Utilization System of Sandalwood in Aceh Besar and Pidie Districts

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Abstract. The utilization of sandalwood is a series of activities to utilize and seek sandalwood, including: managing of sandalwood trees and sandalwood processing. This study aims to evaluating the utilization of sandalwood in Aceh as a unified system. Sandalwood trees management analyzed based on structures of the trees, management techniques and utilization rates of sandalwood. Analysis of the physical characteristics of wood and the proportion of santalol compounds are used for the purpose of sandalwood processing. The results of the study indicate that sandalwood management has not been carried out sustainably with the structure of the sandalwood trees dominated by young trees, no cultivation activities and low harvesting efficiency with harvesting method using tree lenghth logging plus root. Processing of sandalwood for the purposes of woodcrafts and sandalwood essential oils that meets quality standards comes from the trees with a proportion of terrace wood above 48.53% with diameter (dbh) ≥ 15 cm.

1. Introduction

Sandalwood is one of the forest products that has high economic value. In the world, sandalwood known as white sandalwood, east indische sandalwood, sandalo (Portuguese), sandelholz (German), and sandelhout (Dutch). High economic value of sandalwood comes from fragrance of the stems and roots used to be for wood crafts, essential oils, and incenses and traded by weight unit in kilograms [1, 2]. The utilization of sandalwood in Indonesia has long been carried out by the community from Province of NTT and other surrounding areas. The utilization of sandalwood in Province of Aceh have been known from the data of sandalwood production released by the Central Statistics Agency (BPS) of Aceh from 2003 to 2015 in total of 357 124 tons. Areas that have the potential of sandalwood distribution in Province of Aceh including: Aceh Besar and Pidie District. The utilization of sandalwood is conducted by harvesting the main stem and the root part without any other processing activities (as raw material), so it has not been used optimally [3].

The utilization of sandalwood in this study guided the concept of Timber Management by Simon [4] consisting of five activities, e.g. planting, preserving, harvesting, processing and marketing which were then grouped into three sub-systems, namely sub-systems of management, processing and marketing. Studies on the utilization of sandalwood in the context of each sandalwood sub-system have been widely
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done, while studies on the utilization of sandalwood as a system that are regularly interrelated so as to form a totality of those above activities have never been done. This study aimed to evaluating the utilization system of sandalwood in Aceh Besar and Pidie Districts based on management and processing sub-systems, by 1) analyzing sandalwood trees management in terms of sandalwood trees structures, management techniques and harvesting efficiency, and 2) analyzing the relationship of sandalwood quality based on the diameter of the tree and the proportion of terrace wood.

2. Method

This research was conducted in April 2017 - January 2018 in Kuta Malaka and Suka Makmur Sub-districts (Aceh Besar District) and in Muara Tiga and Padang Tiji Sub-districts (Pidie District). Laboratory research was conducted at the Quality Technology and Wood Improvement Laboratory, Department of Forest Products, Forestry Faculty IPB and Non-Wood Forest Product Processing Laboratory, Research and Development Agency, Ministry of Environment and Forestry.

2.1 Sandalwood trees structures

To determine the availability of sandalwood stocks based on the structures of trees, this study calculated the number and measured the diameter and height of sandalwood trees in 50 samples plots by using purposive method [5]. Based on SNI Number 01-5008.6 [6], tree with diameter (dbh) ≥ 15 cm categorized as a tree level.

2.2 Management techniques

Sandalwood management techniques can be identified by conducting observations and in-depth interviews with farmers. Sandalwood management techniques in this study includes planting, preserving and harvesting of sandalwood trees [7]

2.3 Harvesting efficiency

The efficiency of sandalwood harvesting aims to determine the level of the using of sandalwood from sandalwood trees that have been felling down. The harvesting efficiency of sandalwood is conducted by measuring the volume of sandalwood trees, and the volume of sandalwood waste. Sandalwood waste referred to the waste from felling trees process, bucking of stems and transportation of sandalwood [8]. Sandalwood waste volume was calculated by staple meter system [9].

2.4 Physical wood properties

Testing the physical properties of wood was conducted by providing a sample of sandalwood test with a size of 2 cm x 2 cm x 2 cm based on British Standard [10]. Physical parameters of wood used including: terrace color, specific gravity and shrinkage in each side of wood.

