100 gr				ppm	me/100 gr	%	me/100 gr		%		
P. Laut, 1999	1	A	5.2	4.5	3.84	0.33	11.64	18.99	2.80	3.64	0.22	0.55	8.09	21.24	33.95	0.19	0.12	13.76	38.32	47.92
P. Laut, 1999	1	B	5.2	4.1	1.55	0.16	10.33	15.56	2.32	3.34	0.22	0.48	5.69	18.11	35.12	0.06	0.16	17.53	27.59	54.88
P. Laut, 1999	2	A	6.5	5.7	3.70	0.35	10.59	9.27	8.15	4.26	0.20	0.58	5.31	16.65	79.23	0.23	0.01	22.72	30.03	47.25
P. Laut, 1999	2	B	6.2	5.4	1.67	0.20	8.24	9.70	4.06	3.30	0.12	0.53	3.93	10.90	73.46	0.18	0.01	25.41	30.06	44.53
P. Laut, 1999	3	A	5.6	4.8	3.50	0.33	10.76	15.89	5.90	6.42	0.62	0.72	7.17	23.37	58.46	0.06	0.01	21.65	33.42	44.93
P. Laut, 1999	3	B	4.7	4.2	1.49	0.15	9.93	15.64	2.13	2.34	0.20	0.34	6.83	17.01	29.45	0.43	0.03	18.07	31.54	50.39
P. Laut, 1999	4	O	6.7	6.0	22.46	1.09	20.54	41.10	10.62	12.42	1.68	5.17	21.98	37.47	79.77	0.53	0.25	6.24	31.63	62.13
P. Laut, 1999	4	A	5.6	5.5	3.13	0.26	12.04	12.05	2.22	3.54	0.22	1.18	5.18	9.30	77.01	0.36	0.18	11.62	21.23	67.15
P. Laut, 1999	4	B	5.2	4.5	1.17	0.13	9.22	8.15	0.73	1.52	0.29	1.06	3.79	6.50	55.39	2.39	0.88	5.36	20.44	74.20
P. Laut, 1999	5	A	5.2	4.9	2.15	0.18	11.68	11.18	1.56	2.74	0.42	1.12	6.32	7.55	77.37	2.12	0.39	4.99	26.69	68.32
P. Laut, 1999	5	B	4.2	4.7	1.09	0.11	9.53	6.61	0.24	0.64	0.11	0.43	1.43	6.49	21.43	3.97	1.06	19.10	32.68	48.22
P. Laut, 1999	6	A	5.3	4.7	2.37	0.24	9.88	10.29	1.18	1.18	0.34	0.62	6.55	6.26	67.89	2.53	1.20	14.49	33.14	52.37
P. Laut, 1999	6	B	4.8	4.5	1.79	0.18	9.93	6.02	0.36	0.36	0.28	0.38	5.30	3.52	48.01	1.78	0.65	2.58	25.54	71.89
P. Laut, 1999	7	A	5.7	5.2	3.58	0.30	11.95	19.96	4.06	3.34	1.09	0.53	16.35	18.63	48.42	0.13	0.03	16.41	36.34	47.52
P. Laut, 1999	7	B	4.9	4.5	2.16	0.22	9.82	14.80	2.99	5.03	0.17	0.50	10.15	19.70	44.11	0.33	0.02	12.91	31.61	55.48

