Agroclimate Zone Analysis and Its Relationship with Rice and Tobacco Productivity in Temanggung District

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Abstract. Temanggung Regency's rice and tobacco production, in particular, were greatly impacted by the quantity and quality of the weather, particularly rainfall. In order to create a map of the agroclimatic zone, this study employed rainfall data from CHIRPS with a data length of 30 years. The data was then processed using the IDW interpolation method. In Temanggung Regency, the agroclimatic zone based on the Oldeman climate classification underwent climate type changes over a period of three decades. From 1990 to 1999, there were four climate types, including B2 (15%), B3 (10%), C2 (21%), and C3 (54%); from 2000 to 2009, there were three climate types, including B2 (21%), B3 (68%), and C3 (11%); and from 2010 to 2019, there was only one climate type, B2 (100%). The simultaneous occurrence of the La Nina phenomena and negative IOD in 2010 and 2016 led to a pretty severe rise in rainfall. In Temanggung Regency, the excessive rainfall in those years increased rice productivity while lowering tobacco productivity.

Keywords: Agroclimate Zone · Climate · Rainfall · Crop Productivity

1 Introduction

Agricultural activity is strongly influenced by climatic factors because plants' growth is closely related to rainfall, sunlight, temperature, and humidity. Climate, agriculture, and forestry have a strong relationship that influences each other as well as the hydrological cycle which requires energy from the sun to do evaporation and transpiration [1]. Agriculture may experience disruptions as a result of climate change, including changes to climate elements. Additionally, the majority of Indonesians still rely on the agriculture industry for their livelihoods. As a result, climate change is very vulnerable to agricultural activity.

The climate characteristics of every region have differences according to the geographical location and topography that affect the atmospheric process, so it is necessary to identify and classify the climate to obtain a climatic area mapping that describes the climatic boundaries between one regional climatic area and another [2]. The Oldeman's climate categorization is the most appropriate one to utilize for agricultural purposes.

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The Oldeman classification employs the minimal amount of rainfall needed to cultivate most palawija, which is 100 mm/month, as well as the fundamental water requirements of rice and palawija (secondary crops), as the limit of wet and dry months.

Rainfall is one of the climate elements that affect the level of agricultural and plantation productivity, especially on plants that are sensitive to environmental conditions such as climate factors. Agricultural crops such as rice require optimum rainfall of $>1,600$ mm/year and specifically for gogo rice requires a minimum of four wet months, namely months with rainfall >200 mm [3]. Meanwhile, plantation crops such as tobacco require sufficient rainfall at the beginning of planting and also high sun intensity during harvesting and drying. The amount of rainfall will determine the beginning of the rainy season and dry season which become the determining factor in planting time for rice and tobacco crops to increase productivity and reduce losses due to crop failure.

The agriculture sector in Temanggung Regency is one of the sectors which give the highest contribution to the Gross Regional Domestic Product (GRDB). Based on Temanggung Regency's GRDB data at constant prices, the agricultural sector is the sector that provides the highest contribution among the manufacturing sector and wholesale and retail trade, with the highest GRDP value in 2019 of IDR 3.269.024. One of the agricultural commodities that are widely cultivated in Temanggung Regency is rice, which is the main food commodity, especially in Indonesia so the demand for rice plants is high in line with population growth. In addition, there are also commodities from the plantation sector, namely tobacco, a leading commodity in Temanggung Regency with a high selling value and high demand because it is the raw material for cigarettes in Indonesia. Temanggung tobacco growing on the eastern and northern slopes of Mount Sumbing and Sindoro mountains forms a population of Temanggung tobacco with distinctive morphological and physiological characteristics [4].

The mapping of the climatic area or agroclimatic map is needed to discover the suitability of the regional climate to maximize the potential of agricultural crops in that area. Agroclimatic maps based on the rainfall data such as Oldeman spatially and temporally can be used to discover the characteristics of rainfall in each region. The agroclimatic map is used as supporting data for analysis of the effect of rainfall on rice productivity as the main food crop and tobacco as the leading plantation crop in Temanggung Regency. Based on the detailed background above, this study aims to examine the result of the reclassification of the agroclimatic zone according to Oldeman from 1990 to 2019 in Temanggung Regency and to analyze spatially and temporally the relationship between rainfall and rice and tobacco productivity in Temanggung Regency.

