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Identification of climate change and its impact on maize (*Zea mays* L.) production in Majalengka Regency

Abstract. Maize is one of the multipurpose crop whose yields can be affected by climate change. Climate change includes increasing air temperature, increasing sea levels, and changes in rainfall can be a threat and cause a decrease in maize yields. This could be caused by climate change factors. This research aims to identify climate change and analyze the correlation between climate change and maize production in the Majalengka Regency. Maize plantations in the 26 sub-districts are still fluctuative. The method used in this research is quantitative descriptive using trend analysis and correlation. The data used include temperature, rainfall, harvested area, production, and productivity of maize obtained from (i) the Meteorological, Climatological, and Geophysical Agency of Majalengka Regency, (ii) Statistics Indonesia, (iii) Food Security, Agriculture, and Fisheries Office of Majalengka Regency, and other related sources. The results of this research showed that climate change in Majalengka Regency was marked by an increase in temperature trend and a decrease in rainfall trend. The correlation between temperature and changes in maize production in Majalengka Regency was significant, while rainfall was not significant.

Keywords: Global warming · Rainfall · Temperature

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Introduction

Maize (*Zea mays* L.) is the most important cereal crop because its utilization is relatively diverse and its use supports agriculture zero waste (Panikkai et al., 2017). Maize is used as a source of food, such as the people of East Nusa Tenggara who make maize as their staple food (Yusuf et al., 2013). Besides that, maize can be used as feed, fuels, and other industrial raw materials.

Maize has a multipurpose function and is followed by an increasing demand every year. However, maize often experiences production fluctuations. This can be seen from the frequent fluctuations in maize production in West Java from 2019 to 2021, with recorded production of 1.3 million, 1.4 million, and 1.1 million tonnes (Department of Food Crops and Horticulture, 2021).

In the cultivation of maize, climate is an influential factor in its growth and development. Temperature can affect the physiological processes of crop (Herlina & Prasetyorini, 2020). The optimum temperature for the growth of maize crop is 23 – 27 ^{o}C, while the minimum temperature for maize growth is 8 – 10 ^{o}C and the maximum temperature is 40 ^{o}C (Amaru et al., 2013). Rainfall supports the availability of water for crop (Aqil et al., 2007). Increased rainfall can cause flooding, while decreased rainfall can cause drought which can reduce agricultural production. Lack of water in maize crops can reduce maize yields by 15% especially drought during the flowering stage and seed-filling stage (Muhadjir, 2018). Besides that, sunlight helps in the process of photosynthesis. Maize crops need direct sunlight in the process of growth and development.

Nowadays, the climate has changed. Climate change is a condition of climate components where there is a change that deviates from the usual average state. The causes of climate change can occur due to human activities (anthropogenic) so the contents of the atmosphere (the gas layer that protects the planet Earth) experience changes and cause climate change. According to Julismin (2013) climate change in Indonesia is increasingly being felt by the increasing frequency of floods and droughts. In addition, according to the IPCC report in Ridha et al. (2016) the earth's temperature has increased by around 0.8 ^{o}C for the last 100 years. The study is supported by studies on climate change in the Malang Region, East Java, with the result that air temperature has increased by 0.7 – 0.8 ^{o}C and rainfall decreased by around 0 – 550 mm which resulted in Oldeman's classification changing from class C3 to C2 as well as in the South Sumatra region which showed the results of air temperature increasing by 0.4 – 0.6 ^{o}C and rainfall decreased by 0 – 197 mm (Ruminta et al., 2018).