Table 2. Soil chemical properties of Jambi, 1996 and 1999

Location, Year	Cluster	Hor.	pH		C org	N tot	LOI	C / N	Ca	Mg	Na	K	P	CEC	BS	Al	H	Sand	Silt	Clay
			H_2O	KCl	%				me/100 gr				ppm	me/100 gr	%	me/100 gr		%		
Jambi, 1996	1	O	4.6	3.8	6.91	0.66	72.95	10.47	0.42	1.00	0.39	0.43	53.80	33.5	6.7	0.23	0.12	-	-	-
Jambi, 1996	1	A	4.4	3.7	1.52	0.19	-	8.00	0.33	0.23	0.26	0.20	33.70	8.8	11.6	0.34	0.18	33.60	34.29	32.11
Jambi, 1996	1	B	4.0	3.4	10.15	0.72	27.96	14.10	0.66	1.37	0.32	0.49	73.50	29.4	9.7	0.26	0.14	-	-	-
Jambi, 1996	2	O	4.0	3.2	22.58	1.17	36.01	19.30	0.97	3.13	0.23	0.55	55.40	33.6	14.5	0.32	0.24	-	-	-
Jambi, 1996	2	A	4.8	4.0	1.70	0.20	-	8.50	0.09	0.06	0.07	0.07	33.70	3.2	9.2	0.20	0.12	57.04	24.18	18.78
Jambi, 1996	2	B	4.8	4.1	11.78	0.70	-	16.83	0.21	1.15	0.10	0.33	46.40	19.2	9.3	0.14	0.08	49.88	32.38	17.74
Jambi, 1999	1	O	4.9	4.3	11.72	0.60	19.47	23.91	2.28	4.39	1.48	1.72	60.89	24.59	40.14	3.86	1.02	27.55	32.67	39.78
Jambi, 1999	1	A	4.1	3.6	3.80	0.29	12.95	10.02	0.59	2.17	1.55	0.70	18.19	14.64	34.22	4.60	1.14	27.66	38.43	33.91
Jambi, 1999	1	B	4.1	3.5	1.05	0.11	9.54	4.19	0.18	0.30	0.63	0.33	31.95	7.22	19.91	4.93	0.70	24.20	33.50	42.30
Jambi, 1999	2	O	4.6	4.0	9.99	0.56	17.94	25.73	1.40	3.71	0.96	0.96	84.83	21.32	32.97	2.13	0.91	20.76	53.17	26.07
Jambi, 1999	2	A	4.4	3.7	1.69	0.13	13.44	3.72	0.42	0.56	1.72	0.54	26.12	6.62	48.94	2.29	0.49	44.95	41.38	13.67
Jambi, 1999	2	B	4.3	3.5	0.45	0.06	7.37	2.61	0.31	0.39	1.69	0.15	36.32	4.96	51.21	1.83	0.57	40.42	36.82	22.76
Jambi, 1999	3	O	4.5	3.9	18.58	0.99	18.69	48.71	7.15	5.82	1.40	3.16	78.69	33.02	53.09	1.96	0.83	9.14	46.72	44.14
Jambi, 1999	3	A	4.1	3.7	3.25	0.29	11.17	10.59	1.71	1.70	0.94	1.34	24.10	13.29	42.81	6.57	0.94	14.00	45.10	40.90
Jambi, 1999	3	B	4.1	3.5	0.87	0.10	8.56	6.83	0.57	0.88	0.67	0.45	24.03	12.92	19.89	4.75	2.32	9.98	41.60	48.42
Jambi, 1999	4	O	4.9	4.3	13.20	0.62	21.45	30.97	4.20	4.44	1.55	1.94	69.85	18.72	64.80	1.03	1.36	32.58	43.17	24.25
Jambi, 1999	4	A	4.8	4.0	3.05	0.29	10.38	7.58	1.40	2.21	0.89	0.83	14.81	7.92	67.30	2.07	0.47	38.90	39.29	21.81
Jambi, 1999	4	B	4.3	3.6	1.31	0.15	8.86	3.47	0.72	1.21	0.71	0.59	51.84	5.52	58.51	1.84	0.44	44.19	31.84	23.97

Remark: - data not available

Table 3. Soil chemical properties of Sumpol, 1999

Location	Cluster	Hor.	pH H_2O	pH KCl	C org %	N tot %	LOI %	C / N	Ca me/100 gr	Mg me/100 gr	Na me/100 gr	K me/100 gr	P ppm	CEC me/100 gr	BS %	Al me/100 gr	H me/100 gr	Sand %	Silt %	Clay %
Sumpol	8	A	4.9	4.3	3.68	0.32	11.50	15.88	5.88	4.29	0.18	0.23	10.65	11.55	91.60	0.84	0.16	20.07	30.82	49.11
Sumpol	8	B	4.8	4.1	2.33	0.25	9.32	13.45	3.77	4.06	0.20	0.83	8.41	12.13	50.95	0.35	0.20	30.32	25.95	43.73
Sumpol	9	A	5.1	4.5	3.19	0.34	9.38	27.78	1.23	4.59	0.15	0.21	16.23	14.38	58.83	3.58	0.04	16.74	29.05	54.21
Sumpol	9	B	4.9	4.1	2.56	0.24	10.68	20.63	0.83	4.77	0.14	0.19	18.05	12.24	48.45	0.95	1.04	29.40	24.14	45.46

