"Seed Trees Method" System of Silviculture for Harvesting and Managing Mangrove Forest Resources in Indonesia

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Abstract

Mangrove forest is unique ecosystem and its habitat is specific only for the tropical region. This unique ecosystem has a special silvicultural system and probably works only in Indonesia. This paper describes a system of silviculture used for harvesting and managing mangrove forest resources in Bintuni Bay, West Papua, Indonesia, called as Seed Tree method. This silvicultural system has been using to harvest and manage mangrove forest in Bintuni Bay more than 24 years. Various papers, articles, and reports on mangrove forest resources and assessments on seed trees method practices are reviewed and analyzed. Further field studies were conducted to gather the complementary data required. On this paper, general philosophy of seed trees method is briefly described, and practices of the seed trees method to manage and harvest mangrove forest resources at Bintuni bay are highlighted. In addition, several reports on assessments of the seed trees method practices at Bintuni bay are presented.

The results indicate that mangrove silvicultural system of seed trees method is clearly be able to produce natural regeneration of seedling and sapling in notable population. These seedling and sapling are produced by the seed trees, which were designed in order to establish standing stocks of mangrove forest resources for the next cutting cycle. It is also highlighted that population of seedling and sapling at any logged over areas are exceed or even double the minimum population recommended by this silvicultural system. Importantly, using this silvicultural system, the impacts of wood extraction on the forest ecosystem and environment, mainly seedling, sapling, remaining trees and the seed trees, can be eliminated. With respect to activities of the whole forest operations, general philosophy of reduced impact logging on mangrove forest wood extraction can be achieved. Also, it is obviously shown that population of seed trees at any logged over areas are higher than that recommended by the mangrove silvicultural system, and they are in good state or healthy. Under their own crown, remarkable numbers of seedling and sapling are produced.

In summary, it is highlighted that Seed trees method could be used continuously for harvesting and managing mangrove forest resources in Indonesia, as it has been used successfully at Bintuni bay for more than 24 years toward for sustainable.

Keywords: *Seed s method, harvesting and managing mangrove forest, Indonesia*

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1. Introduction

Papua, previously known as Irian Jaya, approximately has mangrove forest of 2.943 million ha or 69,23 % of 4.251 ha million of Indonesian mangrove forest in total (FAO, 1994). There is single mangrove forest concessions in West Papua located at Bintuni Bay, West Papua province, where a mangrove company, Bintuni Utama Murni Wood Industries (BUMWI) Ltd, has been harvesting and managing mangrove forest resources since 1988. Generally, mangrove wood is harvested to produce wood chips, charcoal and other products (Simbolon 1991). However, at Bintuni bay, mangrove wood is extracted for wood chips production, where mostly are collected from the main trunk. Due to economical and technical reasons, mangrove buttress roots, and branches are not collected and designed for residual wastes.

In Indonesia, mainly at Bintuni bay, forest operations to harvest mangrove wood are heavily depending on unskilled or human workers, grouped as labor based activities. It is probably due to habitat of mangrove at Bintuni bay, which is almost entirely covered with seawater (tidal wave). For example, when a full of tidal wave is occurred, there are no activities, likes wood felling, skidding or bucking because all mangroves areas are covered by seawater. Therefore, labor based employments are more suitable to this habitat. It is contrast to the non-mangrove forest or terrestrial logging companies, which are entirely relied on the heavy machines, equipments, and required huge capital investment.

With its unique ecosystem, ecology, habitat, and functions, mangrove sylviculture is also unique. Seed trees method was introduced in 1978 by the Indonesian Ministry of Agriculture, to give a guideline to harvest and manage mangrove forest resources in Indonesia. This silvicultural system is mainly concerned on natural regeneration of mangrove forest by leaving 40-mature and healthy trees aimed to produce seeds for the next rotation or cutting cycle. These-40-mature and healthy trees are then called as seed trees. This system of sylviculture briefly provides guideline for preparing forest extraction, such as forest inventory, forest operation, nursering, reforestation and rehabilitation of logged over forest areas.

In Indonesia, numbers of mangrove forest companies or concession are limited. Recently, there are two mangrove companies operated in Indonesian peninsula, West Papua at (Bintuni bay) and West Kalimantan. It is contrast to the non-mangrove forest companies, which are spread out at every island in Indonesia. Information, practices and publications on mangrove forest harvesting and managing for commercial purposes as well as its silviculture system used, are limited. Therefore, the practices of mangrove silviculture system employed at Bintuni bay could be shared to the others. Scientifically, it is important to gain

deeply understandings and widely views on mangrove forest resources managements, utilizations, and harvests objectively, and proportionally.