If the weather is unsuitable for maize crop, it can make maize productivity decrease. Climate change can occur anywhere, even in Majalengka Regency. Majalengka Regency is one of the maize centers in West Java. Based on the Agriculture and Fisheries Food Security Service of Majalengka Regency (2021) maize production has fluctuations especially from 2017 until 2021, namely 151,646, 138,074, 146,130, 150,647, and 118,795 tons. The increase and decrease in maize production in Majalengka Regency is suspected to be partly due to climate change. Various regions in Majalengka Regency have different microclimates because their topography varies, from lowlands to highlands. This causes differences in microclimate, such as cooler temperatures in highland areas and hotter in lowland areas. The magnitude of the consequences of climate change is felt necessary conducted a study on the estimated impact of climate change on maize production in Majalengka Regency in 1990 – 2021. The purpose of this research is to identify climate change, especially temperature and rainfall in Majalengka Regency and to find out the correlation between climate change and maize production in Majalengka Regency in 1990 – 2021.

Materials and Methods

This research was conducted from October 2022 - January 2023 by quantitative descriptive method. This research collected several data using observation techniques, archival data, and surveys in the form of climate data including temperature and rainfall data as well as maize crop data including planted area, harvested area, production, and productivity each obtained from 1990 – 2021. Climate data were obtained from Meteorological, Climatological, and Geophysical Agency Majalengka Regency, while data for maize farming were obtained from (i)

Statistics Indonesia, and (ii) Food Security, Agriculture, and Fisheries Office of Majalengka Regency. Analysis of research data using trend and correlation analysis is as follows

(a). Trend analysis uses the following equation:

$$Y = b_0 + b_1X$$

$$b_0 = \frac{\left(\sum_{i=1}^{n} y_i\right)}{n}$$

$$b_1 = \frac{\sum_{i=1}^{n} (x_i y_i)}{\sum_{i=1}^{n} (x_i)^2}$$

where: Y = trending value of climate data (rainfall or temperature) or maize crop data (production and productivity); b_0 = constant value, that is the value of Y when the value of X = 0; b_1= The value of the slope of the line, that is the additional value of Y, if X increases by one unit; and X = Year period value

(b). Analysis of the correlation between climate change and changes in maize production uses the following formula:

$$r = \frac{\sum_{i=1}^{n} x_i y_i - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{\sqrt{\left(\sum_{i=1}^{n} (x_i)^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2\right)\left(\sum_{i=1}^{n} (y_i)^2 - \frac{1}{n}\left(\sum_{i=1}^{n} y_i\right)^2\right)}}$$

where: r = correlation coefficient; X_i = data on rainfall or temperature; Y_i = maize production or productivity data.

Processing and analysis of research data using software Minitab 19, SPSS 24, and Microsoft Excel 2019

Results and Discussion

Climate Description of Majalengka Regency. The climate in Majalengka Regency is included in the tropical climate, that is, there are two seasons in one year which consist of a rainy season and a dry season. Throughout 1990 - 2021 Majalengka Regency has an average amount of rainfall of around 2656 mm/year which is included in the pattern group monsoonal, that is during the rainy season and dry season there is a clear difference (Hermawan, 2010) and the humidity is around 79%. In addition, temperatures have varied in Majalengka Regency over the last 32 years around 26.7 – 28 ^oC with an average temperature of 27.33 ^oC.

Analysis of Climate Change in Majalengka Regency. Based on the results of the analysis of temperature and rainfall data for the last 32 years, between period 1 (1990 - 2005) and period 2 (2006 - 2021) in Majalengka Regency, there have been changes as shown in Table 1. Every period consists of 15 years because seeing climate change takes a long time.

Table 1 shows that Majalengka Regency experienced climate change between periods 1 and 2 as indicated by the air temperature increasing by 0.33 ^oC. In addition, the average amount of rainfall between periods 1 and 2 decreased by 56.4 mm. The increased temperature can be supported by the results of calculating dry months in both periods where the number of dry months in period 2 is more. Indonesia has experienced an average temperature increase of around 0.1 ^oC/year since the 1990s (Febrianti, 2018) and according to Runtunuwu & Syahbuddin (2007) global temperature has increased over a period of 95 years by 0.57 ^oC. In the Oldeman climate classification type, Majalengka Regency has not changed, that is type D3. The number of Wet Mont and Dry Mont respectively in period 1 was four each, while in period 2 there were four and five. Therefore, the D3 Agroclimate Zone in the Majalengka Regency area is suitable for planting once rice crop and once palawija crop, such as maize, but still attention guaranteed water availability throughout the year (Anwar et al., 2019).

