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Analysis of vulnerability and risk of maize (*Zea mays* L.) production decrease on rainfed land in Garut Regency due to climate change and its strategic adaptation options

Abstract. Climate change, especially air temperature and rainfall, impacts the agricultural sector, one of which is the reduction of maize production. As an anticipatory effort to reduce maize production due to climate change, a study is needed to identify the possible hazard, vulnerability, and risk of maize yield reduction at the sub-district level in the largest maize-producing center in West Java, Garut Regency. After identifying areas with high or very high levels of potential yield reduction risk, a strategic adaptation that can be applied to deal with climate change can be identified. The method used in this research is descriptive quantitative. The data used include temperature, rainfall, planting area, harvest area, production, productivity, and socio-economic data of farmers obtained from LAPAN, BPS, Garut Regency Agriculture Office, and other related sources. The results of the study stated that the areas with a potential risk of production decrease at a very high level (IR >0.81) are in Wanaraja and Malangbong sub-districts; high level (IR: 0.61-0.80) are in Cisewu, Pakenjeng, Banyuresmi, and Limbangan. Meanwhile, the potential risk level of maize productivity decrease is very high (IR >0.81) in Cisewu, Pamulihan, Banyuresmi, Malangbong, and Limbangan; high (0.61-0.80) in Bungbulang, Singajaya, Cilawu, Bayongbong, Leles, Leuwigoong, Cibiuk, Cibatu, and Selaawi. Adaptation strategy to minimize the potential risk of reduced maize yields can be done by using superior hybrid varieties, managing planting time, water management, minimum tillage, and mixed cropping.

Keywords: Rainfall · Risk · Strategic adaptation · Temperature

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Introduction

Maize (*Zea mays* L.) is one of the agricultural commodities for human consumption but also for livestock feed and industrial raw material, so has quite a lot of benefits. However, the increasing demand for maize is not matched by sufficient availability or production of maize, as happened in 2012-2016 where one of the important components in the calculation of production, namely the maize harvested area in Indonesia, decreased by an average of 2.78% each year (Nuryati et al., 2016). The decrease in maize harvest area is caused by the conversion of agricultural land into other interests such as industry and housing. The impact of climate change on agricultural production is the decrease in maize crop harvested area (Herlina & Prasetyorini, 2020).

Climate change is a condition in which the magnitude of some climate elements tends to change or deviate from average conditions and existing dynamics towards a certain direction (decrease or increase). Global climate change in Indonesia seems to be a reality and has been felt (Ruminta, 2011). This is indicated by disasters such as floods, droughts (long dry season), and shifts in the rainy season which can certainly threaten the resilience of the agricultural sector, especially food, because food crops generally include annual crops that are relatively sensitive to stress, especially excess and lack of water.

Maize production in Garut Regency, which is one of the largest maize-producing centers in West Java, still fluctuates. This can be seen from the data from BPS Garut Regency (2019) where from 2014 to 2019 the production of maize decreased from 567,876 tons to 489,301 tons. This is suspected due to climate change, especially in West Java, including Garut Regency, where maize is predominantly grown on dry or rainfed land. If there is a shift in the rainy or dry season due to climate change, it is feared that there will be land degradation due to soil erosion by water, or drought, which will certainly have an impact on the productivity of maize plants (Estiyaningsih & Syakir, 2017). Likewise, a prolonged rainy season has the potential to result in an increase in the volume of water on the soil surface or inundation in maize crops, which will create anaerobic conditions, resulting in unstable nutrient and water transport to leaf tissues and resulting in closed stomata that will ultimately reduce plant yields.

Therefore, it is necessary to conduct research to find out how much climate change has occurred in Garut Regency from 1982-2018, as well as the need for prediction and anticipation as an effort to minimize losses that can occur by making a study of the potential level of hazard, vulnerability, and risk of reducing maize crop yields.

The purpose of this study is to determine the magnitude of climate change in Garut Regency and analyze which areas have the potential for high to very high levels of risk of decreased maize production so that later it is expected to find a recommendation or strategic adaptation options that are appropriate as an effort to adjust and reduce the risk of agricultural production failure.