1.1. Goals

This paper is prepared to highlight the general philosophy of seed tree method, and provide whole views of practices of seed trees methods to manage and harvest mangrove forest resources for commercial purposes at Bintuni Bay as these practices have been taking place for more than 24 years. Population of natural regeneration of seedling and sapling under this silvicultural system are also briefly introduced.

2. Methodology

2.1. Data collection

Several undergraduate thesis related to practices, assessment, and investigation on sylviculture system of Mangrove available at Faculty of Forestry, The State University of Papua, were analyzed. Field visit to BUMWI Ltd areal concession were conducted in order to gather the complementary data needed.

2.2. Variables

On this paper, numbers of natural regeneration of seedling and sapling produced by seed trees method at logged over mangrove forest resources managed under the seed trees method were evaluated and presented. State of the seed trees at logged over mangrove forest was briefly presented. Natural regenerations under the seed trees were also pictured.

3. Results and Discussion

3.1. Mangrove forest

Mangroves or mangrove forests can be called variously, such as coastal woodland or tidal forest. It is called the coastal woodland because their habitat is mainly at the coastal areas, while the tidal forests is due to their natural existence and growth influenced significantly by tidal occurrence, period, height and seawater salinity (FAO, 1994). Mangroves are littoral plant formation of tropical and subtropical shelter coastline, growing below the high-sea water level and their root systems are immersed with saline water. Vegetation of mangroves are unique, especially their habitats, root systems, and functions. Habitats of mangroves are typically at any coastal areas, at any saline sediment or mud areas and always immerse with seawater. Because of this characteristic, mangrove forests usually are

planted with specific goals such as for buffer zone for tsunami, seawater intrusion, and heavy hurricane, tornado or typhoon mainly in the tropical areas.

Taxonomically, mangrove trees could be differentiated by their phenotypes variables, such as types of roots and seeds. There are four types roots for mangrove trees, still, knee, pneumatophores, plank, and butters roots, respectively (Kusmana et.al., 2003). Mangrove forests are evergreen, and no crown-stratifications, as we have usually seen from the terrestrial forests. Mangrove species have very obvious zonation. Ranging from coastal to inland areas is usually formation of *Sonneratia* spp at the muddy areas, followed by *Avicennia* spp, *Rhizophora* spp, *Bruguiera* spp, and *Ceriop* spp at relatively inland prior to terrestrial areas. However, this zonation is not general pattern. It will be varying and depends on number of factors, such as climate, salinity, coastal morphology, and freshwater outflow (FAO, 1994). At Bintuni bay, the zonation of mangrove forest is in accordance with the previous pattern.

3.2. Mangrove forest resources at Bintuni bay

Indonesian Ministry of Forestry has approved to provide a mangrove forest concession of 137.000 ha for harvesting and managing mangrove forest at Bintuni bay, particularly located from Bomberai – Aramasa rivers for wood chip company of BUMWI L.td (Irian Jaya Forestry Dept. 1994). This area of 137.000 ha is divided into green belt zone or protecting area (19.143 ha, 14 %, consisting of river buffer zone of 12.000 ha, and coastal buffer zone of 6.839 ha, and mangrove genetic biodiversity of 300 ha). Therefore, an area designed for mangrove wood extraction or production forest is 117.857 ha or 86%. This harvesting and managing mangrove forest resources concession started in 1998 and finished in 2006.

According to BUMWI Ltd document, mangrove species at Bintuni bay mostly belong to family Rhizophoraceae. Their compositions are summarized as follows: commercial species of Bakau (*Rhizophora spp)* is a dominant (69%), followed by local commercial species (21 %) of Langadai (*Bruguiera* spp), Api api (*Avicennia officianalis*), Nyirih (*Xylocaprus* spp), and Gedabu (*Avicennia* spp), and Tumuk (*Bruguiera* spp) for 21%. *Rhizophora* spp consist of two species, *R. mucronata (long and bigger propagules)* and *R. apiculata (short and smaller propagule).* They are locally called as blukap, and bakau, respectively. Others mangrove species are Tumuk (*B. gymnorrhiza*), which is characterized with its short seed, and Langadai (*B. parviflora*), characterized with its long seed, and Tengar (*Ceriop tagal*), Kusmana et al., (2003).