2 Methods

This research used a data source, namely secondary data. The secondary data was obtained from several agencies, such as Climate Hazard Group Infrared Precipitation with Station (CHIRPS) daily rainfall data, ENSO (El Nino Southern Oscillation) and IOD (Indian Ocean Dipole) incident historical data, production and land area data of rice and tobacco, agroclimatic maps of Java and Madura according to Oldeman in 1975, Indonesia's digital map of the 1:25,000 scale and the Digital Elevation Model (DEM).

Table 1. Oldeman's climate classification zone

Main Zone	Number of wet month	Number of dry month	Sub-type
A	>9	1	<2
B	7–9	2	2–3
C	5–6	3	4–6
D	3–4	4	7–9
E	<3	5	>9

2.1 CHIRPS Data Extraction and Validation

CHIRPS daily rainfall data that was downloaded had to go through an extraction process to be processed further. CHIRPS data used consisted of 54 points located in the study area for the period from 1990 to 2019 in the form of a raster representing daily global data. CHRPS data then needed to be validated with the rainfall data from the result of field observations to test the accuracy of the data. The field rain data used was the daily rainfall data from the BMKG observation station. Data validation was done using the Pearson correlation test method with a significance level of 0.05 using SPSS software. The validation of CHIRPS data in this research used the validation result carried out by previous research, namely using field rainfall data from Progo Bogowonto Luk Ulo Water Resources Management Center (BPSDA PROBOLO) and rainfall data from Tanjung Emas Maritime Meteorology Station and Ahmad Yani Meteorology Station.

2.2 Oldeman Climate Classification

The daily rainfall data which passed the validation stage then processed into monthly rainfall data to become Oldeman's agroclimatic zone. The climate classification according to Oldeman classified monthly rainfall into wet months and dry months. Months with rainfall of more than 200 mm were defined as wet months and months with rainfall of less than 100 mm classified as dry months. The Oldeman's climate classification was determined based on the length of consecutive wet months and consecutive dry months (Table 1). The result of climate classification was then processed into agroclimatic maps by using the interpolation method Inverse Distance Weighting (IDW) to see the agroclimatic zone spatially.

3 Result and Discussion

3.1 Spatial Pattern of Oldeman Agroclimate Zone in Temanggung Regency

In the period from 1990 to 1999, Temanggung Regency area had four climate types, namely B2, B3, C2, and C3 which were dominated by the C3 climate type which was 46,742 ha or 54% of the total area, then C2 was 18,441 ha or 21%, B2 was 13,304 ha or 15%, and a small part of B3 was 8,780 ha or 10% (Fig. 1).