Table 1. Climate change in Majalengka Regency

Climate Indicator	Climate change		Magnitude of Change
	Period 1	Period 2	
Average Temperature (^oC)	27.16	27.49	0.33 (+)
Average Amount of Rainfall (mm)	2683.8	2627.4	56.4 (-)
Wet Months	4	4	0
Dry Months	4	5	1
Oldeman Climate Classification Types	D3	D3	No changes

Trend analysis is carried out to determine the pattern of tendencies (trends) of a change (Susilokarti et al., 2015). Based on trend analysis, temperature has increased, while rainfall has

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decreased (Figures 1 and 2). The increase in temperature can be affected by the number of population. In 2019 the population in Majalengka Regency reached 1,205,034 people with an average population density of 1,000.66 people/km^2. The population is in line with the increase in greenhouse gas emissions which can increase air temperatures (Maria, 2021). In addition, it was followed by various developments, such as the construction of industrial land, infrastructure, residential areas, and the existence of the Kertajati International Airport (Pramudiyasari et al., 2021). This can affect global warming. Global warming is an increase in global average temperature caused by the emission of greenhouse gases into the atmosphere which has a lot and traps solar heat energy (Kusumawardhani & Gernowo, 2015).

The graph of the rainfall trend shows that the amount of rainfall in Majalengka Regency is relatively varied and tends to decrease. Changes in rainfall can be affected by Monsoon Australia – Asia and El Nino-Southern Oscillation (ENSO) which has an impact, such as increasing extreme climate events, such as floods and droughts. El Nino is a condition of below normal rainfall, while La Nina is a condition of above normal rainfall (Sitompul & Nurjani, 2013). Along with climate change, the El-Nino period is becoming faster, becoming 2 - 3 years, from 5 - 6 years at first (Ruminta et al., 2018). During an El Nino, maize production can decrease by around 7.4% during an El Nino (Santoso, 2016).