At average, the virgin forest of mangrove forest resources at BUMWI Ltd concession has density of 448 n/ha. *Rhizophora* spp and *Bruguiera* spp have densities of 189 and 154 n/ha, respectively, and the commercial species has of 343 trees/ha. Class diameter (ϕ) of 10-15 cm has density of 127 n/ha, while ϕ 50 cm up have an average density of 19 n /ha. If those standing trees are converted to volume in cubic meter (m^3), the commercial species has volume of 156,35 m^3/ha at average. This virgin forest, seedling population is 24.042 n/ha, and sapling population is 6.819 n/ha in average (Irian Jaya For. Depart 1994).

3.3. General philosophy of seed trees method

Indonesian sylviculture for mangrove forest is well known as Seed Trees Method, where harvesting mangrove wood and forest regeneration are whole processes, correlated activities, and depend one to another (Min. of Agriculture, 1978). Principally, when mangrove wood extraction or harvesting is conducted, a number of selected trees are left to produce seed for natural regeneration prior the next cutting cycle. This sylviculture system is a combined approaches of harvest and regeneration, in which an appropriate number of individual trees are left across an area to provide seed for the production of the next crop of trees (Ezell, 1942).

In general, seed trees method could be described as follow:
a) Cutting cycle or rotation is 30 years; b) 40 healthy, good shape of trees with diameter (Φ) ⊇ 20 cm, balanced crown, and well distributed across areas are left or availability of number of seedling is 1500 per hectare; c) trees prior for cutting is of ⊇ 10 cm at diameter at breast high (DBH); d) green belt zone of 50 m is for coastal side, and 10 m is for river side; e) Intensity of timber cruising is 5%, f) it is areas for stacking log maximum 1% of total areas; and g) Thinning is allowable Et+ 15-20, or 15-20 years after cutting.

3.4. Practices of seed trees method at Bintuni bay

Seed trees method practices and application at Bintuni bay, could be grouped into three important activities, such as Planning, Cutting, and Reforestation and rehabilitation. Detailed activities as listed as follows:

A. PLANNING

1. Mapping cutting unit area	Et-3
2. Forest inventory	Et-2
3. Labeling and numbering the seed trees	Et-1
4. Marking coastal and river buffer zone, protected areas	Et-1
5. Forest Engineering (infrastructures)	*Et-1*

B. CUTTING	Et
C. RE-FORESTATIONAND REHABILITATION	
1. Logged over area inventory	Et+2
2. Nursering	Et+3
3. Enrichment planting	Et+4
4. Rehabilitation	
4.1. Rehabilitation I	Et+3
4.2. Rehabilitation II	Et+4
4.3. Rehabilitation III	Et+5
5. Thinning	Et+5-20

Briefly, the sylviculture practices can be summarized as follows: 1) rotation or cutting cycle for mangrove forest is 30 years, each cutting unit area (CUA) is 100 ha, and a year consisting of 10-30 CUA (1000-3000 ha); 2) an inventory of standing stock of mangrove forest is conducted using systematic strip sampling, where 10 m is the wide strip, divided into 5 m left and right symmetrically, and distance among strip is 200 m. Sampling plot of 2 m x 2 m, and 5 m x 5 m are designed for seedling and sapling investigations, respectively. Ten sampling plots are made in one strip of 1000 m long, with 100 m distance for one sampling to another. Trees are recorded along with strip area (10 m x 1000 m, 1 ha), and trees diameters are measured at 110 m breast height (DBH); 3) A diameter of 10 cm up is a diameter limit for selecting trees to be felled. Axes or chain saws are used for cutting tools; 4) 40 trees in a hectare (n/ha) of mature, good shape (bole and crown) and healthy trees from commercial species having diameter 20 up cm at DBH are left for next rotation, aiming to produce seeds for natural regeneration. Importantly, the distance among these selected trees is 17 m at minimum; 5) Chain saw operator are felt the trees, and bucking into 2 m long. 6). Logs are debarked by cutting crew; 7) Debarked wood (log) are manually transport from cutting area by man using wooden sledge, shown in Figure 1a, and stacked near the riverside (Figure 1b).

a) b)

Figure 1. Skidding method (a) and stacking log used for harvesting mangrove wood at Bintuni bay, West Papua.

