The impact of climate variables on nutmeg (*Mirystica fragrans* HOUTT) production in Saparua Island, Central Maluku Regency

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**Abstract.** Nutmeg is a prime estate commodity that has high economic value, a major source of income for farmers in some areas of Maluku as well as a source of Indonesian foreign exchange through export. Nutmeg is originally from Banda archipelago, Maluku, Indonesia. Nutmeg grows in specific areas with certain agroclimatic condition, therefore climate as an environmental factor plays an important role in nutmeg production. The objective of this study was to determine the influence of climate variables on the productivity of nutmeg in Saparua Island. The study was conducted in Saparua Island, Central Maluku Regency from April to October 2017. Survey method was used in this study. Three villages were chosen purposively since they are the center of nutmeg production on the island. Direct observations were done in the fields as well as interviewing key respondents. Statistical and climate data was obtained from related institutions. Rainfall trend was analyzed to determine climate change and regression analysis was done to see the relationship between climate variables (air temperature, air relative humidity and annual rainfall) with nutmeg production in the last 10 years. The result showed that there has been an increased in total rainfall of 374 mm (13.0%) in the study area in the period of the last 30 years (1987-2016) compared with the previous period (1957-1986) which indicates there has been climate change in Saparua island. The contribution of climate variables (air temperature, air relative humidity and rainfall) to nutmeg production were 45.52%; 37.13% and 55.12% respectively.

1. **Introduction**

The history of world trade has recorded Maluku as a high-quality spice producing region, especially nutmeg. This commodity has high economic value and is the main source of income for farmers in several areas in Maluku. Most of the nutmeg plantations are owned by local communities in the form of agroforestry system that called *dusung* and only a few are managed by the government and the private sector. In 2016, there were around 27,782 nutmeg farmers with a land area of 30,357 ha of nutmeg planting in Maluku [1]. The production of this plant from time to time fluctuates due to various factors, including plant factors, climate, and harvest area. Therefore, if there is no strategy to deal with these factors, the state income and livelihoods of thousands of farmers will be threatened to decline.

The nutmeg plant is native to Indonesia, originating from the Banda Islands, Maluku. The plant of nutmeg requires rainfall of 2000 - 4,500 mm/year with 100-160 rainy days, temperatures of 25-26°C and relative humidity of 60-80% so that climate variables play important role in the productivity of nutmeg [2]. Climate change occurs due to changes in climate variables, such as air temperature and rainfall, which occur...
continuously over a long period of time between 50 and 100 years [3]. Temperature increases have occurred in recent years in various regions in this world.

Climate change is a change in temperature, air pressure, wind, rainfall, and humidity as a result of global warming. In Indonesia there is an increase in the annual average temperature of about 0.3°C and a decrease in annual rainfall decreases by 2-3%. In addition, there are changes in rainfall patterns in various regions, where the pattern tends to decrease in the southern region and increases in the northern region [4]. These changes increase vulnerability to disasters and to various livelihood sectors such as agriculture and fisheries. The agricultural sector is very vulnerable to climate change because it affects cropping patterns, planting time, production, and yield quality [5]. The climatic elements mentioned above greatly affect the growth, production, and quality of crop yields. The negative impact caused by climate change is a decrease in agricultural potential production due to rising temperatures and a decrease in regional water availability due to drought. Climate change can reduce agricultural production between 5-20 percent [6] so that it can affect food security.

Climate is one of the main elements in the metabolic system and plant physiology, so changes in several climatic elements can have a negative impact on plant growth and productivity. Increased air temperature affects plant respiration and transpiration thereby increasing water consumption [7]. This increase can also enhance growth and development of plant pests and diseases [8, 9]. Increased air temperature will accelerate the ripening of fruit and seeds, thereby reducing the quality of crop yields. Changes in rainfall affect the crop production process. Several climate variables even influence each other so that they can be the limiting factors in agricultural production.

This study aims to provide scientific-based information about the influence of climate variables on the productivity of nutmeg in Saparua Island, Central Maluku Regency.

2. Materials and Method

The research was carried out on Saparua Island. Saparua is a small island in the Central Maluku Regency located 74 km East of Ambon Island. Saparua Island covers a land area of 112.4 km². There are 2 districts and 17 administrative villages on Saparua Island [10]. The research was conducted from April to October 2017 where three villages on this island were chosen purposively, namely Booi, Paperu and Itawaka villages (● in Figure 1) because they are the centers of nutmeg production over there.

