The impact of climate change on the resin productivity of dammar tree (Agathis alba) in Inamosol subdistrict, West Seram district, Maluku-Indonesia

J M Matinahoru1,*

1Department of Forestry, Faculty of Agriculture, Pattimura University, Jl. Ir. M. Putuhena, Kampus Poka, Ambon 97233, Maluku Indonesia

*E-mail: johan.matinahoru@faperta.unpatti.ac.id

Abstract. This research was aimed to determine the impact of climate change on the resin productivity of dammar tree. This research will be useful as data and information for farmers and government to maintain the resin of dammar tree to be optimal and sustainable in production. This research was conducted in Inamosol Sub-district, West Seram District, Maluku Indonesia, during September-October 2020. Village and farmer samples were determined by purposive sampling technique. The selected villages were Honitetu, Hukuanakota and Rambatu. Furthermore, from each village, it was ten farmers to select for interviews and filling the questionnaire. The results showed that the average resin production of farmers in 2019 was 904.2 kg/farmer, while in 2020 was 523.7 kg/farmer. This means that it occurred a decline in resin production in 2020 about 42.08 % for each farmer—the leading cause of the decreased production as climate change factors, namely rainfall, temperature and humidity. Based on climate data of West Seram District in 2019 indicated that rainfall has occurred during six months with an average temperature of 27 °C and relative humidity of 82 %. Meanwhile, in 2020 the rainfall occurs for nine months with an average temperature of 26.5 °C, and relative humidity of 85 %.

1. Introduction
Dammar tree (Agathis alba) is a type of plant from the Araucariaceae family, with a cylindrical trunk, diameter at breast height up to 2 m, a tree height up to 60 m the bark always emits sap if injured. In Indonesia, the dammar tree grows and spreads from Sumatra, Kalimantan, Sulawesi to Maluku. In Maluku, the dammar tree is found growing naturally on the island of Seram, in the mountainous area of Sub-districts of Taniwel, West Seram, and Inamosol at an altitude of 700 m above sea level. Dammar tree is a highland and humid tropical plant, found at an altitude of 500-1,200 meters above sea level. The observation showed that in Inamosol Sub-district, West Seram District, dammar forest grows and develops well on humus cambisol soils in mountain peaks with sufficient sun exposure and temperature condition of 24-28 °C and relative humidity of 76-90 %. The dammar tree that is naturally growing in Maluku is a type of Agathis alba, and it can produce sap well at the age of over 25 years [1].

The benefits of resin are industrial raw material, especially as a base material for the paint, turpentine, varnish, ink and cosmetics [2]. In related to this utility, farmers considered the dammar forest to be a bank that can provide cash for farmers at any time to meet their various needs.

In Inamosol Sub-district, West Seram District, there are three marketing system channels for the resin products, namely: 1) Farmers sell to collectors in the village at a selling price of IDR 8,000-
12,000/kg; 2) Farmer's market to collectors in the sub-district city with a selling price of Rp.10,000-13,000/kg; and 3) Farmers sell to collectors in Provincial City at a selling price of IDR 14,000-15,000/kg. In general, farmers prefer to use the first marketing chain because it will require quite high transport costs if they choose another marketing channel.

Because the resin is quite economically valuable, there is often a theft by people who do not have dammar forest. To overcome tree resin's theft, farmers usually take precautions according to the custom, namely the Sasi system. Sasi is a customary prohibition to take other people's belongings without the owner's permission. If someone takes another person's belongings, they will receive punishment or expected sanctions [3]. The resin sap is usually harvested by tapping with a machete. The sap that is tapped or treated with a machete will fall into a container made merely of wood bark or sago midrib.

This study aims to determine the impact of climate change on the productivity of resin. It is hoped that this research results can be useful as data and information for farmers and the government to maintain the productivity of resin.

2. Methods

This research was conducted in resin production villages in Inamosol Sub-district, West Seram District, Maluku Indonesia from September to October 2020. The sample of village and farmer in this study was determined by using a technique of purposive sampling. The selected villages were a village that still relies on resin sap as cash. Meanwhile, the sample of farmers is a farmer who actively manages the resin forest. Therefore, the selected villages were Honitetu, Hukuanakota, and Rambatu. In each village, ten farmers were chosen to conduct an interview and fill out the questionnaire lists.