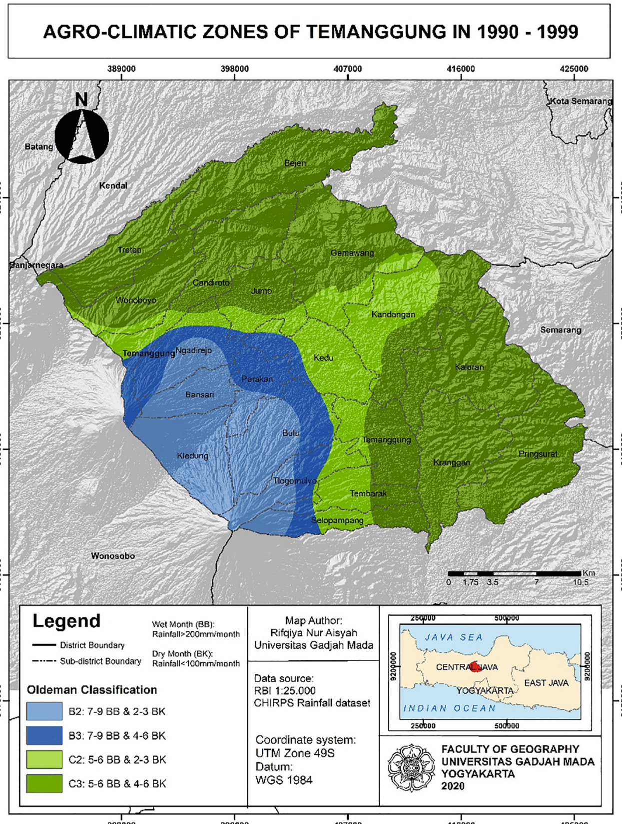

Fig. 1. Agroclimatic Zone Map of Temanggung Regency period 1990–1999

The C3 climate type Agroclimatic zone in Temanggung Regency is in a hilly topography with a wavy to steep morphology. The Agroclimatic zone type C has a wet month period of 5–6 months in a row with a dry month of 4–6 months in a row, thus according to Oldeman it is suitable for a cropping pattern of two rice crops, namely upland (gogo) rice and lowland (sawah) rice and 1-time cropping pattern of palawija. C climate type has a shorter wet month period compared to B type, so it is recommended to choose upland (gogo) rice as an alternative because it requires less water.

The C2 climate type Agroclimatic zone in Temanggung Regency is in the plain topography. The Agroclimatic zone type C2 has a wet month period of 5–6 months in a row with dry months of 2–3 months in a row, which is suitable for a cropping pattern of two times rice [4], namely upland (gogo) rice and lowland (sawah) rice and one time cropping pattern of palawija. The B2 Agroclimatic type zone in Temanggung Regency is located in a mountainous topography with a steep to a very steep morphology covering the Kledung sub-regency, Bulu subregency, Selopampang sub-regency, Tlogomulyo sub-regency, Bansari sub-regency, and Ngadirejo sub-regency. The B2 Agroclimatic type zone has a wet period of 7–9 months in a row with dry months of 2–3 months in a row,

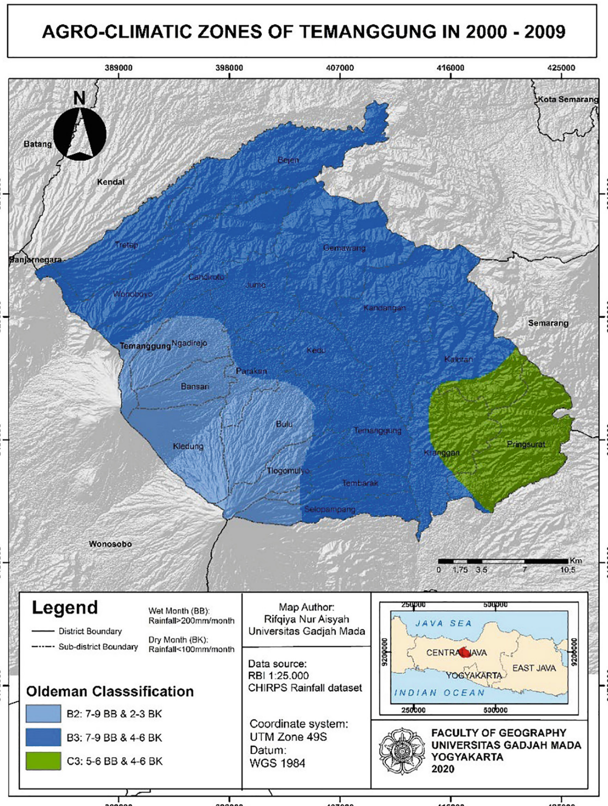

Fig. 2. Agroclimatic Zone Map of Temanggung Regency period 2000–2009

therefore it is suitable for a cropping pattern of two times lowland rice and one time of palawija by considering the short period of dry months [5].

The B3 Agroclimatic type zone in Temanggung Regency is located on the slopes of the mountain. The Agroclimatic zone type B3 has a wet month period of 7–9 months in a row with dry months of 4–6 months in a row and suitable for a cropping pattern of two times for lowland rice and one time for *palawija* by doing the *bero* system during crop rotation in a year.

In the period from 2000 to 2009, Temanggung Regency area had three climate types, namely B2, B3, and C3 which were dominated by B2 climate type, which was 59,291 ha or 68% of the total area, then B3 was 17,959 ha or 21%, and C2 was 10,016 ha or 11% (Fig. 2). In the period from 2010 to 2019, Temanggung Regency area only had one climate type, namely B2 covering an area of 87,266 ha (Fig. 3). B2 climate type has the number of wet months of 2–9 months and dry months of 2–3 months, the length of the wet months period in this climate type indicated that rainfall was quite high throughout the year in this period.