Table 4. Soil chemical properties of Kediri, 1999

Location	Cluster	Hor.	pH H_2O	pH KCl	C org %	N tot %	LOI %	C / N	Ca me/100 gr	Mg me/100 gr	Na me/100 gr	K me/100 gr	P ppm	CEC me/100 gr	BS %	Al me/100 gr	H me/100 gr	Sand %	Silt %	Clay %
Kediri	1	O	5.3	4.4	5.90	0.42	13.05	14.10	6.15	3.45	0.23	0.86	38.46	13.75	77.75	0.09	0.02	91.14	9.22	2.64
Kediri	1	A	5.0	4.1	1.94	0.18	5.63	10.59	1.80	0.71	0.27	0.69	31.84	5.32	65.22	0.06	0.05	90.25	7.52	2.33
Kediri	1	B	4.9	4.0	1.62	0.17	8.14	9.56	1.70	1.16	0.26	0.41	26.35	4.82	73.32	0.22	0.05	87.07	7.50	5.43
Kediri	2	O	5.3	4.5	3.02	0.22	6.14	13.49	3.03	1.70	0.21	0.55	46.47	6.89	79.68	0.11	0.01	92.14	5.93	1.93
Kediri	2	A	5.2	4.1	1.79	0.16	4.90	11.21	2.79	1.01	0.23	0.34	34.54	5.16	84.69	0.09	0.02	92.11	5.62	2.27
Kediri	2	B	4.8	3.8	1.83	0.18	6.33	10.04	1.90	0.30	0.26	0.64	26.42	4.00	77.50	0.37	0.01	91.30	6.74	1.96
Kediri	3	O	5.1	4.5	3.30	0.24	5.96	13.57	4.53	0.79	0.19	0.40	44.88	8.63	68.37	0.11	0.03	89.62	5.48	4.90
Kediri	3	A	4.9	4.0	1.76	0.19	4.59	9.15	1.77	0.25	0.19	0.27	40.78	3.76	65.96	0.27	0.02	90.22	7.24	2.54
Kediri	3	B	4.9	3.9	1.34	0.18	6.24	7.53	1.41	0.37	0.26	0.34	29.62	3.89	61.18	0.16	0.02	92.99	4.75	2.26
Kediri	4	O	5.4	4.7	3.37	0.33	8.66	10.27	5.58	2.85	0.18	0.63	51.64	10.50	87.90	0.06	0.01	92.50	4.56	2.94
Kediri	4	A	5.3	4.5	1.84	0.13	3.55	14.63	1.46	0.18	0.15	0.17	42.25	3.53	55.52	0.15	0.03	90.56	7.31	2.13
Kediri	4	B	5.2	4.2	1.19	0.09	3.45	13.03	1.15	0.65	0.23	0.32	20.94	3.17	74.13	0.06	0.05	90.75	4.08	4.17
Kediri	5	O	5.6	4.9	3.25	0.32	9.35	10.23	5.08	2.03	0.16	0.44	40.44	9.61	80.22	0.06	0.05	88.26	8.05	3.69
Kediri	5	A	5.0	4.5	2.19	0.22	5.90	9.86	2.20	0.80	0.22	0.43	27.16	5.96	61.24	0.19	0.04	92.67	5.21	2.12
Kediri	5	B	4.9	4.2	1.59	0.17	5.26	9.56	1.10	0.49	0.22	0.23	26.49	3.14	61.97	0.21	0.09	90.29	7.54	2.17

Table 5. Basal area in each cluster

No.	Location	Cluster	Basal area (m^2)	
			1996	1999
1.	Pulau Laut	1	2214.43	2401.47
		2	749.38	1136.34
		3	608.98	698.21
		4	1374.40	1210.68
		5	1462.47	1023.53
		6	1423.19	900.85
		7	2246.92	2379.65
2.	Jambi	1	907.97	1049.18
		2	832.58	781.82
		3	-	959.29
		4	-	934.30
3.	Sumpol	8	-	843.47
		9	-	916.11
4.	Kediri	1 (5 years)	-	214.70
		2 (7 years)	-	478.52
		3 (3 years)	-	115.77
		4 (6 years)	-	336.14
		5 (4 years)	-	308.93

Remark: - data not available

Table 6. Correlation between basal area and soil chemical properties (1996 and 1999) in natural forest

No.	Location	Cluster	Parameters	Coefficient Correlation		P value	
				1996	1999	1996	1999
1.	Pulau Laut	1, 2, 7	C-org	-0.20	0.01	0.01	0.87
			Ntot	-0.25	-0.18	0.00	0.01
			K	0.08	-0.21	0.28	0.00
			P	-0.12	0.16	0.12	0.02
			LOI	-	0.22	-	0.00
			CEC	-	0.20	-	0.00
			BS	-	-0.23	-	0.00
2.	Pulau Laut	4, 5, 6	C-org	0.02	0.11	0.76	0.35
			Ntot	0.02	0.03	0.76	0.77
			K	0.02	0.12	0.76	0.30
			P	-0.01	-0.12	0.80	0.27
			LOI	-	0.12	-	0.29
			CEC	-	0.13	-	0.26
			BS	-	0.11	-	0.33

Table 6. (Continuation)