The logs, then, are shipped into industry through rivers, or sea; 8) Re-plantations or regenerations of commercial species, Rhizophoraceae family, are undertaken at any damage areas with less seedling such as, former stacking log, skidding tracks, worker/based camps, and unreachable tidal wave; 9) 200 m and 100 m in width for wide, and narrow rivers, respectively, are designed as undisturbed areas for green belt zones

3.5. Harvesting mangrove wood

Harvesting mangrove wood, sometimes called as extraction of wood mangrove forest, is conducted in accordance to seed trees method, as described at the previous paragraph. After forest inventory and forest operation action plans have been approved, harvesting mangrove forest is initiated. Mangrove trees are felled down using small handily chain saw, usually Sthill 90, and the felled logs are bucked into 2 m long by chain saw operator, and debarked by the logging workers. Group of workers of six-eight people are responsible for debarking, and transporting (*skidding*) logs to the stacking place, mainly closed to the riverside.

Four or five debarked logs were wrapped with plastic ropes on the wooden sledge, a wooden device for skidding. The skidding tracks are constructed with residual wood of mangrove, such as branches, and arranged in such pattern manually, as described in Figure 2. Two or three workers pull the wooden sledge forward following the skidding tracks (see Figure 1a) to the stacking logs at near the riverside, as illustrated in Figure 1b.

Figure 2. Skidding track are manually constructed

From Figure 1(a-b) and 2 clearly shows that there are no heavy machines or equipments, such as skidding tractor (*skidder*), jack loader, operated on the mangrove wood extraction in the forest site. This skidding method, as illustrated in Figure 1, which is manually conducted by group of workers, can eliminate the environmental damages, for example soil compaction and erosion, water and soil pollution, and injuring or harming the remained standing forests. More importantly, this skidding method significantly supports the principles or philosophy of reduced impact logging (RIL) for harvesting wood extraction, which mainly applied for terrestrial of tropical forests

After being stacked at temporary log place, as illustrated in Figure 1b, the mangrove logs were measured for their volume. Because of irregular shapes, taping formation etc, the staple meter (m^3), length x width, and height, were used to determine the volume of the log stack. However, one staple meter is equally converted to 0.5 m^3 of real log volume. The log stack is marked using special white chalks for legality and identification.

Loading mangrove logs to pontoon, opened wood-ship, to be transported o wood chips industry is established during low tidal wave. Mangrove logs are loaded manually by logging workers using the principle of gravitation forces. When the tidal wave is rising, the pontoon is transported out from the forest sites to the industry by tugboats or ships. After being unloaded from the pontoon, these logs are stacked in mixture, rolled to conveyor prior to be chopped by chipper. The woods chips produced are stored in the open field and loaded into the ship for export.

Because mangrove wood is processed into the wood chips, mainly for export market, the smallest diameter of trees, 10 cm are eligible to be felled or harvested. At Bintuni bay, the mangrove species being felled are *R. apiculata*, *R. mucronata*, *B. gymnorrhiza*, *B. parviflora*, and *Ceriop tagal*. These mangrove

species have highly economic value used for raw material of pulp and papers, charcoal, and briquette (Simbolon 1991).

3.6. Selecting and marking the seed trees

There are three mangrove species selected for seed trees purposes, namely *Rhizophora* spp, *Bruguiera* spp, and *Ceriop* spp prior for the next cutting cycle. The trees being selected must fulfil four criteria, such as healthy without injury (bark, root, branches, and trunk), had good and ideal shape (straight bole, crown distributed symmetrically, at lest 17 m in distance between the selected trees, and had ϕ 10 cm up. Then, the selected seed trees are marked water proof yellow plastic of 2.0 cm square, and clammed into the trees at 200 cm height, where number of seed trees and cutting plot number are written for identity and mapping purposes. 40 trees or even more are selected in one hectare. Therefore, it will be at least 4000 selected trees for seed production in one cutting plot (100 ha for each). When the seed trees are felt down or damages, a new seed trees is selected.

Mangrove seed or propagules are very light, not bulky as compared to mangrove wood, or its branches. When the seawater up or tidal level are up, the mangrove seed could move or migrate from one to another places in accordance to the tidal water flow. Therefore, these mangrove seeds could migrate widely, and then grow sporadically at any opened or shaded areas at any logged over mangrove forest. Mostly, the mangrove seeds are growing at the seaside of the mangrove forest due to heavy density of seedling at the outer of coastal area. At this case, mangrove seeds could not penetrate the heavy dense of seedling at outer part of mangrove zonation.

