Estimating of *Gonystiluss Bancanus* Growing Stock in Indonesia (Case study: Riau and Central Kalimantan)

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**Abstract.** *Gonystylus bancanus* is protected species because it is included in list of critically endangered plant species that is heading to be extinct. Export banned *Gonystylus bancanus* log trigger illegal logging caused ramin’s demand is high. This study aimed to estimate *Gonystylus bancanus* growing stock in Indonesia. Time series of satellite image was used to identify land use change. Spatial analysis by overlaying of land cover and peatland map found the potential habitat of *Gonystylus bancanus*. Cluster sampling method was applied to predict growing stock recently year. The study found that growing stock in peat swamp forest in Central Kalimantan (Sebangau National Park area) tend to be elevated. It is also occurred in production forest of peat swamp that is harvested, especially in concession area of Diamond Raya Timber Ltd that also tend to elevate. The most increasing of growing stock is caused by ingrowth. Growing of *Gonystylus bancanus* seedling is hardly occurred. It is caused by youngest seedling characteristics that are need a covering.. *Gonystylus bancanus* (growing stock) is not be spread evenly overall growing stages. This study also found that *Gonystylus bancanus* growing stock ranging between 4.2 m³/ha to 15.2 m³/ha. The growing stock of *Gonystylus bancanus* is between 3.3% to 5.4% of all species in peat swamp forest. Average of *Gonystylus bancanus* increment about 0.63 m³/ha/year. Average growing stock of all species is 3.1 ~ 20.5 m³/ha/year).

1. Introduction
Ramin is species included in Appendix II CITES because it is critically endangered plant species [4]. Large scale of ramin exploitation have been conducted since year 1970 which is support by peat swamp forest exploitation licence. In 1980, ramin log export banned triggered illegal logging because ramin demand was still hight relatively. This situation can threat ramin survival in natural habitat so that it can be extinct.

There are at least three spesies *Gonystylus* in Sumatera which have scientific name *G. bancanus, G. velutinus* and *G. xylocarpus. G bancanus* is the most number of species which have been international trade comodities. This species is recognized as main component of peat swamp forest community in Kalimantan, Peninsular of Malaka and Sumatera. Ramin contruct stand of peat swamp forest community. Ramin grow in peat swamp forest with organic soil having periodically inundation,
un inundation area until 100 meter above sea level [1]. Ramin population have corelation with thickness of peatland [9, 19].

Ramin population is vary, depend on site condition. More thickness of peatland, it is more attending of ramin. Ramin can grow well within depth of peat land more than one-meter i.e depth peat until very depth of peat. Undisturbed ramin population have richness stand, which can form pure ramin stand. It is occured in peat swamp forest of Berbak National Park. Hereby, ramin dominate stand population of the forest [13]

The most constrain of sustainable ramin stand management is difficulties to obtain acurate data and quick providable. Morever, the data is needed to determine harvesting volume and cutting cycle. Now, data and information available is still unfulfilled rate of tree growth which obtained from a time measurement. Periodically of forest inventory is needed to examine the growing of tropical species plant [17]. The use of remote sensing tecnology for forest inventory have more advantages than using terrestrial forest inventory, such as (1). required lesser human resource/labors (2). Less time consuming (3). Unit cost per unit area is cheaper (4) may produce comparable accuracy than terrestrial method [10].

Estimates of growing stock can be obtained from interpolating measurements from a relatively small number of plots typically for ecological studies; averaging measurements from a large number of forest inventory plots determined by rigorous statistical [3], sampling stratifying and multiplying field measurements with categorical land cover [7]; geographic information system modeling with environmental variables such as soil, elevation [4]. Remote sensing data also can be use to map standing stock. Radar technologies such as InSAR [2] can retrieve canopy height (CH), which can be used to improve standing stock mapping.