![Figure 1. Map of Saparua Island [11]](image-url)
This study used a survey method with the following techniques: 1). Direct observation in the field; and 2) Interviews with key informants (key respondents/farmers). These two stages were carried out to obtain primary data regarding land resources, cultivation systems, agroclimatic conditions, and production.

The number of farmer respondents (owners/tenants) is 10% of the number of head of family per village. Secondary data were collected from related institutions in the form of statistical data [1] and climate data. Climate data were collected from [12] in the form of climatology data period of 1976-2016, historical data of average rain fall period of 1941-1970 [13,14] then generated and analyzed in the Laboratory of Climate Data and Analyzes, Faculty of Agriculture, Pattimura University from.

Analysis of climate aspects, which is one of the environmental aspects that affect the productivity of the nutmeg plant was carried out using regression analysis between the climate variables (air temperature, air relative humidity and annual rainfall) and the productivity of the nutmeg plant in the last 10 years. Descriptive data was tabulated and descriptive statistical analysis was carried out using Microsoft Excel.

3. Results and Discussion

3.1. Ownership and physiography of nutmeg plantation

One of the main capitals in agricultural development efforts is the availability of sufficient and suitable land for the characteristics of the plants to be developed. The number of dusung (plantation) owned and its area influence production yields and income received by farmers. The average number of dusung owned by farmers and their areas in the research location varies from 1.20 to 1.33 (average of 1.27) hectare and the area of 1.37 to 1.53 (average 1.38) hectares (Table 1).

The nutmeg dusung has flat to wavy physiography with a slope of 0-20% and dominance by the land with a slope of 0-10% (66.67%) (Tabel 1). Flat land usually has problems with standing water when the rainfall is high.

Nutmeg plants grow and produce well at an altitude of 0-700 m above sea level (asl), 73.33% of farmers' land is at an altitude of less than 200 m asl, while those at an altitude of more than 400 m asl are only 10% so it can be said that the altitude of the land owned by the farmers is suitable for the growth and production of nutmeg plants. This also shows that most of the dusung are located on the coastal area. Land owned by farmers in the research location has been obtained through inheritance from their parents. Sixty percent were private-owned, 13.3% were family owned and 26.67% were mixed between private or family owned (Table 1).

Table 1. Number, land area, physiography and ownership of dusung

| Village | Average Number of dusung Owned | Average Land Area Owned (Ha) | Slope (%) | Altitude (above sea level) (%) | Land Ownership (%) |
|---------|--------------------------------|-----------------------------|-----------|-------------------------------|-------------------|
|         | Total                          |                             | 0-10      | 10-20 | >20 | <200 | 200-400 | >400 | Private-Owned | Family-Owned | Private/Family |
| Booi    | 1.27                           | 1.27                        | 70        | 20   | 10  | 80   | 20       | 0    | 80           | 20           | 0              |
| Paperu  | 1.20                           | 1.33                        | 40        | 40   | 0   | 60   | 20       | 20   | 50           | 10           | 40             |
| Itawaka | 1.33                           | 1.53                        | 90        | 10   | 0   | 80   | 10       | 10   | 50           | 10           | 40             |
| Average | 1.27                           | 1.38                        | 66.67     | 23.33| 3.33| 73.33| 16.67    | 10.00| 60.00        | 13.33        | 26.67          |

3.2. Climate and nutmeg production

3.2.1. Climate change trends. Determining the trend of changes in rainfall aims to determine the extent to which climate change has occurred in the study area. This requires long-term time series climate data and according to the available data, rainfall data for 60 years of observation can be used (1957-2016) [12, 13,14].
Rainfall data for the period 1957-2016 is divided into two observation periods; the first period of 30 years (1957-1986) and the second period of the last 30 years (1987-2016). The length of this period is in accordance with [15] who stated that the rainfall data for 30 years of observation is representative to describe the climatic conditions in a region.

The main cause of climate change is the increase in mean surface temperature caused by greenhouse gases such as carbon dioxide, methane, and nitrogen oxides. The concentration of greenhouse gases has increased sharply in line with the increasing activity of global development and industry. The increase in the temperature of the earth's surface, known as global warming, causes changes in climate patterns. Changes in climate patterns lead to uncertain climate conditions. The impact of climate change is a change in the distribution of rainfall both spatially and temporally and triggers an increase in the chance of extreme weather and climate events [4].

The results of the rainfall analysis show that there has been a change in the average rainfall in the study area in the last 30 years (1987-2016) compared to the previous period (1957-1986) (Figure 2) which indicates that there has been climate change in Saparua [16].

