Species Grouping of *Shorea* spp. Based On Responsive Scale of Periodic Individual Diameter Increment

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**Abstract.** The purpose of this research was to determine species grouping of *Shorea* sp. based on the characteristics of periodic individual diameter increment on natural forest. The study was conducted on Labanan forest research station located in Berau, East Kalimantan. This study was using data series on logged over forest permanent plots with total of 8 ha along 1990-2018. *Shorea* spp. species group was determined based on the number of classes (5 classes) as responsive scale of periodic diameter increment rates. The consistency assessment analysis was conducted using compares of two approaches which as by interval class and euclidean distance method. The identified results of measuring 26 species of Shorea, 16 species can be further analyzed into species grouping based on their increment. The interval class rates approach has different scale with euclidean distance rates for cluster similarity method. *Shorea parvifolia, S. johorensis, S. pinanga* and *S. scrobiculata* were recommended as very responsive or fast-growing species. Whereas *S. patoiensis, S. beccariana* and *S. smithiana* were in the slow growing species group. This result is providing the recommendation of selection of priority species based on the increment rates characteristic for increasing the productivity especially on production forest stand.

1. **Introduction**

The importance of information potential economic species as priority species to develop in production natural forest to ensure the economic value in the future. The lack of information those species caused by limiting data available to determine the growth characteristic of each species. Growth tree is a change or increase in size or dimensions of the organ of life along the age that causes changes in the size of the height, diameter and volume of trees [1, 2, 3, 4]. The growth of individual trees or stands constituent is derived from the total interaction of genetic and environmental properties [3]. The pattern of individual tree growth is strongly influenced by environmental factors and growing space will form a different stand growth [5, 6, 7]. The increment is growth at a certain time period. Individual tree increment approach has the flexibility for a wider projection on various range of conditions. For tropical forests, more complex structured growth model based on ecosysystems, species composition of the high and the irrelevance of the variable age [8]. There was any variation in growth rates that often is not random, this indicated as some trees shown higher growth than others [9]. The tree growth on stand forest affected by opening crown or canopy structure and tree morphology [10].

Diameter is one of dimensional tree most often used as the parameter of growth in natural forests as a substitute of age, although not always positively correlated [2, 11, 12]. Diameter dimension becomes important in the management of forest stands because it has properties that are correlated with the growth of other dimensions (e.g. basal area and volume) and can be easily measured and accurately [13]. Increment of individual trees approach has the flexibility for a wider projection on various range
of conditions. For tropical forests, growth model has structured based on more complex of ecosystems, species composition of the high and the irrelevance of the variable age [8]. So, the equation is based on the diameter increment or basal area that is reliable to be used in the prediction stands in total based on site conditions and stand itself. The resulting of diameter growth of trees causing by vary depending on the tree size, species and other tree-related factors [14].

Quantitative assessment of individuals with a variety of conditions increment of different nature forest stands showed different responses of species groups. The approach of species grouping of stands or different dimensions can be done to see the effect of variation or group response to variations on forest stand conditions after logging [15, 16]. Different response of each species is one-dimensional quantitative assessment approach review of stand characteristics that important for consideration of constituent species diversity variation stands [17,18]. With the availability growth estimation curve with variables input as quantitative tools for better forest planning [19]. Dimensional quantitative assessment in the long term also useful for the evaluation of a given silvicultural techniques and as updating the forest inventory [20, 21]. By reviewing the characteristics of the constituent species group of stands are important in studying the growth of tree species based on ecological and quality of tree formation [22].

The characteristics of natural forest stands after logging function as biological response and time function of recovery becomes a factor forming of stand dimensional. The importance of vegetation response review as the main constituent (species/species group) on mixed stands will be able to provide an evaluation of silvicultural treatments to be provided. The needs to enrichment planting especially using dipterocarps species to improve the quality and quantity on natural forest as potential and conserving propose [23]. To increase tropical forest productivity after logging by enrichment planting need considered new approach to selected species such as some element of growth and assessment optimum environmental manipulations [24].

The purpose of this research was to determine species grouping of *Shorea* sp. based on the characteristics of periodic individual increment in logged over forest and primary condition. As a scientific base in the development of multi silvicultural systems for the management and increased productivity of production natural forest stand through providing the information on characteristics of selection of priority species based on the increment rates.

2. Methods

2.1. Research Site
The experiment was conducted on permanent sample plots were located within the Forest Area Special Purpose (KHDTK) Labanan forest research station located in the village Labanan, Berau regency of East Kalimantan. Geographically located between 117°10'22"-117°15'35" east longitude and 1°52'43"-1°57'34" north latitude. Labanan forest area has slopes of ramps (0-8%) to steep (> 45%), and the topography is hilly with an altitude area tend to be up to 500 m above sea level. Soil type include red-yellow podzolic, latosol and litosol. Based on climate classification of Schmidt and Fergusson (1951) of climate monitoring stations Kalimarau KHDTK Labanan included in climate type B (very wet) with a Q value = 14.3%.