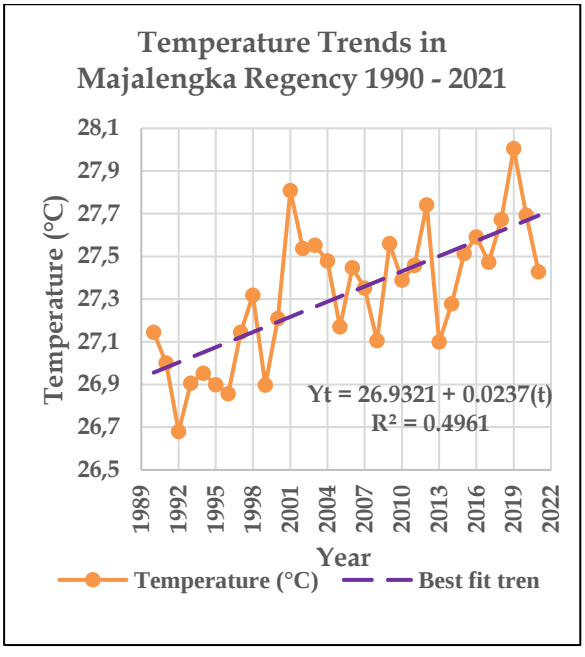

Figure 1. Graph of air temperature trends in Majalengka Regency 1990 – 2021

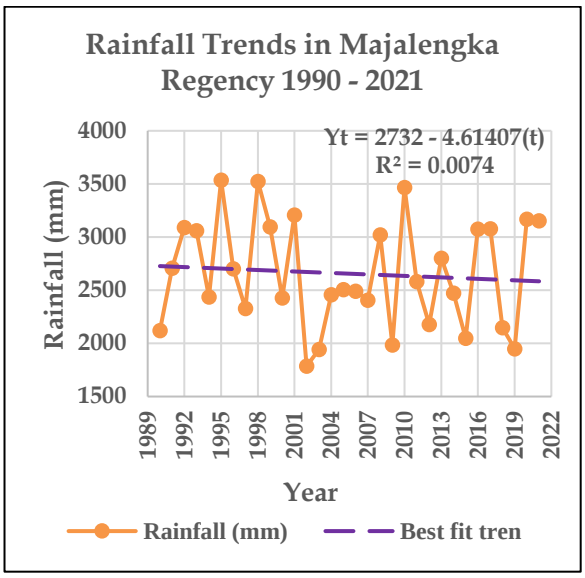

Figure 2. Graph of rainfall trends in Majalengka Regency 1990 – 2021

Analysis of Changes in Maize Production in Majalengka Regency. From the graphic image of the trend maize production in Majalengka Regency 1990 – 2021, it shows a line that tends to increase (Figure 3). This is because farmers generally have implemented maize cultivation properly, such as using certified seeds and planting 1 - 2 seeds/hole. Planting maize with 1 seed/hole will relatively give good results because it reduces competition, such as space, water, light, and nutrients between crops (Bolly, 2018). The use of hybrid seeds has also been widely applied, such as the Bisi 18 and NK 212 varieties which are drought resistant and capable of producing an average yield of 9.1 and 9.5 t/ha of dry shell (Cereal Crops Research Institute, 2012). Hybrid seeds have better quality than composite seeds which are usually used by farmers before using hybrid seeds. This is because hybrid seeds have dominant genes that give high yields (Haryati & Permadi, 2015). In addition, the temperature in the last 32 years shows values in the range of 26.7 – 28 ^{o}C and this shows a sufficient temperature for the growth and development of maize crop which has an optimum temperature of 23 – 27 ^{o}C (Amaru et al., 2013). The optimum temperature is the best temperature for ideal crop growth.

On the other hand, maize production has often decreased. In previous observations it was seen that rainfall was decreasing and this had

the potential to cause drought. Drought can affect the physiological processes of maize crop, such as the process of photosynthesis, growth, the seed filling phase is hampered, and the weight of maize kernels decreases and the size of the seeds decreases (Hirich *et al*., 2012). When the temperature exceeds the suitable for maize crop it will give different results (Herlina & Prasetyorini, 2020).