The study on the use of high-resolution satellite had been started since 2006 leaded by the Ministry of Forestry. The studies were examined in Sumatera, Kalimantan, Sulawesi, Maluku, Papua and Bali. For swamp forest, a predictive model for estimating standing stock was developed using two independent variables, i.e., crown diameter (D) and crown closure (C) having coefficient of determination more than 50%. The variable D and C are mainly derived from high-resolution satellite imageries. For swamp forest, the study showed that crown closure gave more accurate prediction than crown diameter. Therefore, the study of estimasing growing stock use remote sensing and ecological characteristic of ramin. Ramin habitat commonlys is in peat swamp especially in lowland. It corelate with terrain so terrain features can be a key features for forest stand development i.e overall climate characteristics and site productivity [12] Spatial analysis such as classic geostatistical methods i.e the kriging and cokriging techniques can calculate distances between the monitoring points or plot sample. These techniques are linear estimators [5]. Combination remote sensing data series and spacial analysis approach was used because the use of such historical data is important for development of conservation strategi and effective la nd management policies. Study aimed to estimate ramin growing stock and to develop map of ramin potency in Kalimantan and Sumatera.

2. Method

2.1. Sampling design
Ramin growing stock analysis carried out through (a) references study (b) secondary data analysis and (c) measurement and field check (d) spatial analysis. Sampling technique applied were stratification and satellite image classifierification method. The images used are Landsat TM 1989, Landsat ETM 2004, and Landsat 8 OLI 2014 to obtain the forest closure degree. Field sample was laid out by cluster method. Some cluster were representing the level of forest density and the depth of peat [11]. Cluster is square sample unit sized 100 m x 100 m. Each cluster comprised of 5 element for vegetation measurement. In each element, it was made measurement plot and comprised of 3 sub plot, that are sub-plot sized 2 m x 2 m for seedling measurement, 5 m x 5 m for sapling measurement and sub plot sized 10 m x 10 m for pole measurement and sub plot sized 20 m x 20 m for tree measurement.
Ramin will be found in peat depth about 120 cm - 600 cm. More depth of peat, ramin will be founded more number relatively. Within peat depth 120 – 500 cm, ramin is not dominate the stand forest while it is dominant in peat depth >500 cm [11]. So, sampling was determined base on distribute of crown density and depth of peat (Figure 1). Crown density consist of 3 (three) density classes that are high crown density, moderate crown density and lower crown density, and 3 (three) types of peat depth that are less than 3 m, between 3 m and 6 m, and more than 6 m.

![Figure 1. Sampling frame](image)

2.2. Data collecting
Data were collected from sample plot permanent and field survey. Data collection from field survey, tree parameter and stand parameter that are encompassed (i) tree diameter measurement (ii) tree height measurement i.e total height and branch height. In Sumatera island, field sample unit is located in primary forest and secondary forest and log over area (LOA) aged 1, 2, 3, 4 and 5 years. While in Central Kalimantan, sample unit was located in log over forest area aged 10 aged.

2.3. Data analysis
Data from field survey were analyzed to obtain the number and volume all species tree as well as volume of ramin i.e. 1) tree volume (equation 1), 2) stand volume of plot sample (equation 2) and stand volume per hectare (equation 3). Data of permanent plot sample were also analyzed to know stand increment.

\[ V_i = \frac{1}{4} \times \pi \times D^2 \times H \times f \]  
(1)

where \( p \) is constanta value (\( \text{phi} \)) 3.14, \( D \) is diameter breast height (m), \( H \) is height at first branch (m), \( L \) is sample plot area (ha), and \( f \) is form factor (0.65).

\[ V_i = \sum_{i=1}^{n} V_i \]  
(2)

where \( V_i \) is volume of “i” tree (m\(^3\)), and \( V_i \) is volume of stand in “t” sample plot (m\(^3\)).

\[ V_{st} = V/L \]  
(3)

where \( V_{st} \) is volume of stand per hectare (m\(^3\)/ha) and \( n \) is the number of sample plot tree.
2.4. Spatial analysis

Data analysis result the standing stock of all species for each combination of depth peat. Ramin standing stock was calculated using equation 4 for Central Kalimantan and equation 5 for Riau. Therefore, spatial analysis is carried out to produce map distribution and ramin standing stock in Kalimantan dan Sumatera [8].

\[ V_{\text{ramin}} = 0.023 \ V_{\text{allspecies}} \]  
\[ V_{\text{ramin}} = 0.050 \ V_{\text{allspecies}} \]  

where \( V_{\text{ramin}} \) is growing stock of ramin per hectare (m\(^3\)/ha), \( V_{\text{allspecies}} \) is growing stock of all species tree per hectare (m\(^3\)/ha),

3. Results and Discussions

Field measurement show distribution of ramin growing stock is not smoothly each growing stage. In Sumatera virgin forest, ramin tree was found frequently while it was not found in log over forest area. It indicate that ramin was remained in log over area. All species volume of tree is 283.87 m\(^3\) per ha in Sumatra peat swamp forest, while ramin volume tree is 15.23 m\(^3\) per ha (5.36 % of all species volume). Tree density is about 204 ind/ha while ramin density is about 6 ind/ha. So, it can be state that ratio between ramin and all species is approximated 2.92 %.