2.2. Data Collection
The plots study was conducted in logged forests and primary forests through the development of permanent plots. Each plots size 200 mx 200 m (4 ha) divided into sub-plots of 100 m x 100 m (1 ha) and 25 sub-subplots size 20 mx 20 m. The total plots were 8 ha. Data collected by census inventory techniques for all species of *Shorea* sp. with diameter limit 10 cm on permanent plots included data such as: species, girth or diameter (at breast height 1.3 m or 20 cm above buttresses). Measurements were taken periodically every 2 years that used 9 times remeasurement.
2.3. Data Analysis
Calculation of periodic increment (periodic annual increment/PAI) approach with Loetsch et al. [33] and Husch et al. [3] formula following:

\[ \text{PAI} = \frac{\text{Cummulative Dimension on periodik of } n \text{ years}}{n \text{ years}} \]

Calculations based on the individual increment the average diameter increment (cm 2yr\(^{-1}\)) following:

\[ r_d = d_0 - d_i \]

where as:
\( r_d \) = tree diameter increment (cm 2yr\(^{-1}\))
\( d_0 \) = initial measurement of diameter (cm)
\( d_i \) = subsequent measurement of the diameter for 2 years (cm)

Grouping techniques based on the species growth response rate on logged over forest condition comparing with primary forest. Grouping technique uses two approaches techniques to determination of interval class [25] and cluster techniques with methods of euclidean distance [26] with the following formula:

Interval class = \( \frac{\text{Value max} - \text{Value min}}{\text{number of classes}} \)

Euclidean distance \( d(x,y) = \sqrt{\sum_{k=1}^{p} (x_k - y_k)^2} \)
\( x = x_1, x_2, x_3, \ldots x_p \) \( y = y_1, y_2, y_3, \ldots y_p \)

Responsive scale of increment rates of Shorea sp. species group determined based on the number of classes that built 5 classes: species group (SG) I: very slow; SG II: slow; SG III: medium; SG IV: fast and SG V: very fast. The main species grouping based on consistency assessment of two approaches for same species on primary forests and logged-over forest.

3. Result and Discussion

3.1. Periodic Diameter Increment
Characteristics of growth Shorea sp. species group. based on mean of periodic diameter increment values depicted on primary natural forests as natural growth characteristic. The results of the calculation of the average value of periodic diameter increment (cm 2yr\(^{-1}\)) for each species are presented on Figure 1.

Mean periodic diameter increment value for all species of Shorea sp. on primary forests (as natural conditions) ranged of 0 - 2.5 cm 2yr\(^{-1}\). Periodic diameter increment will vary based on the diameter at breast height of trees. In the logged forest condition having distribution of mean periodic diameter increment value will have a wider range (Figure 2). The Mean value of periodic diameter increment in logged forest ranged from 0 to 8.2 cm 2yr\(^{-1}\). After logging, periodic diameter increment rates response occurs very large, especially on diameter class 10-20 cm. This suggests that young stands would have a greater response to growth after logging. Comparing with other results, shown the rates of diameter increment having similar pattern both of primary forest and logged over forest.
Response after opening gaps due mainly to selective logging techniques indicate that *Shorea* sp. have a positive response based on increased rates of periodic diameter increment. Shorea as one of member family Dipterocarps, which Dipterocarps will have a positive growth response to the opening canopy after harvesting generally [21]. On the natural forests in East Kalimantan, diameter increment value generally indicates that on logged forest after 2 years for all species becomes two times larger than the primary condition [27]. Opening of the canopy by logging will form as growing space to support the growth or increase the increment rates individually, if which optimal will support the
optimal growth [28]. Forest after logging affected changes in the abundance of density of tress, that given the close relationship between increased tree diameter and number tress [29].

Mean diameter increment value in 10 provinces in Indonesia for commercial species groups of 0.49-79 cm yr\(^{-1}\), non-commercial species of 0.33-0.78 cm yr\(^{-1}\) and for all species of 0.38-0.79 cm yr\(^{-1}\) [30]. The results of the study in Brazil, Costa Rica, Guyana and Papua New Guinea with repeated measurements on permanent plots 3-10 years at 11 study sites generate individual tree diameter increment ranged 0.15 – 1.36 cm\(^{-1}\) [29]. In Central Kalimantan forest after selective logging, Dipterocarps species has higher growth rates (0.40 cm yr\(^{-1}\)) than other species (0.22 cm yr\(^{-1}\)) [23]. Individual tree diameter increment value is in the same range as the results of this study, especially for dipterocarp species groups. This shows the variation in the condition of tropical forest stands have tree diameter increment range is quite wide [16, 21, 32, 33]. Different responses from diameter increment is one of dimensional quantitative assessment important to review of stand characteristics for consideration response and assessment itself [17, 18, 21]. The varian of diameter of growth respon depending on characteristic of ecological site [10, 14].