2.5 Santalol compound

The standard for determining the quality of sandalwood essential oil is the proportion of Santalol compound. Sandalwood grinded into sandalwood powder through a 20 mesh filter, based on the tree diameter classes and the proportion of terrace wood on the stems and roots (Table 1). Sandalwood powder was distilled using a water and steam methods for 8 hours to produce sandalwood essential oil. To find out the proportion of the santalol compound on sandalwood oil analyzed by GC-MS method.

| Diameter classes | Tree diameters (cm) | Terrace wood proportion (%)|
|------------------|--------------------|----------------------------|
|                  | Stem               | Root                       |
| 1                | < 5                | 0.00                       | 0.00                       |
| 2                | 5 - < 10           | 31.04                      | 38.54                      |
| 3                | 10 - < 15          | 36.73                      | 39.48                      |
| 4                | ≥ 15               | 48.53                      | 52.36                      |
3. Result and discussion

3.1 Sandalwood trees structures

The structure of sandalwood trees at the study location was dominated by young trees (seedlings and saplings) with 493 individuals and volumes of 1.02 m$^3$, while the mature trees (poles and trees) were only 51 individuals of 1.75 m$^3$ (Figure 1). This structure pointed out the need of intensive preservation to reach tree level, and showed that the sustainability of sandalwood trees with existing management techniques were not be achieved yet.

Sandalwood tree structure at the study site formed an inverted J-shape like the structure of normal forest trees with an exponential equation $Y=1399.2 \ e^{-1.21x}$ ($R^2 = 96.38\%$). The proportion of matures and young level of sandalwood trees is 10.34% (low), higher than the proportion matures and young level of sandalwood trees in 23 villages in the Timor Tengah Selatan Regency, NTT Province (9.25% with the number of young trees of 1 286 individuals and mature trees of 119 individuals) [5].

![Figure 1. Sandalwood trees structures.](image)

Sandalwood regeneration at the study site growth naturally through root sprouts and seeds. The highest number of seedlings originating from root sprouts were in Muara Tiga by 35 individuals and Padang Tiji by 25 individuals, while the highest number of seedlings originating from seeds were in Suka Makmur by 33 individuals and Kuta Malaka by 8 individuals. This shows that the growth of sandalwood trees originating from root sprouts was dominant than seedlings with clumps characteristics. Sandalwood regeneration for sapling level which comes from the largest number of root spouts in the Suka Makmur and Padang Tiji by 6 individuals, for Muara Tiga by 3 individuals and Kuta Malaka only 2 individuals. Sandalwood natural regeneration originating from root spouts has the greatest potential of growth compared to regeneration from seeds which reaches 18.46% - 27.21% [12]. Sandalwood regeneration using a root sprout system through lateral root cutting can be used as one of the techniques to produce seedlings for sandalwood cultivation in large numbers, so it is expected to be able to increase the successfull of sandalwood cultivation [13].

3.2 Management technique

Sandalwood management techniques carried out by the Mukim community are still traditional, including the activities of protection, preservation and harvesting of sandalwood. Mukim community does not carry out nursery and planting activities (cultivation), this is due to Mukim community's perception of sandalwood trees which are difficult for cultivating. This perception may influenced by poor local knowledge on seedlings and planting of sandalwood [14]. Community reluctance for planting sandalwood was generally due to the low success rate of sandalwood regeneration around 20% and the hemi-parasite characteristics of sandalwood which required the existance of host plants [1].
The role of the Mukim community to restore sandalwood trees is to assist the process of natural regeneration, maintaining and protecting of existing natural sandalwood regeneration. Activities carried out by Mukim community to assist the natural regeneration process by spreading sandalwood seeds during the fruiting season. The efforts from the community to do independently in developing sandalwood trees through artificial regeneration are very difficult, this is due to the local knowledge and technology of artificial regeneration owned by the community were limited.

Protection activities undertaken by the community for sandalwood regeneration are by producing fences using easel trees and iron wires to prevent livestock (goats) from eating sandalwood leaves and stepping on sandalwood seedlings that will damage or even kill the existing natural regeneration. The activity of maintaining sandalwood natural regeneration by the community were carried out by clearing the land of sandalwood regeneration from weed and other competing plants which can disturbing the growth of sandalwood seedlings.

The stages of sandalwood harvesting carried out by the community including: root excavation, clearing of branches and twigs, bucking of stems (commercial and non-commercial) and transporting of logs. These harvesting stages are similar to the stages of sandalwood harvesting that carried out by the local community in Province of NTT, including felling of trees, bucking of stems, extracting roots and transporting [7]. The tools used in harvesting of sandalwood trees are manually by using axes, saws, machetes, hoes and crowbars. The harvesting stages in sandalwood trees are very different compared to other commercial trees harvesting (Dipterocarp family), which generally consists of felling, stem bucking, skidding, loading and unloading and transportation using mechanical equipment [8]. The distribution of sandalwood tree volume that is felling down, the volume of waste and the level of harvesting for each sandalwood tree at the study site can be seen in Figure 2.