3. Results and discussion

3.1. Resin production

The resin tree is found to grow naturally in Inamosol Sub-district, especially in Honitetu, Hukuanakota and Rambatu. In these villages, some of the farmers have a dammar forest that can produce sap every year to collect for sale to collectors. In the management of the dammar forest, farmers usually had problems related to maintaining or increasing resin production. Farmers always strive to do this, so their income can increase. The resin production is determined by tree diameter, tree height, bark thickness, and tree crown density [1]. Furthermore, it was concluded that the increasing in diameter, tree height, bark thickness and tree crown would increase resin sap production. On the other hand, the resin production is also determined by the shape and location of the tapping, where the shape of the letter (W) and the directional tapping to sunlight will be better in the production of sap [4] [5]. The trees number of production age, maintenance intensity, habitat conditions and season are strongly determining the resin production of dammar tree [6][7]. When the injury of tree bark is applied properly, the tree age of 25-60 years can produce an average resin of 1-4 kg/tree, the age of the tree 61-120 years can give sap of 4-6 kg/tree, and trees over 120 years old can have resin of 6-8 kg/tree [8].

The research results on the amount of resin that harvested and sold by farmers during 2019 and 2020 were as follows.

| Sample of Farmers | Honitetu Village | Hukuanakota Village | Rambatu Village |
|-------------------|-----------------|---------------------|-----------------|
|                   | 2019 2020       | 2019 2020           | 2019 2020       |
| 1                 | 1.200 720       | 1.300 754           | 1.450 841       |
| 2                 | 560 364         | 890 534             | 1.210 701       |
| 3                 | 700 420         | 900 513             | 1.010 606       |
| 4                 | 450 284         | 560 308             | 676 419         |
| 5                 | 670 396         | 1.100 583           | 490 290         |
| 6                 | 1.300 637       | 701 421             | 674 425         |
The research results in table 1 show that resin production in 2019 and 2020 was very varied, with the highest average sap production in Rambatu with 1029 kg/farmer in 2019 and 601.4 kg/farmer in 2020. This variation is caused by the number of trees in production age and the maintenance intensity that carried out by the farmers themselves. Interviews with farmers showed that farmers in Rambatu carried out more intensive maintenance activities on their resin trees than farmers in other villages. In Honitetu village, the intensity of maintenance is only twice a year due to the long-distance access to the dammar forest, the lack of workers in the family, and the existence of other business alternatives that can generate income.

In these three research villages, the frequency of applying the injury to the tree bark to encourage sap production and thinning the disturbance trees to create space for sunlight to exposure the tree trunks was the maintenance activity that carried out. It can increase the temperature and reduce humidity, facilitating the discharge of sap from tree trunks that have been injured. The practice of wounding or applying injury to the tree bark is usually carried out 2-3 times/year to each production age dammar tree. First, the bark stem injury is generally done in early summer, namely in October or November, and the second time in January or February. Thus, the resin harvest can only be done after six months from the second application of the bark injury.

However, farmers' main complaint is the problem of seasonality or climatic factors, wherein 2020 the sap production is deficient because the rainy season is longer than usual, which only occurs for three hot months and nine rainy months.

### 3.2. Climate of 2019 and 2020

In general, the West Seram District's normal climatic conditions are six months of summer and six months of the rainy season. The average resin production per tree ranges from 4-6 kg/tree/year. In this condition but in abnormal season conditions, such as in 2020, resin production only reaches an average production of 1-3 kg/tree/year.