On pole stage, all species volume is about 59.00 m\(^3\) per ha, while ramin volume can not found. It show a gap in pole stage of peat forest. Hight exploitation, unsustainable harvesting [13] and ramin trading [18] trigger decreasing of ramin populatin in pear swamp forest. Natural regeneration and planting carried out can not met with the level of exploitation. It supported by regular data measurement of consesion company that show all tree species volume is about 344.14 m\(^3\)/ha. \textit{Shorea} sp. have the highest volume about 51.33 m\(^3\)/ha, while ramin species have volume about 5.07 m\(^3\)/ha (Table 1). Average number of tree is about 264 individu/ha where \textit{Syzygium} sp. have higest tree number about 48 ind/ha. While ramin species only has tree number about 5 individu per ha (Table 2).

| No | Local name     | Scientific name | Volume (m\(^3\)/ha) |
|----|----------------|-----------------|---------------------|
| 1  | Meranti Batu   | Shorea sp.      | 51.33               |
| 2  | Balam          | Syzygium sp.    | 50.09               |
| 3  | Punak          | Tetrameristra glabra | 24.37           |
| 4  | Kelat          | Syzygium sp.    | 17.62               |
| 5  | Pisang-pisang  | Mezzetta parviflora | 16.48             |
| 19 | Ramin          | Gonystillus bancanus | 5.10               |

| No | Local name     | Scientific name | Number (ind/ha) |
|----|----------------|-----------------|----------------|
| 1  | Balam          | Syzygium sp.    | 48             |
| 2  | Jambu-jambu    | Eugenia sp.     | 22             |
| 3  | Kelat          | Syzygium sp.    | 22             |
| 4  | Mangga-mangga  | Mangifera sp.   | 15             |
| 5  | Mahang         | Macaranga sp.   | 13             |
| 19 | Ramin          | Gonystillus bancanus | 5               |
On pole phase, sample plot data show *Syzygium* sp have the most number of tree (96 individu per ha), while pole stage of all species have 431 individu per ha (Table 3). While ramin species was found about 23 individu per ha on pole phase. There are growing stock of ramin because ramin was found on pole stage. The highest volume of pole phase is *Syzygium* sp volume about 16.63 m$^3$/ha, while ramin has volume 3.48 m$^3$/ha (Table 4). So, volume of pole phase is 67.83 m$^3$/ha and number of tree is about 431 individu/ha.

| No | Local name | Scientific name | Number (ind/ha) |
|----|-------------|-----------------|-----------------|
| 1  | Balam       | *Syzygium* sp.  | 96              |
| 2  | Pasir-pasir | *Temonurus secundiflorus Blume* | 35          |
| 3  | Kelat       | *Syzygium* sp.  | 31              |
| 4  | Mangga-mangga | *Mangifera* sp. | 31         |
| 5  | Jambu-jambu | *Eugenia* sp.   | 27              |
| 6  | Ramin       | *Gonystillus bancanus* | 23 |

Table 3. The number of pole stage in Sumatran peat swamp forest

| No | Local name | Scientific name | Number (ind/ha) |
|----|-------------|-----------------|-----------------|
| 1  | Balam       | *Syzygium* sp.  | 6.54            |
| 2  | Timah-timah | -               | 3.06            |
| 3  | Pasir-pasir | *Temonurus secundiflorus Blume* | 2.14             |
| 4  | Jambu-jambu | *Eugenia* sp.   | 1.85            |
| 5  | Babi Kurus  | *Crudia scortechinii Prain* | 0.96 |