![Figure 2](image.png)

**Figure 2.** Trees volume, waste volume, and harvesting efficiency of each sandalwood tree.

Sandalwood harvesting techniques carried out by the Mukim community have in common with the method of tree length logging (TL) in the harvesting of commercial trees in natural forests. The TL method in commercial trees in natural forests is carried out by harvesting trees where the process of removing the wood is carried out simultaneously between the branch-free stem and the stem above the first branch up to a minimum diameter of 20 cm [15]. The TL method on sandalwood trees has a minimum limit on the diameter of stems, plus the process of extracting the root part. The terrace wood found on the stems and roots of the sandalwood tree is the most valuable part of trees and has a high proportion of Santalol compounds. Root extracting in the harvesting activity by leaving the living lateral roots can increase the growth chances of root sprouts than the seeds [12].
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Average volume of sandalwood trees harvested is 0.0346 m³ with an average waste generated of 0.0054 m³ or has a harvesting efficiency rates of 66.46%. The efficiency rate of sandalwood was lower than the efficiency rates for other commercial trees in natural forests which reaches 74% -75% [8]. Many parts of harvested sandalwood stems with diameter around 5 cm become waste without any proportion of terrace wood. Low efficiency rate of sandalwood harvesting is due to the traders do selecting of sandalwood raw material based on diameter and proportion of terrace wood. Sandalwood can be traded if it has a diameter > 2.5 cm with a minimum length of 100 cm, has terrace wood, and free from cracks and rot defects [16].

3.3. Sandalwood processing Sub-system

The use of sandalwood for specific purposes such as wood craft, essential oil and incense determined by the physical properties of wood and the proportion of Santalol compounds [17]. The physical properties of wood that affect the quality of sandalwood products including: color, wood specific gravity and retention/shrinkage capacity [18]. The proportion of Santalol compounds in sandalwood produce the distinctive fragrance of sandalwood for essential oil or incense. Santalol compound are main component of sandalwood essential oil which is used as the main benchmark in determining the quality of the oil. Optimization in utilizing sandalwood based on the physical properties of wood and Santalol compounds can increase the value of sandalwood. The physical wood properties and Santalol compounds found in sandalwood products showed in Table 2 [11].

| Trees diameter classes | Proportion of terrace wood (%) | Color of terrace wood | Wood specific gravity | T/R shrinkage (%) | Color of essential oil | Oil specific gravity | Santalol compounds (%) |
|-----------------------|-------------------------------|-----------------------|----------------------|------------------|-----------------------|----------------------|------------------------|
| S. Stems:             |                               |                       |                      |                  |                       |                      |                        |
| 1                     | 0.00                          | -                     | 0.69                 | 2.57             | yp                    | 0.9636               | 14.00                  |
| 2                     | 31.04                         | b                     | 0.73                 | 2.32             | yp                    | 0.9641               | 34.04                  |
| 3                     | 36.73                         | bdb                   | 0.79                 | 2.13             | yp                    | 0.9673               | 35.73                  |
| 4                     | 48.53                         | bdb                   | 0.87                 | 1.93             | yp                    | 0.9695               | 45.83                  |
| Roots:                |                               |                       |                      |                  |                       |                      |                        |
| 1                     | 0.00                          | -                     | 0.71                 | 1.63             | yp                    | 0.9641               | 11.10                  |
| 2                     | 38.54                         | b                     | 0.78                 | 1.58             | yp                    | 0.9648               | 33.52                  |
| 3                     | 39.48                         | bdb                   | 0.81                 | 1.58             | yp                    | 0.9681               | 39.73                  |
| 4                     | 52.36                         | bdb                   | 0.88                 | 1.46             | yp                    | 0.9696               | 44.96                  |

Where: b : brown       bdb : brown and dark brown  yp : yellow pale

3.3.1 Wood crafts

The usage of sandalwood as a wood crafts material has been widely carried out in the Province of Yogyakarta and Bali. The use of sandalwood as a wood crafts material such as for carving, sculpture and souvenirs are based on several parameters, including: having a color gradation of terrace wood, wood specific gravity from medium (0.40–0.75) to heavy (> 0.75) and low ratio of tangential and radial shrinkage (<2.00%). Sandalwood for sculpture and carving with high artistic value must be protected from cracks or broken defects caused by shrinkage of wood especially in tangential and radial plane. Sandalwood with medium to heavy specific gravity generally has high cell cohesiveness and thick cell walls, so it tends to be more resistant to the possibility of deformity. Standard categorization for the woodcraft purpose including color (there are any gradation), wood specific gravity (medium to heavy) and T/R shrinkage ratio (<2.00) [19, 20]. Based on this standard, the diameter class of sandalwood trees that meets the standards was from diameter class 4 (dbh ≥ 15 cm) with the proportion of terrace wood ≥ 48.53%.