| Months   | Average Rainfall (mm) | Average Temperature (°C) | Average Relative Humidity (%) | Average of Solar intensity (lux) | Average of Solar Duration (hour) |
|----------|-----------------------|--------------------------|-------------------------------|---------------------------------|---------------------------------|
| January  | 75                    | 54.0                     | 28.5                          | 29.0                            | 16.000                          | 15.000                          | 10         | 12         |
| February | 125                   | 57.0                     | 28.3                          | 28.8                            | 15.500                          | 14.600                          | 8          | 9          |
| March    | 198                   | 220                      | 28.0                          | 27.0                            | 15.200                          | 14.100                          | 7          | 10         |
| April    | 149                   | 98.0                     | 28.4                          | 27.2                            | 15.000                          | 14.300                          | 7          | 7          |
| May      | 304                   | 298                      | 27.0                          | 26.8                            | 13.600                          | 13.200                          | 6          | 7          |
| June     | 504                   | 601                      | 24.5                          | 24.0                            | 9.000                           | 8.500                           | 4          | 1          |
| July     | 481                   | 500                      | 25.0                          | 24.5                            | 9.500                           | 8.100                           | 5          | 1          |
| August   | 406                   | 497                      | 25.5                          | 25.0                            | 10.000                          | 9.300                           | 5          | 3          |
| September| 310                   | 450                      | 26.5                          | 25.7                            | 11.000                          | 10.251                          | 6          | 4          |
| October  | 188                   | 248                      | 27.2                          | 26.8                            | 12.500                          | 11.912                          | 7          | 6          |
| November | 156                   | 240                      | 27.8                          | 27.0                            | 13.000                          | 12.675                          | 8          | 6          |
| December | 120                   | 235                      | 28.3                          | 28.0                            | 13.500                          | 12.122                          | 8          | 7          |
| Average  | 251.3                 | 291.5                    | 27.0                          | 26.5                            | 12.816                          | 12.005                          | 6.75       | 6.08       |
The research results in table 2 show that the average rainfall in 2019 is 251.3 mm with an average temperature 27 °C and relative humidity 82 %. Meanwhile, the year 2020 has an average rain 291.5 mm with an average temperature 26.5 °C and relative humidity 85 %. This shows that the average rainfall intensity in 2020 is higher and longer, namely during the nine months of the rainy season. Also, it can be seen that the average intensity of radiation and the duration of solar radiation in the Inamosol Sub-district in 2020 is lower than in 2019. In general, West Seram District, Maluku Indonesia has two seasons, namely the dry season, namely October-April, and the rainy season from April-October. However, in 2019 there was a slight change, namely five wet months and seven dry months, and in 2020 there were nine wet months and only three dry months. This change has a significant impact on the production of resin as a non-timber forest product.

Plants use various methods to protect themselves from pests and diseases, such as what dammar plant species do by removing sap to cover wounds on the trunk or roots, and branches of trees. Resin sap is produced in the sap tubes found in the parenchyma in the xylem and stem cortex and then channelled to epithelial cells in tree bark. Resin formation occurs due to injury to tree bark due to friction or damage by animals and humans. Resins are plant products insoluble in water, harden when exposed to air, do not play a role in fundamental plant growth processes, and are generally produced by woody plants. The epithelial cells secrete resin into large central resin ducts, where the resin is deposited until an injury occurs. One or more layers of axial parenchyma cells (sheaths) envelop the duct structure of the resin. The resin channel or resin channel extended in the space between tubular cells and surrounded by epithelial cells secrete the resin into the canal. These canals are oriented longitudinally and radially between the fusiform ray. They are usually found in denser woods-growing late in the season such as *Pinus merkusii* [9].

The epidermis of wood contains a layer of cells called keratinocytes. Keratinocytes are the stem cells for epithelial cells. The cells are arranged neatly to form the epidermis layer of the bark or known as the epidermis's main cells. Epithelial tissue is widely distributed throughout the epidermis, forming the covering of all body surfaces, body cavities and orifice organs, and is the gland's main network. They perform various functions that include protection, secretion, absorption, excretion, filtration, diffusion, and sensory reception [10][9].

Cortex resin channels are important resin reservoirs during the early stages of plant development, whereas xylem resin channels are the main source of resin in mature trees. Axial resin channels are present in the xylem and the cortex of roots and stems. Pines produce resin acids, turpentine, essential oils, resene (a non-volatile neutral organic mixture) and water. Common resin compounds are toxic to protect plants from various herbivores, insects and fungi. Resins are plant products that are insoluble in water and harden when exposed to air. Some woody plants generally produce resins although they do not play a role in fundamental plant growth. To increase the purity and density of resin, and the essential oils as a whole, which are then converted into trichomes and turpentine, so plants need nutrients in high concentrations, especially phosphorus (P), potassium (K), and silicic acid (Si) [11].

4. Conclusion

The average resin production of farmers in 2019 and 2020 is 904.2 kg/farmer and 523.7 kg/farmer, respectively. There was a decrease in resin production by about 41.5 % in 2020 if compared to 2019. The leading cause of farmers’ declining average resin production is climatic factors, especially the duration of rainfall, temperature, humidity, intensity, and solar radiation duration. Farmers have considered the dammar forest as a bank in providing cash for their daily needs.

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