Table 4. Volume of each pole phase in Sumatran peat swamp forest

On sapling phase, *Syzygium* sp also has the most number of tree (231 ind/ha (Table 6) and volume about 6.54 m$^3$/ha (Table 7). The number of all species within sapling phase about 939 individu per hectare. Unfortunately, ramin was not found in this phase tree growing. Existing ramin is remained tree species left by logging activities. It show a gap of ramin growing stock on sapling phase. It is potentially to decrease ramin growing stock [16] next time.

| No | Local name | Scientific name | Number (ind/ha) |
|----|-------------|-----------------|-----------------|
| 1  | Balam       | *Syzygium* sp.  | 231             |
| 2  | Timah-timah | -               | 154             |
| 3  | Pasir-pasir | *Temonurus secundiflorus Blume* | 108             |
| 4  | Jambu-jambu | *Eugenia* sp.   | 92              |
| 5  | Babi Kurus  | *Crudia scortechinii Prain* | 46 |

Table 6 The number of sapling phase in Sumatran peat swamp forest

| No | Local name | Scientific name | Volume (m$^3$/ha) |
|----|-------------|-----------------|-------------------|
| 1  | Balam       | *Syzygium* sp.  | 6.54              |
| 2  | Timah-timah | -               | 3.06              |
| 3  | Pasir-pasir | *Temonurus secundiflorus Blume* | 2.14             |
| 4  | Jambu-jambu | *Eugenia* sp.   | 1.85              |
| 5  | Mangga-mangga | *Mangifera* sp. | 0.96            |
On seedling phase, *Eugenia* sp) have the most number of individu about 9,643 individu per ha (27.92 %). Ramin seedling is about 2,500 individu per ha or 0.42 % (Table 8). This number is quite few that indicate the growing stock of ramin slowly.

| No | Local name       | Scientific name          | Number (Ind/ha) |
|----|------------------|--------------------------|-----------------|
| 1  | Jambu jambu      | *Eugenia* sp.            | 9,643           |
| 2  | Medang telor     | *Litsea* sp.             | 7,857           |
| 3  | Balam            | *Syzygium* sp.           | 5,714           |
| 4  | Milas            | *Parastemon urophyllum*  | 2,500           |
| 5  | Ramin            | *Gonystillus bancanus*   | 2,500           |

In Kalimantan island, ramin was found on all tree growing phase. The number of all phase of vegetation growing tend to decrease corespond to ramin age. Seedling phase have the most number of individu about 595 individu per ha. In Central Kalimantan, stand volume of all species about 126.37 m³ per ha of tree phase and 76.45 m³ of pole phase. Wherever, ramin volume of tree phase is about 4.12 m³ per ha or equavalent with 3.2 % all species volume in Kalimantan. Stand inventory of peat swamp forest also found all species of tree about 192 ind/ha, while the number of ramin is 8 ind/ha (Table 10). Ratio between the number of ramin and all species is 4.35 %.

Table 10. Comparison between volume (V) and the number of tree all species and ramin of each plot (N) in National Park of Sebangau, Central Kalimantan.

| Cluster | Species       | Plot | Average per hectare |
|---------|---------------|------|---------------------|
|         |               | 1    | 2                   | 3                   | N (ind/ha) | V (m³/ha) |
| 1       | All species   | 3    | 1.70                | 2                   | 5.24       | 42        | 57.86     |
| 2       | All species   | 1    | 1.10                | 8                   | 3.02       | 75        | 34.27     |
|         | Ramin         | 1    | 0.59                | 8                   | 4.92       |           |           |
| 3       | All species   | 11   | 9.31                | 9                   | 3.92       | 15        | 7.29      | 292       | 170.97    |
| 4       | All species   | 8    | 3.91                | 16                  | 12.30      | 18        | 10.66     | 350       | 223.94    |
|         | Ramin         | 2    | 1.14                | 1                   | 1.44       | 17        | 9.51      |           |           |
| 5       | All species   | 12   | 8.33                | 11                  | 8.15       | 12        | 6.12      | 292       | 188.33    |
|         | Ramin         | 1    | 0.34                | 1                   | 0.33       | 17        | 5.58      |           |           |
| 6       | All species   | 8    | 4.90                | 17                  | 10.93      | 5         | 4.12      | 250       | 166.26    |
|         | Ramin         | 2    | 1.10                | 2                   | 1.10       | 17        | 9.17      |           |           |
| 7       | All species   | 2    | 3.09                | 3                   | 2.07       | 42        | 42.95     |           |           |