3.2. Species Grouping of Shorea sp.

Based on interval class of mean periodic diameter increment on primary forests and logged forests showed that all species of Shorea sp. has responsive to the opening of the gap or space to growth. The changed of class rates status in the vary condition both of primary forest and after logging are presented in Figure 3.

![Figure 3](image_url)

**Figure 3.** Changes of class rates of individual increment for *Shorea* sp. on primary forest (PF) and logged over forest (LOF)

In the primary forest, *Shorea* sp. will have class rates of increment of 1, 2 and 3 (very slow to medium rates), while on logged over forest has class rates of increment were 2, 3, 4 and 5 (slow – fast). Grouping is conducted by responsiveness with same assessment scale (interval increment rates 0.5 cm 2yr\(^{-1}\)) for each species. With this approached resulting grouping categorized into 5 groups (Table 1).

Grouping approach of species based on the degree of closeness or similarity (%) to determine the cluster from the calculation of euclidean distance shown by projections dendogram (Figure 4). Grouping is done based on the proximity assessment scale that forms in the same cluster on 5 group class. This result different with response scale with interval class method. With this approached resulting class interval of increment rates between class are not the same of range value. Results of this
species grouping calculation were presented on Table 2. Consistency of the assessment of species group class both of class interval and euclidean distance approached showed the appropriate class. Classification by increment rates were: (a) slow growth namely Shorea patoiensis, (b) medium growth were Shorea hopeifolia and Shorea parvistipulata, (c) fast growth namely Shorea pinanga and (d) very fast growth namely Shorea parvifolia.

Table 1. Species grouping (SG) and scale periodic intervals of mean diameter increment rates (cm 2yr⁻¹) based on class interval

| SG I    | SG II   | SG III  | SG IV   | SG V    |
|---------|---------|---------|---------|---------|
| Mean of Periodic diameter increment (cm 2yr⁻¹) |
| 0 -0.49 | 0.5 – 0.99 | 1.0 – 1.49 | 1.5 – 1.99 | > 2      |

| Shorea patoiensis | Shorea angustifolia | Shorea hopeifolia | Shorea macroptera | Shorea johorensis |
| Shorea beccariana | Shorea atrinervosa | Shorea parvistipulata | Shorea exelliptica | Shorea scrobiculata |
| Shorea smithiana | Shorea superba | | | |
| Shorea multiflora | | | | |

Table 2. Species grouping (SG) and scale periodic intervals of mean diameter increment rates (cm 2 yr⁻¹) based on Euclidean distance clustering

| SG I | SG II | SG III | SG IV | SG V |
|------|-------|--------|-------|------|
| Mean of Periodic diameter increment (cm 2yr⁻¹) |
| 0 – 0.2 | 0.2 – 0.49 | 0.5 – 1.9 | 1.99 – 2.99 | > 2.99 |

| Shorea patoiensis | Shorea beccariana | Shorea angustifolia | Shorea johorensis | Shorea parvifolia |
| Shorea smithiana | Shorea atrinervosa | Shorea exelliptica | Shorea pinanga | Shorea scrobiculata |
| Shorea hopeifolia | Shorea leprosula | Shorea macroptera | Shorea multiflora | |
| Shorea parvistipulata | | Shorea superba | | |

Differences response of periodic increments in each group based on the type of site condition variations has tightness in relation to stand dimensions and growth factor is determined by the interaction potential by genetic, environmental factors including climate (temperature, light, wind, rain) and given of silvicultural techniques [3, 5, 35, 35, 36]. Adam and Kolbs [6] showed a different pattern of growth in the same species on the different location that indicated growth would be strongly influenced by environmental factors such as drought, temperature, slope and species composition. A significant relationship between the growth of individual trees and growing gap also explains the form of growth in the various stands [7]. The different growth response was determined by size of stands which small diameter (young stands) having more responsive than large diameter (old stand).
4. Conclusion

All species of *Shorea* sp. were responsive by the canopy opening (gap). Mean periodic diameter increment on logged over forest conditions will be higher than its natural condition (primary forest). Interval scale of *Shorea* sp. species grouping has different scale on interval scale approach and euclidean distance for cluster similarity. The consistency of the assessment of species group class both of class interval and euclidean distance approached showed the appropriate class. Classification of species grouping by increment rates were: (a) slow growth namely *Shorea patoiensis*, (b) medium growth were *Shorea hopeifolia* and *Shorea parvistipulata*, (c) fast growth namely *Shorea pinanga* and (d) very fast growth namely *Shorea parvifolia*. Recommendation for priority species to develop based on growth rates namely *Shorea parvifolia*, *Shorea johorensis*, *Shorea pinanga* and *Shorea scrobiculata*. Overview of the characteristic response by species/species group to provide an evaluation of silvicultural treatments that applied, especially for commercial species on production natural forest.

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