3.7. Statue of logged over area of mangrove forest resources at Bintuni bay

3.7.1 State of seed trees in logged over forest

Evaluation and investigation on the statues of logged over mangrove forest, natural seedling production, as well as state of the seed trees were conducted by several researchers. Previous research at Bintuni bay revealed that numbers of the seed trees recorded at logged over mangrove forest a year after cutting, with sampling intensity of 25 % (5 of 19 cutting unit area (CUA) of 2002 year period), is 99 n/ha at average. They consist of four commercial mangrove species, *R. apiculata*, *B. gymnorrhiza*, *B. parviflora*, and *C. tagal*, respectively (Ukru, 2003). Surprisingly, there were two CUA, which more than 100 seed trees per ha, 168 and 112 (n/ha) were recorded. These numbers of seed trees are exceed the minimum seed trees required by the mangrove silvicultural system, which is only required for

40 trees (Ministry of Agriculture 1978). These finding shows that the numbers of the seed trees are double than that recommended.

With regards to the seed trees state, their condition, and level of injury due to felling activities, an assessment of intensities of seed trees damages due to practices of seed trees sylvicultural system at BUMWI Ltd has been investigated (Ukru, 2003). Percent values of injury of the seed trees (K) are determined by dividing the numbers of injury seed trees (R), with the total numbers (S+R) of the seed trees, healthy (S) and injury (R), in one CUA and expressed in percent (%). Three categories were used to express the injury levels of the seed trees (K), where K≤ 25 % is poor, >25 ≤ 50 % is medium, and >50 % is weighty (Ukru 2003). It is reported that only 23 % (22.6 of 99 n/ha) of the seed trees were injured. Surprisingly, majority or 77 % (76.6 of 99 n/ha) of the seed trees are healthy or in good state. It is then concluded that the injury levels of the seed trees at BUMWI Ltd operated in Bintuni bay are poor, or less than 25 %.

With respect to the diameter of the seed trees, it is also highlighted that 33.1 % of the recorded seed trees have an average diameter of ≤ 20 cm, while majority (66.9 %) have diameter ≥ 20 cm (Ukru 2003). This findings clearly support that activities of mangrove wood extraction using seed trees method have a limited effects or even tolerable impact on the remained seed trees. Also, it is proved that generally this sylvicultural system result in minor injury on the logged over mangrove standing stock. From these results, it is presumably that the seed trees with $\phi > 20$ cm could produce enormous number of seeds than those of $\phi \leq 20$ cm.

If the states of the seed trees are evaluated in detailed, the bole or trunk injury occupy of 8.6 %, crown injury of 8.6 %, and injuries for roots or buttress of 5.4 %. If we compared among mangrove species, the highest injury was recorded from *R. apiculata (*11.8 %), followed by *B. gymnorrhiza* (9.6 %), while the lowest was from *B. parviflora (*1.2%), Ukru (2003). From these findings, it is clearly shown that minimum injury of the seed trees are probably due to two reasons, due to mangrove tree characteristic, and their standing density. Mangrove trees at Bintuni bay is very tall, more than 25 m in high and produce at average with clear bole of 20 m, diameter 60 cm (Kusmana et al., 2003). Consequently, the crown is standing at upper side of trees, and when the trees are felled down not harmed any serious injury to the other trees because the trunks has tall clear bole part. Typically, mangrove forest is very dense, as illustrated in Figure 3. This dense could generate mangrove trees to grow vertically and produce a tall clear bole or straight trunk. In other words, the productions of branches are minimum. Therefore, when mangrove trees are being felled, the damage of bole, crown, and root are minimum because there are no branches being crash down by the felled trees.

Figure 3 Dense of natural regeneration of *Rhizophora* spp after 15 years cutting at mangrove forest concessions area of BUMWI Ltd.

3.7.2. Natural regeneration under the seed trees at logged over area two years after cutting (Et+2)

Population of seedling and sapling under the seed trees at the mangrove logged over area two years after cutting at Bintuni bay has been reported by Elnatan (1997). Two commercial mangrove species were selected, *Rhizopora spp* and *Bruguiera spp*, divided into four-class diameter. Population of natural regeneration of seedling and sapling were investigated using sampling plot of 3 m x 3 m and 4 m x 4 m for seedling and sapling, respectively. 15 trees were selected to represent each diameter class. The results are summarized in Table 1.

Table 1 Population of seedling and sapling under the seed tree at the mangrove logger over area two years after cutting at Bintuni bay.