Based on the rainfall data for the last 30 years, 2010 and 2016 were the peak points of the highest rainfall, namely 4,547 mm and 4,587 mm. The increase in rainfall during

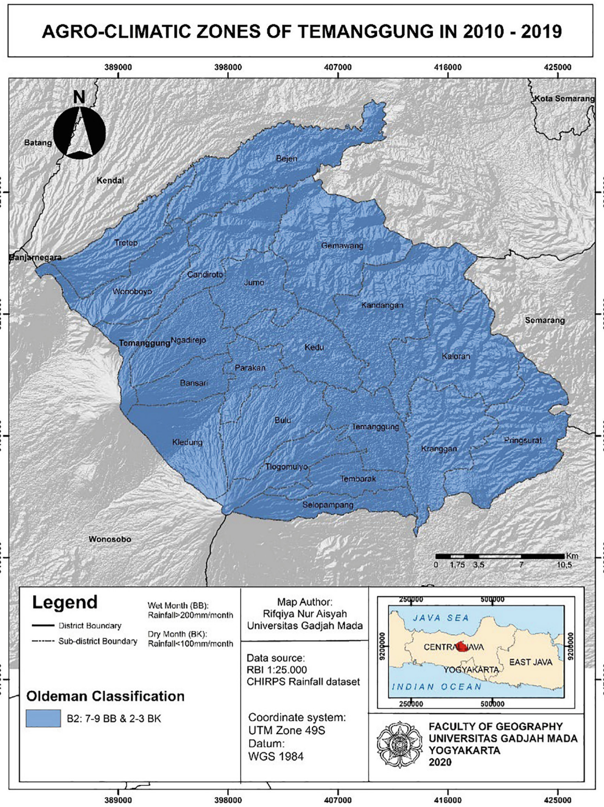

Fig. 3. Agroclimatic Zone Map of Temanggung Regency period 2010–2019

those years was caused by the climate anomaly by the La Nina phenomenon and Negative IOD that were happening simultaneously. La Nina was indicated through sea surface temperatures in the Western Pacific Ocean which were warm due to trade winds blowing from the east, causing convection clouds that cause high rainfall. Meanwhile, Negative IOD occurred due to the center of high air pressure in the Western Indian Ocean, so that the wind blew from high pressure to low pressure which caused an increase in the sea surface temperature in the Eastern Indian Ocean, causing convection clouds that cause high rainfall in that period.

Based on farmer interview data [6] in 14 sub-regencies of tobacco centers, namely Wonoboyo, Tretep, Candiroto, Jumo, Bansari, Ngadirejo, Kledung, Parakan, Kedu, Temanggung, Bulu, Selopampang, Tlogomulyo, and Tembarak, in fact, they rarely grow rice but apply seasonal vegetable cropping pattern – tobacco – seasonal vegetables in a year with the dominance of chili and onion vegetables. The sub-regencies that apply the rice-tobacco-paddy cropping pattern are Parakan, Kedu, and Temanggung sub-regencies, these sub-regencies are sub-regencies located on the lower slopes of Mount Sindoro-Sumbing which are volcanic alluvial plains that have more potential groundwater and

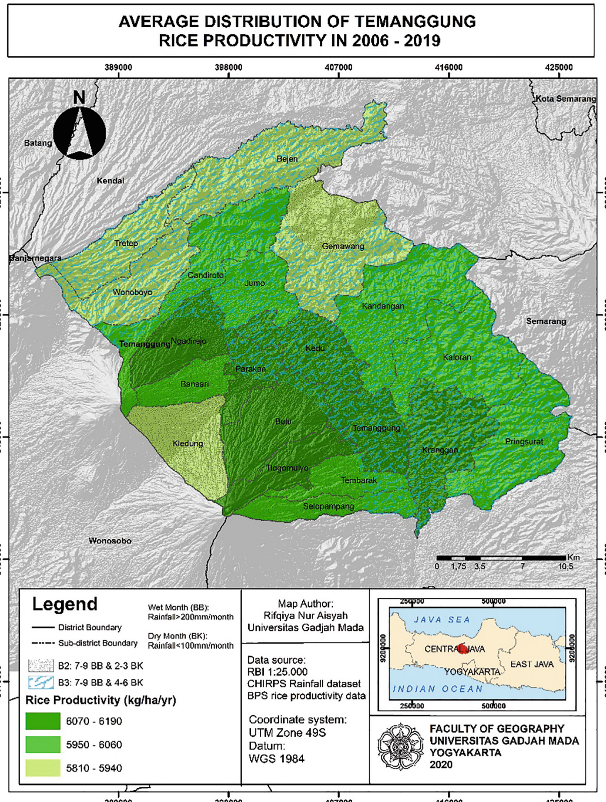

Fig. 4. Rice Productivity Map of Temanggung Regency period 2006–2019

surface sources for growing rice and supported by the suitability of agroclimatic zones B2 and B3.