In the Saparua Island area, the annual rainfall tends to increase by 374 mm or 13.0%, from 2890 mm to 3264 mm. The largest percentage change in rainfall occurred during the rainy season (April-September) by 15.7% or 343 mm, while during the dry season (October-March) the increase was only 4.5% or 31 mm. In a year, the monthly rainfall tends to increase for 8 months: April to August, and December to February with a range of 23 - 125 mm or 14.5 - 26.2%, while for 4 months the rainfall tends to decrease: March, and September to November with a range of 5 - 31 mm or 3.2 - 18.0% (Figure 2).

Figure 2. Changes in Rainfall Trend and Rainfall Occurring on Saparua Island in 60 Years (Comparison between Period I: 1957-1986 and Period II: 1987-2016)

[A = average monthly rainfall for Period I: 1957-1986 and Period II: 1987-2016
B = trend of change in the amount of monthly rainfall (mm)]
3.2.2. The relationship between climate variables and production. Climate variables are environmental factors that affect plant productivity. These environmental factors can be a limiting factor for the productivity of nutmeg plants. Climate variables: air temperature, air relative humidity, and rainfall influence one another. From the data obtained, it can be said that the climate variable (temperature, humidity and rainfall) has an effect on the production of nutmeg.

Regression analysis to see the relationship between temperature (°C), humidity (%) and rainfall (mm), with the productivity of nutmeg plants obtained by the equation and coefficient of determination (R²) as shown in Figures 2, 3 and 4. From the equation below it can be said that the temperature, humidity, and rainfall affect the production of nutmeg.

The coefficient of determination symbolized by $R^2$ is interpreted as a contribution or influence given by the independent variable ($x =$ temperature, relative humidity, and rainfall) on the dependent variable ($y =$ production of nutmeg plants).

The regression analyses showed that air temperature contributed to the production of nutmeg by 45.52% ($R^2 = 0.4552$) (Figure 3). The difference in air temperature is characterized by the height of the place above sea level (asl). In the research location, the distribution of nutmeg based on altitude asl is relatively the same; which is between 0 - 700 m (asl). According to [2], the optimal temperature for the growth of nutmeg plants is between 25-30°C. Contribution of temperature on production of nutmeg is 45.52%. Nutmeg plantations in the highlands (more than 700 m asl) will reduce production due to high relative humidity, thereby stimulating fungal disturbance. Thus, the right recommendation to choose a nutmeg plantation area is at an altitude of less than 700 m (asl) [17].

![Figure 3. Relation between annual average temperature and nutmeg production (2007-2016)](image)

Relative humidity (%) contributed to the production of nutmeg by 37.13% ($R^2 = 0.3713$) (Figure 4). Monthly relative humidity at the study site is usually high during the rainy season and low during the dry season (Figure 2). Air humidity conditions have a linear correlation with rainfall conditions and air temperature.

Water is needed by plants for photosynthesis, mineral transport, and photosynthetic products, to support the body, growth, and transpiration. In dry land agriculture, the main source of water to meet crop needs comes from rainfall.
Nutmeg plants require high rainfall throughout the year or are suitable in tropical wet climates with rainfall > 2,000 mm/month. Nutmeg plants in Maluku are scattered in areas that have climate types A and B [18]. Based on the level of climate suitability, nutmeg is very suitable to be developed in areas that have an average rainfall of 2000 - 4,500 mm/year [19].

The relationship between rainfall and production has a greater coefficient of determination which illustrates that the contribution of rainfall to production is 55.12% ($R^2 = 0.5512$) (Figure 5).

**Figure 4.** Relation between annual relative humidity and nutmeg production (2007 -2016)

**Figure 5.** Relation between rainfall and nutmeg production (2007 -2016)
Nutmeg plants need rainfall 2000 - 4,500 mm/year with 100-160 rainy days, temperature of 25-26°C and relative humidity of 60-80%. Judging from these prerequisites, the nutmeg plant will develop well and be suitable for growing in the research location. However, according to the available data, climatic elements (temperature, relative humidity, and rainfall) provide a significant contribution to plant productivity. In general plant cultivation activities, elements of climate i.e: air temperature, humidity and rainfall are directly related to plant growth; among other things, variable of climate has a significant effect on the nutmeg production.

4. Conclusion
Based on the results of the study, it can be concluded that climate change in the study location was marked by an increase in total rainfall of 374 mm (13.0%) between the last 30 years (1987-2016) compared to the previous period (1957-1986). The climate variables (temperature, humidity, and rainfall) have an effect on the production of nutmeg in which rainfall provides the largest contribution as high as 55.12%.

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