Mangrove Species	Class of Diameter (cm)	Seed trees number (n)	Clear bole (m)	Mean of High	Mean of crown diameter (m)	Seedling (n)	Sapling (n)	Total Nat. Reg. (7+8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Rhizophora spp	20-29	15	9.02	10.67	3.55	359	15	374
	30-39	15	12.6	12.73	4.50	529	13	542
	40-49	15	10.73	14.33	6.41	577	6	583
	50 up	15	11.6	12.6	5.95	691	7	698
Total		60	43.95	50.33	20.41	2156	41	2197
Mean			**10.99**	**12.58**	**5.10**	**539**	**10.25**	**549.25**
Bruguiera spp	20-29	15	8.73	10.6	3.63	1856	6	1862
	30-39	15	9.17	13.33	4.45	1218	18	1236
	40-49	15	6.93	10.73	4.37	372	3	375
	50 up	15	9.8	11.63	4.7	331	14	345
Total		60	34.63	46.29	17.15	3777	41	3818
Mean			**8.66**	**11.57**	**4.29**	**944.3**	**10.25**	**954.5**

Sources : Elnatan (1997)

In spite of class diameter, Table 1 indicates that mangrove species of *Bruguiera* spp produce seed or propagules higher that those of *Rhizophora* spp. For *Bruguiera* spp, higher in trees diameter, will produce less seedling, and class diameter of 20-29 cm produce the highest seed or propagules. However, this phenomenon is against for *Rhizophora* spp.

3.7.2 Natural regeneration at mangrove logged over area

Mangroves are widely known for its remarkable regeneration, mainly for producing seeds. Mangrove trees produce huge quantity of seeds compared to other forest vegetation, such non-mangrove trees. An example of young seeds produced by *R. apiculata* at age of 10 years near the base camp of BUMWI Ltd in Bintuni bay are shown in Figure 4a, while Figure 4b show the seed production of *R. mucronata*. From this figure, it is clear that mangrove species could produce enormous seeds. When these seeds are mature, they will fall down, sometimes, dipping to the ground soil, and grow naturally as seedling. This natural characteristic of mangrove species is of their unique characteristic to be used in

formulating the sylvicutural system of seed tree method in Indonesia (Ministry of Agriculture 1978).

a) b)

Figure 4. Young seeds of *R. apiculata* (a) and *R. mucronata* (b) near base camp BUMWI Ltd

An investigation of natural seed regeneration for different sites at logged over mangrove forest areas two years after cutting at Bintuni Bay, has been investigated and reported by Beto (2003). Four different sites selected for collecting the data are at stacking log, camp of worker, skidding tracks, and unreachable tidal wave, respectively. A summary for number of seedling and sapling population (n/ha) recorded from those three sites is tabulated in Table 2.

Table 2 Population of natural regeneration for different sites at logged over mangrove forest areas two year after cutting at Bintuni bay.

Logged over areas of mangrove forest sites	Number of natural regeneration (n/ha)		
	Seedling	Sapling	Total
Stacking log	895,83	70,84	966,67
Working camp	4166,67	900,00	5066,67
Skidding track	3058,33	606,93	3665,26
Unreachable tidal wave	359,38	26,04	385,42

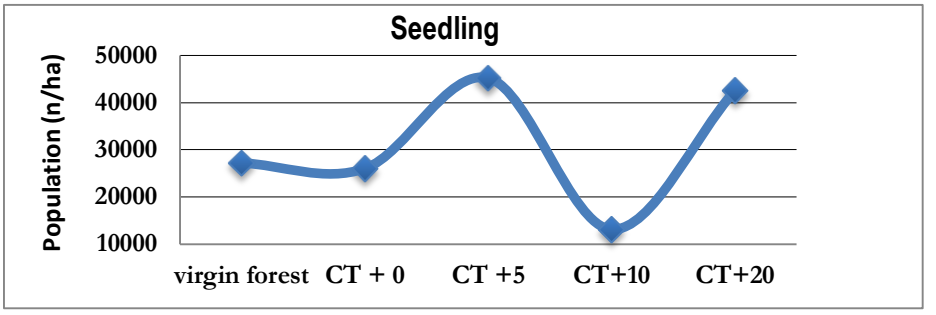
Source: Beto (2003)

Table 2 indicates that majority of logged over mangrove forest sites had enormous quantity of mangrove seed regeneration, except for unreachable tidal wave. This area has the lowest seedling (359,38 n/ha) and sapling (26,04 n/ha). This means that re-plantation is highly required for this area. However, the other