No.	Location	Cluster	Parameters	Coefficient Correlation		P value	
				1996	1999	1996	1999
3.	Jambi	1, 2, 3, 4	C-org	-0.04	0.11	0.58	0.04
			Ntot	-0.04	0.09	0.58	0.08
			K	0.04	0.03	0.58	0.56
			P	-	-0.07	-	0.22
			LOI	-	-0.02	-	0.75
			BS	0.04	-0.05	058	0.34
			CEC	0.04	0.10	0.58	0.06
4.	Sumpol	8, 9	C-org	-	-0.04	-	0.68
			Ntot	-	0.04	-	0.68
			K	-	-0.04	-	0.68
			P	-	0.04	-	0.68
			LOI	-	-0.04	-	0.68
			CEC	-	0.04	-	0.68
			BS	-	-0.04	-	0.68

Remark: - data not available

Table 7. Correlation between basal area and soil chemical properties (1999) in plantations forest

No.	Location	Age, years	Parameters	Coefficient Correlation	P value
1.	Kediri	3, 4, 5, 6, 7	Corg	- 0.04	0.31
			Ntot	- 0.06	0.09
			K	- 0.05	0.21
			P	0.01	0.87
			LOI	- 0.03	0.37
			CEC	0.01	0.78
			BS	0.08	0.03

Table 8. Correlation between C organic and soil chemical properties (1996 and 1999) in natural forest

No.	Location	Cluster	Parameters	Coefficient Correlation		P value	
				1996	1999	1996	1999
1.	Pulau Laut	1, 2, 7	Ntot	0.88	0.58	0.00	0.00
			K	-0.82	0.40	0.00	0.00
			P	-0.13	-0.70	0.08	0.00
			LOI	-	-0.24	-	0.00
			CEC	-	0.54	-	0.00
			BS	-	-0.27	-	0.00

Table 8. (Continuation)

No.	Location	Cluster	Parameters	Coefficient Correlation		P value	
				1996	1999	1996	1999
2.	Pulau Laut	4, 5, 6	Ntot	0.99	0.75	0.00	0.00
			K	0.95	0.52	0.00	0.00
			P	-0.83	-0.93	0.00	0.00
			LOI	-	0.56	-	0.00
			CEC	-	0.82	-	0.00
			BS	-	0.43	-	0.00
3.	Jambi	1, 2, 3, 4	Ntot	1.00	0.94	0.00	0.00
			K	-1.00	0.49	0.00	0.00
			P	-	-0.66	-	0.00
			LOI	-	-0.41	-	0.00
			CEC	-1.00	0.84	0.00	0.00
			BS	-1.00	-0.26	0.00	0.00
4.	Sumpol	8, 9	Ntot	-	-1.00	-	0.00
			K	-	1.00	-	0.00
			P	-	-1.00	-	0.00
			LOI	-	1.00	-	0.00
			CEC	-	-1.00	-	0.00
			BS	-	1.00	-	0.00

Remark: - data not available

Table 9. Correlation between C organic and soil chemical properties (1999) in plantations forest

No.	Location	Age, years	Parameters	Coefficient Correlation	P value
1.	Kediri	3, 4, 5, 6, 7	Ntot	0.70106	0.0001
			K	0.45588	0.0001
			P	- 0.73723	0.0001
			LOI	0.62480	0.0001
			CEC	0.63685	0.0001
			BS	- 0.32686	0.0001

Note :
Age 3 years = Cluster 3
Age 4 years = Cluster 5
Age 5 years = Cluster 1
Age 6 years = Cluster 4
Age 7 years = Cluster 2

Table 10. Correlation between basal area and soil chemical properties (1996 and 1999) in overall cluster

No.	Parameters	Coefficient Correlation		P value	
		1996	1999	1996	1999
1.	C-org	0.14	0.17	0.00	0.00
2.	Ntot	0.15	0.12	0.00	0.00
3.	K	0.18	-0.03	0.00	0.34
4.	P	-0.01	-0.09	0.87	0.01
5.	LOI	-	0.04	-	0.32
6.	CEC	-0.15	0.26	0.00	0.00
7.	BS	-0.17	-0.13	0.00	0.00

Remark: - data not available

Table 11. Correlation between C organic and soil chemical properties (1996 and 1999) in overall cluster

No.	Parameters	Coefficient Correlation		P value	
		1996	1999	1996	1999
1.	Ntot	0.98	0.91	0.00	0.00
2.	K	0.91	-0.05	0.00	0.16
3.	P	-0.07	-0.48	0.09	0.00
4.	LOI	-	-0.27	-	0.00
5.	CEC	-0.68	0.80	0.00	0.00
6.	BS	-0.75	-0.04	0.00	0.31

Remark: - data not available

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FOREST HEALTH MONITORING TO MONITOR THE SUSTAINABILITY OF INDONESIAN TROPICAL RAIN FOREST

MOF - ITTO - SEAMEO BIOTROP - USDA Forest Service

VOLUME II