Wood with T/R ratio > 2.00 for sculpture and carving materials can trigger defects due to the drying process. Shrinkage of wood may occur due to loss of water in wood cells during the drying process in a
short time. Evaporation of water and movement of water in wood cells are very dependent on its location in the wood, the temperatures and the duration of the drying process. In the longitudinal plane of wood the movement of water evaporates faster than the tangential and radial planes. The movement of water that too fast through a longitudinal section (cross section) and not balanced with tangential and radial section will produce deformities, such as cracks, breaks, and curves [20].

3.3.2 Essential oils

Sandalwood essential oil is a very important product in fragrances, soaps, cosmetics and pharmaceutical industries. This is because sandalwood essential oil has a distinctive fragrance and it’s used as a binding agent for other fragrances and it’s difficult to reproduce synthetically [21, 22]. The fragrance of sandalwood essential oil is caused by santalol compounds (α- and β-santalol) which are main characteristic of sandalwood essential oil [21, 23]. Based on the previous trials, sandalwood essential oil is effectively produced through the distillation process using water and steam method for 8 hours. The distillation process takes a long time due to sandalwood essential oil has a high boiling point compared to the boiling point of water [24].

Sandalwood essential oil that’s produced from the distillation process is not a pure compound but a mixture of several organic compounds. To find out the quality of sandalwood essential oil in each diameter classes of sandalwood trees, three parameters were tested, e.g. color, specific gravity and proportion of Santalol compounds (α- and β-santalol). These three parameters compared with standards ISO 3518 2002, such as: color (yellow pale), Specific gravity (0.968-0.983) and proportion of santalol compounds (α-santalol 41-55%, and β- santalol 16-24%). Based on this comparison results, the tree diameter classes of sandalwood that meets the quality standards for the purpose of essential oil was from sandalwood with diameter class 4 with proportion of terrace wood > 48.53%.

Sandalwood essential oil which comes from stems and roots in diameter class 4 also meets the quality standards of > 43% for α-santalol compound and > 18% for β-santalol compound. Proportion of α-santalol and β-santalol compound which were able to meet these standards showed that sandalwood oil was obtained from materials derived from mature trees and suitable for harvested [25]. This shows that sandalwood trees with diameter class 4 (≥ 15 cm and proportion terrace wood > 48.53%) has been meet mature trees and suitable for cutting compared others diameter classes and meets the quality requirements for sandalwood essential oil.

The proportion of α- and β-santalol that do not meet the requirements standards [25, 26] can provide an early indication for sandalwood oil with low quality. Low proportion of α- and β-santalol showed that the material for essential oil were not purely from sandalwood, but derived from young trees, synthetic or semi-synthetic reproduction compounds (sandella or santalidol), or from other species of sandalwood, such as: S. spicatum, S. acuminatum, S. lanceolatum, S macgregorii, and S. austrocaledonicum [25]. Diameter of sandalwood trees has a positive correlation with the proportion or diameter of terrace wood and the proportion of Santalol compounds, so that big diameter of sandalwood tree with big proportion of terrace wood will produce high quality of sandalwood essential oil which characterized by high Santalol compounds [27]. Therefore, it can be concluded that the diameter class 4 of sandalwood tree with the proportion of terrace wood> 48.53% is a mature tree and ready for felling down and suitable for sandalwood essential oil.

3.3.3 Incense

The socio-cultural value of sandalwood towards the community can be known from its use for fragrant incense in the process of certain religious rituals and ceremonies. Utilization of sandalwood for the purpose of incense materials is mainly derived from the residual of stems and roots, such as: sapwood, branch parts and waste from the distillation process. Incense material should produce fragrant smoke when it is burned or comes from fragrant material [28]. Therefore, all tree diameter classes in the stems and roots of sandalwood trees have met the requirements for incense, which are fragrant materials and producing fragrant smoke when burned. Fragrant odor and fragrant smokes are characterized by the presence of Santalol compounds (α- and β-santalol) for each diameter class of sandalwood trees.
4. Conclusion

Sandalwood management system carried out by the community in Aceh does not guarantee the sustainability of sandalwood, due to the structure of sandalwood trees was dominated by young trees and there are no cultivation activities (nursery and planting) only protecting an existing natural regeneration. Sandalwood tree harvesting technique was conducted using TL plus roots method with a low efficiency harvesting. Sandalwood trees that meets quality standards for the purpose of wood crafts, essential oils and incenses comes from sandalwood trees with diameter (dbh) above 15 cm and the proportion of terrace wood above 48.53%. Selection of tree diameter and proportion of terrace wood can be used as a basic for policies in order to selecting sandalwood trees suitable for cut or mature trees.

Acknowledgments

Authors are thankful to The Ministry of Environment and Forestry of the Republic of Indonesia eq. Center for Education and Training of Human Resources MoEF for the financial assistance to conduct this research. Forestry Research and Development Center, Ministry of Environment and Forestry of the Republic of Indonesia, Department of Forest Products, Faculty of Forestry, Bogor Agricultural University for the facilities provided during the research.

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