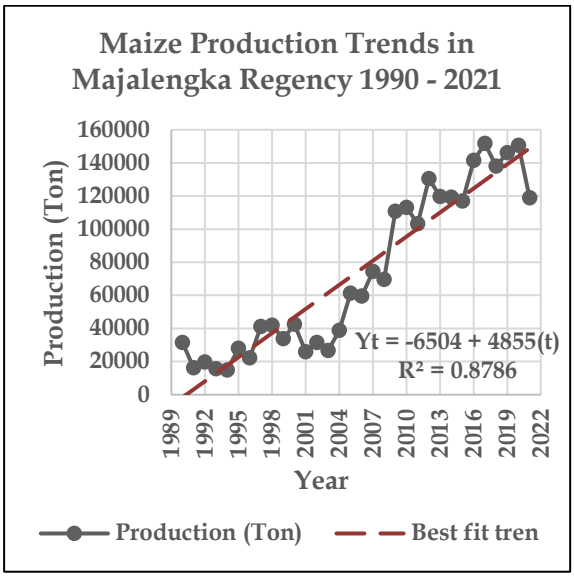

Figure 3. Graph of maize production trends in Majalengka Regency 1990 – 2021

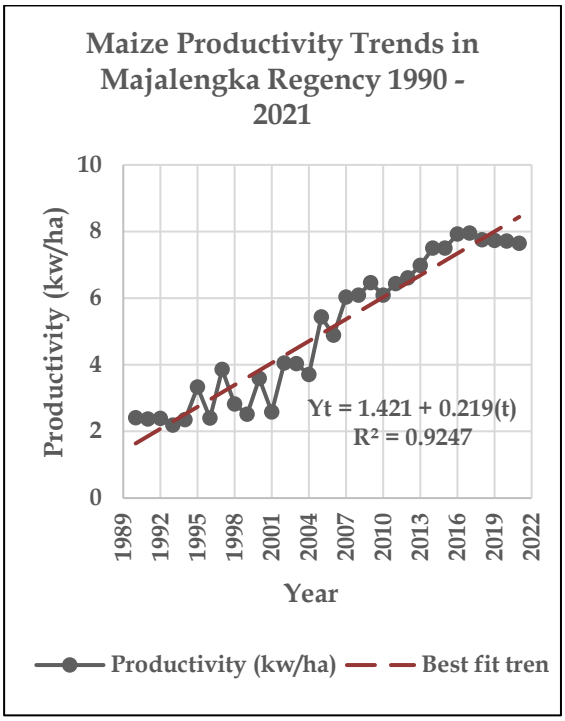

Figure 4. Graph of maize productivity trends in Majalengka Regency 1990 – 2021

Not only on production, analysis of the maize productivity was also carried out (Figure 4). Maize productivity is influenced by production yields and maize crop area. Productive land use can determine the productivity of agricultural commodities, especially food crops, which are a source of food security in West Java. The area planted for maize still fluctuations, for example from 2017 until 2021, namely 21.054, 15.967, 18.120, 19.477, and 15.909 ha. One of the challenges currently faced in agricultural cultivation activities is land conversion. This is also a challenge in the use of agricultural land in Majalengka Regency with higher population growth which can change the local environment. This can be seen in the use of agricultural land in 2020 which has decreased compared to previous years to reach 371 Ha. One of them is the Development of the West Java International Airport (BIJB) in Majalengka Regency which has resulted in the conversion of agricultural land so that farmers lose their livelihoods and change farmers income (Hidayat et al., 2017). With a variety of human activities, it can add greenhouse gases which will accumulate in the atmosphere and trigger global warming (Aldrian et al., 2011).

Correlation of Climate Change Relationship with Changes in Maize Production in Majalengka Regency. Maize yields are influenced by two factors, biotic factors and abiotic factors including pests, diseases, weeds, soil microorganisms, soil, and climate. Changing climatic conditions will affect the production of a crop, as well as the maize crop (Nurmala et al., 2015). The analysis technique commonly used to determine the strength and direction of the linear relation of two variables is the Pearson correlation analysis technique. Pearson correlation analysis was used to determine whether there is a relationship between changes in temperature and rainfall on changes in maize production and productivity. The results of the correlation analysis between changes in temperature and rainfall on maize production and productivity in Majalengka Regency are shown in Table 2.

Table 2 showed temperature changes were significantly correlated with a positive direction, while changes in rainfall were not significantly correlated with a negative direction on maize production and productivity. Changes in

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temperature with a significant correlation illustrate that temperature changes affect changes in the production and productivity of maize. Based on previous study by Herlina & Prasetyorini (2020), temperature and productivity have a relation. The positive direction indicates that when the temperature increases, maize production and productivity also increase to a certain extent (23 – 27 ^{o}C). This is because temperature can activate enzyme performance, when temperature increases, enzyme performance increases, and causes the rate of photosynthesis to increase (Su'udi et al., 2022). The rate of biological metabolism increases as the rate of enzymes increases, such as the Rubisco enzyme in the photosynthesis process. The rubisco enzyme catalyzes the reaction of adding CO_2 to RuBP and produces 3-PGA. This is a step in converting light energy into chemical energy that crops can need. Rubisco enzyme efficiency has a direct impact on photosynthesis rates and crop productivity (Moore et al., 2021). If the temperature is not normal for maize crop, the increase in maize production will be hampered.