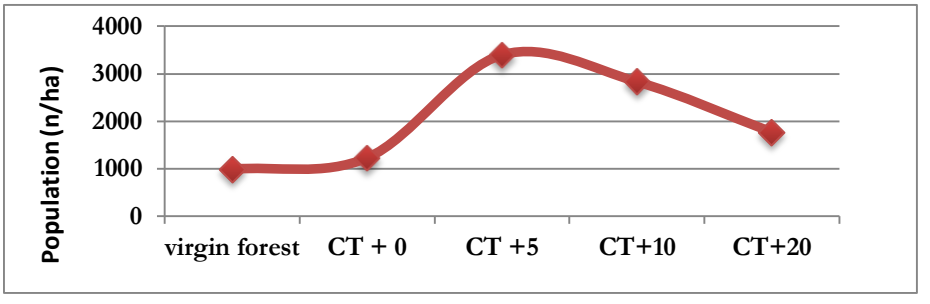
sites, stacking log, working camp, and skidding track, had relatively higher natural regeneration. The silviculture system of mangrove forest indicated that at former stacking logs or the most outer of the cutting plot must have at least 2500 n/ha of seedling. Therefore, an extra works for re-plantation is highly needed at this site, as the number of mangrove regeneration is only 966,67 n/ha, still needed to match a minimum of 2500 n/h recommended. The two other sites, working camps, and skidding tracks, are not additionally be replanted, because of their mangrove regeneration are exceed of the number required by the seed trees method, which is 2500 n/ha for seedling and sapling.

Another state of standing mangrove vegetation, such as seedling, sapling, and trees, respectively, of logged over mangrove forest from East Kalimantan has been investigated and reported by Kusmana (2010). Their results are summarized and shown in Figure 5 a – c.

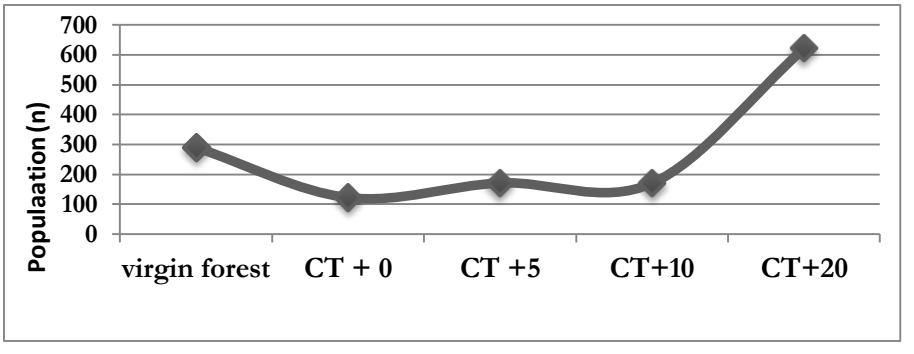
a)



b)



c)



CT+0 : cutting year, CT+1 : 1 year after cutting, CT+5 : 5 years after cutting, CT+10: 10 years after cutting, and CT+20: 20 years after cutting

Figure 5. Densities of vegetation of mangroves, Seedling (a), Sapling (b), and Trees (c), from logged over forest from East Kalimantan.

As illustrated by Figure 5-a, population of seedling at logged over mangrove forest are fluctuated, but in general the seedling regeneration are increased substantially. More importantly, the density of seedling is higher (42.500 n/h) at 20 year after cutting (CT+20) than that of virgin forest. Figure 5-a also shows that their densities are still exceeding 2500 n/ha as required by the seed trees method sylvicultural system (Ministry of Agriculture 1978).

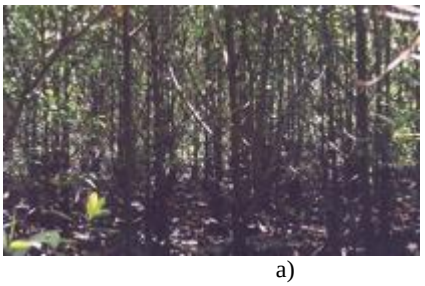
Natural regeneration of sapling is also exceeding the density required by the mangrove sylvicultural system of 2500 n/ha, particularly at five and ten year after cutting, CT+5 of 3.397 and CT+10 of 28.232 n/ha, respectively, as shown by Figure 5-b. This Figure 5-b also indicates that 20 years after cutting, the sapling mangrove vegetation is decreasing due to changing the state to the mangrove trees.

Density of trees at logged mangrove over forest is increased gradually from 10-20 years after cutting, as been illustrated by Figure 6-c, and at 20 years after cutting the density (622 n/ha) is remarkable higher than that of the virgin forest (290 n/ha). It is presumably that cutting trees will automatically open the forest canopy, more sunlight reaching the forest ground. They will promote and generate to grow the mangrove seeds more fastly.