3.2 Analysis of the Relationship Between Agroclimatic Zones and Rainfall with Rice and Tobacco Productivity

In general, there are two types of agroclimatic zones in Temanggung Regency, namely B3 and B2. According to [7] Oldeman's climate types B2, B3, and C2 are classified as land suitability classes that are very suitable for rainfed lowland rice cultivation. Type B3 agroclimatic zone covers most of Temanggung Regency. Based on the map in Fig. 4, the sub-regencies included in the B3 area with high rice productivity (6,070–6,190 kg/ha/year) are Parakan, Temanggung, Kranggan, and Kedu. Meanwhile, the sub-regencies included in the B2 area with high rice productivity are Bulu, Tlogomulyo, and Ngadirejo.

Rice productivity in Temanggung Regency has an increasing linear trend with an increase of 96.2 kg/ha/year (Fig. 5). The average rice productivity in Temanggung Regency in the last period was 6,055 kg/ha. Below-average productivity occurred in

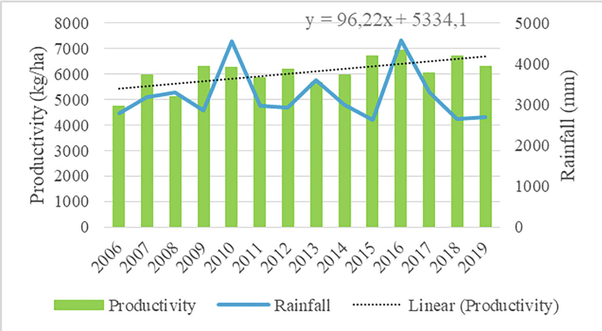

Fig. 5. Rice Productivity Trend of Temanggung Regency period 2006–2019 ENSO and IOD occurence in the period of 2006–2019

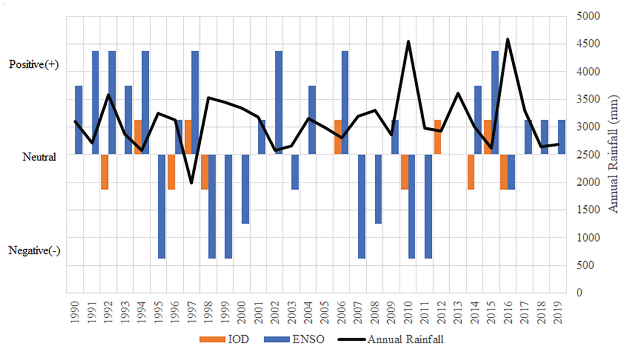

Fig. 6. ENSO and IOD occurrence in the period of 2006–2019 Tobacco Productivity Trend of Temanggung Regency period 2006–2019

2006, 2007, 2008, 2011, 2013, and 2014. Meanwhile, the peak of productivity occurred in 2016 which was 6,940 kg/ha.

Rainfall in Temanggung Regency in the period from 2006 to 2019 had the two highest peaks of rainfall, namely in 2010 at 4,547 mm/year and in 2016 at 4,587 mm/year. In 2010 rice productivity in Temanggung Regency was quite high around 6,260 kg/ha, and in 2016 rice productivity increased from the previous year to 6,940 kg/ha and was the highest rice productivity rate in the last period. The highest rainfall in 2016 affected the increase in production yields and caused high rice productivity in Temanggung Regency that year. The increase in rainfall in 2010 and 2016 coincided with the occurrence of strong La Nina phenomena and Negative IOD (Fig. 6).