Table 2. Correlation of changes in maize production with climate in Majalengka Regency

Correlation	Temperature	Rainfall
Production	0.637*	-0.225
Productivity	0.628*	-0.278

Note: (*) significant

Changes in rainfall with no significant correlation indicate that changes in rainfall don't directly affect changes in the production and productivity of maize. This is because even though rainfall tends to decrease, it is enough to meet the water needs of maize crop. Based on previous study by Herlina & Prasetyorini (2020), rainfall doesn't have a significant correlation with maize productivity. The resulting negative direction illustrates that when rainfall decreases, the production and productivity of maize crops will increase. This is because when the rainy season coming, farmers in Majalengka Regency prefer to plant rice crop. After all, this crop can survive in flooded conditions. High rainfall can cause puddles in maize planting land resulting in abiotic stress. Stagnant water in maize crop can reduce production by 30 - 50% from normal conditions (Li et al., 2011). Conversely, when the dry season enters, farmers prefer to plant maize crop (Ekopranoto, 2019). Rainfall tends to decrease causing clouds to rarely appear so that sunlight can be maximally received by the earth. The intensity of sunlight that is fully captured by maize crop can increase the rate of photosynthesis of these crops (Yustiningsih, 2019). Sunlight is the main energy source in the photosynthesis process in converting water and CO_2 into oxygen and glucose. Leaves absorb 1 – 5% of solar energy and with sufficient water they can optimize the use of sunlight in the photosynthesis process. If there is water stress, the stomata tend to close in response to reduce water evaporation (Taiz & Zeiger, 2010).

There is also a correlation analysis between temperature and maize production and productivity in 26 sub-districts in Majalengka Regency which is contained in the form of a map. (Figure 5 and Figure 6). There are various colors on the map which reflect that the darker the color, the stronger the relationship between these variables, and the lower the relationship, the more faded the color. A positive correlation or a one-way relationship between variables is depicted in green on the map, while a negative correlation or a relationship in the opposite direction is depicted in blue on the map. The results of the correlation analysis in Figure 5 show a positive correlation that dominates, meaning that an increase in temperature will be in line with an increase in maize production in the sub-district and various relationship categories. The very low category correlation includes the Sub-Districts of Sumberjaya, Palasah, Sukahaji, and Banjaran with a coefficient value of 0.038 – 0.186, while the low category consists of the Sub-Districts of Jatitujuh, Ligung, Jatiwangi, Kadipaten, Bantarujeg, and Talaga. Kertajati, Panyingkiran, Majalengka, Cigasong, Sindang, Rajagaluh, Sigwangi, and Cingambul Sub-Districts belong to the enough category, while the strong category, namely Kasokandel, Argapura, Lemahsugih, and Cikijing Sub-Districts, has a coefficient value close to 1, which is between 0.639 – 0.735.

The negative correlation means that the increase in temperature is not in the same direction as the increase in maize production in the sub-district. The very low category includes the Sub-Districts of Dawuan, Maja, and Malausma with coefficient values between 0.033 – 0.192, while Leuwimunding is a sub-district with a low category which has a coefficient value of 0.285.

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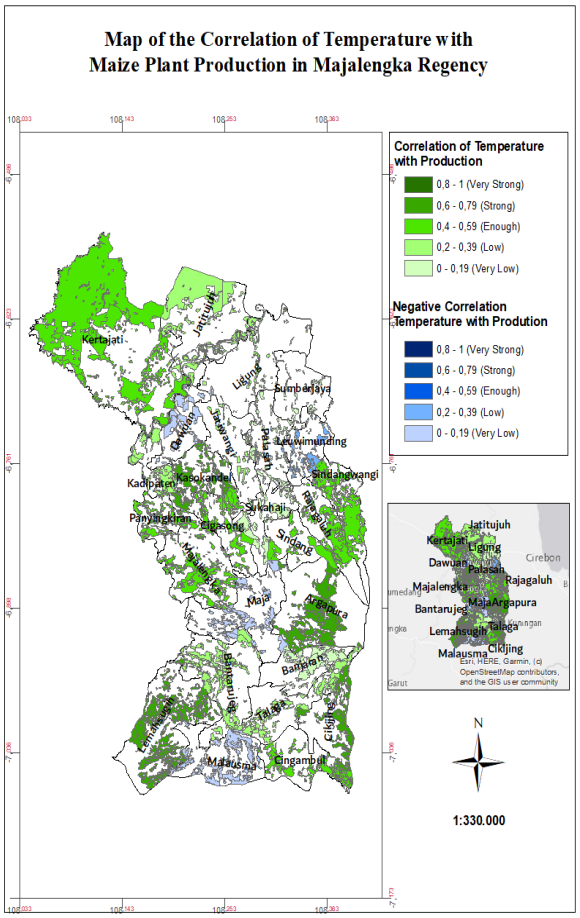