3.8. What are needed for the mangrove silvicultural system

Application of the seed trees method for mangrove silvicultural system clearly indicates that regeneration of logged over mangrove forest at East Kalimantan 20 after years cutting can naturally well-developed. Similarly, this sylviculture system is also working well at Bintuni bay, as been elaborated at the previous paragraphs. These results clearly indicated that seed trees method could be used continuously for mangrove forest wood extraction and management in Indonesia.

With respect to the natural capacity of mangrove species to re-generate themselves naturally, it is clearly indicated by the fact that the density of natural regenerations for sapling state at the logged mangrove forest at BUMI Ltd in Bintuni bay after ten year cutting are absolutely dense, as shown in Figure 6 a-b.



a)

b)

Figure 6. Dense of natural regeneration for sapling sate of *Bruquiera* spp (a) and *Rhizophora* spp (b) after ten year cutting at Bintuni bay.

Figure 6 shows the density of natural regeneration from the two mangroves species, *Bruquiera* spp (Fig. 6-a), and *Rhizophora* spp (Fig. 6-b) at sapling state or after ten years cutting at BUMWI Ltd Bintuni bay. As illustrated by Fig. 4, and Fig.6 (a-b), respectively, numbers of natural regeneration for mangrove at sapling states, are enormous quantity, and they are very dense. At this state of condition, competition among the individual sapling is very high, and consequently will establish a low quality of mangrove standing stock for the next rotation. Therefore, thinning is one way to improve this condition. Thinning is silvicultural action to reduce competition among the forest vegetation aimed to establish high quality and quantity of forest standing stock for the next cutting cycle.

If we used an illustration of state of mangrove regeneration in Figure 6-b, the thinning action could be undertaken from ten years after cutting. The thinned mangrove wood could be processed to wood chips. Therefore, for future practices of seed trees method, human intervention is needed to establish a valuable mangrove standing stock for sustainable and progressive productions, like thinning, processing residual waste (branches and buttress) of wood extraction.

Re-plantation at any low mangrove regeneration is also highly required to establish mangrove-standing stocks for the next cutting cycle. This silvicultural actions are mainly focused at any logged over areas, which have less natural regeneration, such as former areas of skidding tracks.

3.9. Remarkable achievement of Seed trees method practices today at Bintuni bay

Official and collaborative inspections and evaluations of practices the seed trees method at mangrove forest concession for Bintuni Utama Murni Wood industry (BUMWI) Ltd have been conducted, Irian Jaya Forest Dept. (1994). The results indicated that this company gained score of 8.46 of 10.00. This means that the mangrove silvicultural system of seed trees method has been using to manage and harvest mangrove forest resources.

Pertaining to its great records and achievement in applying seed trees method for harvesting and managing mangrove forest at Bintuni bay, West Papua for more than 24 years, a new mangrove forest concession of 82.100 ha, for the second term, has been approved since 2007 for BUMWI Ltd (Indonesia Ministry of Forestry, 2007). Furthermore, upon successfulness of practices of this Seed trees method to harvest and manage mangrove forest resources at Bintuni bay, two certificates of " Sustainable management for production forest, and Chain of custody", respectively, has been awarded (Sarbi, 2011. Various assessments on practices of the Seed trees method at Bintuni bay, and East Kalimantan clearly give

evidences that this mangrove silvicultural system is working. Statue of the natural regeneration of seedling and sapling, and the seed trees at any logged over area of mangrove are also measureable. More importantly, this seed trees method is suitable, and adoptable for harvesting and managing mangrove forest toward for sustainable.

4. Conclusion

It can be summarized that mangrove forest has a unique habitat, and vegetation. Seed trees method of silvicultural system developed for harvesting and managing mangrove forest has been in practices in Indonesia since 1978, and now day this system is still working, particularly at BUMWI Ltd in Bintuni bay. It is clearly indicated that using this silvicultural system, the mangrove forest are able to regenerate naturally in producing seedling, sapling to establish standing stock for the next cutting cycle.

This system of silviculture is also resulted in minimum impact on the environment, and ecosystem of the logged over areas. The states of the seed trees at logged mangrove forest area are mostly in good condition and noticeable seed production. As mangrove forest harvests are human based labor, and no-heavy or logging machines are used, the impacts on the surrounding environment and ecosystem are eliminated. This method does really supports the philosophy of reduced impact logging (RIL).

With this seed trees method not only the government, mainly the ministry of forestry, but also independent certification organization have acknowledged the practices of this silvicultural system to harvest and manage mangrove forest resources in proportional ways toward for sustainable

In addition, it is recommended that the thinning action could be undertaken for sapling vegetation in order to improve growing performance and increase standing stock for next cutting cycle.

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