The trend of tobacco productivity for the last 14 years from 2006 to 2019 fluctuated but the linear trend line showed an increase of 9.98 kg/ha/year (Fig. 7). The average tobacco productivity in Temanggung Regency in the last 14 years is 554 kg/ha/year. Tobacco productivity is below the average productivity in 2006, 2008, 2009, 2010, 2013, and 2016. In 2010 and 2016 tobacco productivity experienced a significant decline. The lowest productivity occurred in 2010 and 2016, at 440 kg/ha and 360 kg/ha. The

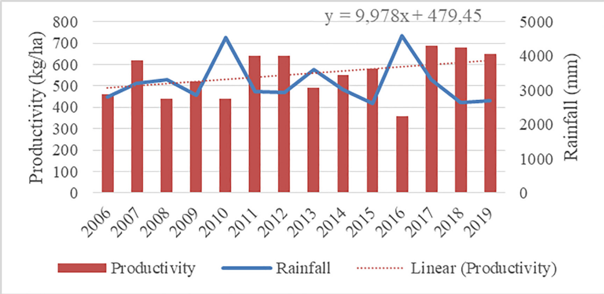

Fig. 7. Tobacco Productivity Trend of Temanggung Regency period 2006–2019

decline in tobacco productivity that year occurred at the peak of the highest annual rainfall in Temanggung. High rainfall due to the influence of the La Nina phenomenon accompanied by Negative IOD in 2010 and 2016 caused the dry months to become wet, so many tobacco plants experienced decay during the harvest process.

The altitude suitable for tobacco cultivation is the highlands with an altitude of 700–1,500 m above sea level [8]. The tobacco center sub-regency is centered in the northwest to southwest of Temanggung Regency, which is an area on the slopes of Mount Sindoro and Mount Sumbing. The tobacco center sub-regency has high productivity, which is between 470–670 kg/ha per year. Based on the quantity, the level of tobacco productivity in the center subregency is quite high in the last period, but the large quantity does not guarantee that farmers get maximum profit from sales because there is an assessment of the quality of tobacco by tobacco consumers, especially cigarette factories. The higher the quality resulted in the higher the selling price of tobacco. The quality of black tobacco grown in mountainous areas is higher than that of yellow tobacco grown in paddy fields. According to [9], there is a positive correlation between the effect of elevation on the height and age of tobacco plants. Areas with high elevations have lower temperatures and less intensity of sunlight causing the slow process of photosynthesis, so plant height is hampered. In addition, the lack of sunlight intensity at high elevations causes a slow growth process, so that the tobacco life becomes longer. As a result of long life, the accumulation of carbohydrates and the accumulation of nicotine stored in the leaves are higher [10].

4 Conclusion

The results of the classification of agroclimatic zones based on Oldeman's climate classification using rainfall data for 30 years from 1990–2019 in Temanggung Regency resulted in four climate types in the period from 1990 to 1999, namely climate types B2, B3, C2, and C3, climate type areas C3 covers the largest area of 46,742 ha or 54% of the total area. The agroclimatic zone in the period from 2000 to 2009 changed to wetter with three climate types, namely B2, B3, and C2, B3 climate type has the largest area of 59,291 ha or 68% of the total area. While the agroclimatic zone in the period from 2010 to 2019 experienced a very significant change to become wetter with only one climate type, namely B2.

The average rice productivity in Temanggung Regency in the last 14 years period from 2006 to 2019 was 6,055 kg/ha. The highest peak of rice productivity occurred in 2016 which was 6,940 kg/ha in the same year with the highest peak annual rainfall of 4,587 mm/year due to the La Nina phenomenon and Negative IOD occurring simultaneously. Rice productivity in Temanggung Regency increases when rainfall is high but productivity does not decrease when rainfall is low. Rice productivity is spatially influenced by physical factors such as topography and hydrology. The level of rice productivity in the middle slopes to the lower slopes of Mount Sindoro and Mount Sumbing has high rice productivity compared to the northern and eastern regions of Temanggung Regency which are hills.

The average tobacco productivity in Temanggung Regency in the period from 2006 to 2019 was 554 kg/ha. The highest productivity in 2017 was 690 kg/ha with an annual rainfall of 3,306 mm. There was a significant decrease in productivity in 2010 and 2016 to 440 kg/ha and 360 kg/ha. High rainfall in 2010 and 2016 (4,547 mm and 4,587 mm) was the cause of tobacco harvest failure due to decay. The quantity and quality of tobacco are spatially influenced by climatic conditions, namely temperature, rainfall, and sunlight intensity as well as elevation. High tobacco productivity (470–670 kg/ha) is centered in the tobacco center sub-regencies of Mount Sumbing and Sindoro areas.

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