Figure 5. Map of the correlation of temperature with maize production in Majalengka Regency

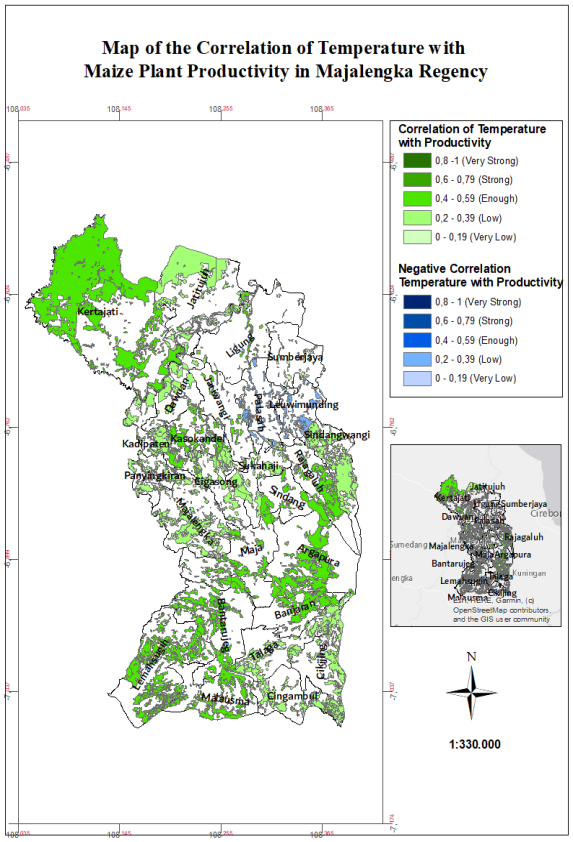

Figure 6. Map of the correlation of temperature with maize productivity in Majalengka Regency

The results of the correlation analysis in the Figure 6 show a positive correlation that dominates, which means that the increase in temperature is in line with the increase in the productivity of maize in the sub-district. The very low category correlation is Sumberjaya Sub-District with a coefficient value of 0.105, while low correlation includes Jatitujuh, Dawuan, Kadipaten, Panyingkiran, Majalengka, Cigasong, Sukahaji, Sindangwangi, Talaga, Cingambul, and Cikijing Sub-Districts. Kertajati, Ligung, Jatiwangi, Kasokandel, Rajagaluh, Sindang, Maja, Argapura, Banjaran, Bantarujeg, Lemahsugih, and Malausma Sub-Districts are in the enough correlation category with a coefficient value of 0.400 - 0.482. The negative correlation that indicates the increase in temperature is not in line with the productivity of maize in Palasah and Leuwimunding Sub-Districts with coefficient values of 0.390 and 0.220.

Conclusion

Majalengka Regency has experienced climate change as indicated by an increase in average air temperature of 0.33 ^{o}C which is characterized by an increasing trend and a decrease in rainfall of 56.4 mm which is indicated by a decreasing trend. Based on the results of the correlation analysis, changes in maize production and productivity in Majalengka Regency are significantly correlated with temperature changes, while not significantly correlated with changes in rainfall. Efforts that can be implemented to deal with climate change are the use of superior seeds from high-yielding and early maturing hybrid varieties, managing planting time, building reservoirs, and reforestation as a form of reducing GHS emissions.

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