Ramin volume of pole phase is 0.61 m³ per ha or 0.8 % volume of all species volume. It show ramin growing stock is not similar within all phase growth processes. Base on study carried out on 2009 in Kalimantan peat swamp forest show volume of all species is estimated about 97.9 m³ per ha (Table 11), with volume of species is estimated 2 m³/ha or 2 % [8]. Volume ratio of ramin species elevate during 2009 – 2014 that is 1.2 % or 2.12 m³ recently.
Table 11. Comparation volume ratio of ramin between 2009 and 2014 year

| Island   | 2009 |      |       | 2014 |      |       |
|----------|------|------|-------|------|------|-------|
|          | All species | Ramin | Ratio | All species | Ramin | Ratio |
| Kalimantan| 97.9 | 2    | 2 %   | 126.37 | 4.17 | 3.30 %|
| Sumatera | 185.5| 9.2  | 5 %   | 283.87 | 15.23| 5.36 %|

In 2009, Sumatran peat swamp forest, stand volume of all species is predicted 185.5 m³ per ha, while ramin stand volume predicted approximately 5% of all species volume or around 9.2 m³ per ha [8]. Recently, ramin volume is approximated about 5.36% of all species volume in peat swamp forest. Stand increment measurement found that mean of volume increment for all species is 11.70 m³ per ha per year (case in Sumatra), while mean of increment for ramin is about 0.63 m³ per ha per year. It show there is elevating of ramin growing stock although it is quite small relatively compare with other tree species of peat swamp forest (Table 12).

Table 12. Comparation tree volume of remained stand inventory (RSI) and field survey year of 2014.

| Year   | Volume RSI (m³/ha) | Inventory 2014 (m³/ha) | Period (year) | Increment (m³/ha year) |
|--------|--------------------|-------------------------|---------------|-------------------------|
| 2010   | 209.57             | 311.85                  | 5             | 20.46                   |
| 2011   | 203.18             | 215.45                  | 4             | 3.07                    |

Mean of increment

|                      | All species | Ramin |
|----------------------|-------------|-------|
|                      | 11.76       | 0.63  |

Main cause of ramin growing stock decreasing is forest harvesting. It also has been going to worse by illegal logging activities. Ramin seedling is intolerant species for light when it is growing. Meanwhile in higher phase, ramin become tolerant for light. Different adaptation with environment is predicted as causing a gap of pole phase growth.

Ramin distribution spatially is predicted using peat map and landcover map released by Indonesian ministry of forestry. Peatland map is categorized into three class that are shallow peatland (0-200 m), moderate peat (200 – 400 cm) and depth peat (more than 400 cm). Primary and secondary peat swamp forest landcover type is predicted having ramin stand. Distribution map of ramin growing stock is developed for Kalimantan area (Figure 2b) and Sumatera area (Figure 2b) using ramin habitat approach ecologically. Ramin growing stock of distribution map indicate volume potensial of ramin per hectare for pole and tree phase growth. Ramin growing stock estimation is ratio between ramin potency and all species potency in peat swamp forest. In Kalimantan island, growing stock potency is approximated around 0.735 million m³ for moderate depth peat, and 3.247 million m³ depth peat. It is part of peat land covering 2.763 million hectares. In Sumatera, ramin growing stock potency for depth peatland is 0.466 million m³, and moderate depth have growing stock about 3.071 million m³. The ramin growing stock potency spread in peat land of Sumatera covering 2.85 million hectares.
4. Conclusions
Ramin growing stock potency of Kalimantan peat swamp forest tend to increasing. It indicate succession process and growth process in natural peat swamp forest. It also found in Sumatera peat swamp forest, the ramin growing stock tend to increasing. Stand ingrowth contribute for increasing of growing stock. Regeneration or growing stock of ramin is not proportional distributed at all growth phase. Ramin growing stock is range from 4.2 m$^3$/ha to 15.2 m$^3$/ha which is small part of all species growing stock. The ramin proportion is range from 3.3% to 5.4%. Research concluded that increment mean of ramin is about 0.63 m$^3$/ha/year which is small part of all species mean increment for peat swamp forest 11.8 m$^3$/ha/year (or 3.1 – 20.5 m$^3$/ha/year).

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