Materials and Methods

The experiment was conducted in March-August 2022. This research used a quantitative descriptive method, with data collected from 1982-2018 which was then interpreted using ArcGIS software. The data used in the research include rainfall and temperature. data on land area, harvest area, production, productivity of maize, altitude, and socio-economic of farmers obtained from LAPAN Garut, Garut Regency Agriculture Office, and BPS.

The stages of analysis used include the following

(1). Hazard Analysis

a.) Effect of Temperature Increase on Maize Yield

Ruminta & Handoko (2012) revealed that an increase in air temperature can lead to an increase in plant respiration which has the potential to reduce crop yields. The relationship is written with the following *Temperaturweretient* formula.

$$\mathbf{Q_{10} = 2^{(T-20)/10}}$$

An increase in temperature can result in a decrease in yield, written in the following formula.

$$\mathbf{\Delta Yp_1 = Y_0\,(Q_{10}\text{-}Q_{10o})}$$

Where: T = temperature (^oC); $\Delta Yp1$ = potential yield reduction due to crop respiration (ton/ha); Y_0 = crop production before air temperature increase (ton/ha); Q_{10} = temperature quotient after temperature increase; Q_{10o} = initial temperature quotient.

Relationship between yield reduction due to an increase in air temperature.

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$$Yp_2 = Y_o\ (T_o - T_b)/(T - T_b)$$
$$\Delta Yp_2 = Y_o - Yp_2$$

Where: ΔYp2 = potential yield reduction due to decreased crop age (ton/ha); Yo = crop production before air temperature increase (°C); T_o = initial air temperature (°C); T = air temperature after temperature increase (°C); Tb = plant base temperature (°C).

b.) Effect of Rainfall on Crop Yields

$$\Delta Yp_3 = k\ .\ \Delta P$$

Where: ΔYp3 = potential reduction in maize yield (ton/ha) due to drought; P = change in rainfall (mm/season).

$$\Delta Y_a = \max\ (\Delta Yp_1, \Delta Yp_2, \Delta Yp_3)$$

Where: ΔY_a = reduction in crop yield due to increased air temperature (ton/ha); ΔYp1 = potential reduction in yield due to plant respiration (ton/ha); ΔYp2 = potential reduction in yield due to decreased crop age (ton/ha); ΔYp3 = potential reduction in maize yield (ton/ha) due to drought.

(2). Vulnerability Analysis

$$V = E \times S\ /\ AC$$

Where: V = vulnerability; E = exposure; S = sensitivity; AC = adaptive capacity.

(3). Risk Analysis

$$R = H\ .\ V$$

Where: R = Risk; H = Hazard.

In this study, a survey was also conducted with maize farmers and officers of the Agriculture Office to find out the adaptation options maize farmers in Garut Regency have.

Results and Discussion

Analysis of Climate Change in Garut Regency. Based on the analysis of air temperature and rainfall data from 1982-2018, Garut Regency has experienced climate change as shown in Table 1.

Table 1. Climate Changes

Climate Indicator	Climate Changes	
	Period of 1982-1999	Period of 2000-2018
Average Air Temperature (°C)	26.64	26.84
Average Rainfall Amount (mm)	1872.71	2392.49
Consecutive Wet Months (BB)	3	4
Consecutive Wet Months (BK)	2	1
Oldeman Classification	D2	D1

Table 1 shows that Garut Regency in the period 1982-1999 and 2000-2018 experienced an increase in air temperature of 0.2°C. The analysis results also show that rainfall in Garut Regency during the period 1982-1999 and 2000-2018 increased by 519.78 mm. The increase in rainfall is an impact of the increase in temperature in Garut Regency, and this is in line with the statement of Prasetyo et al. (2021), which states that in tropical areas, the increase in air temperature is followed by an increase in rainfall intensity as a result of high evaporation.

Besides the increase in rainfall, the climate type of Garut Regency has also changed, which is characterized by an increase in the average wet month in the 2000-2018 period. The climate type grouping used in the study is the Oldeman climate type. In 1982-1999 Garut Regency was included in the D2 agroclimatic zone area, then in the next period, namely 2000-2018 Garut Regency experienced an increase in wet months consecutively to 4 months (D1). The addition of 1 wet month in the 2000-2018 period is allegedly related to the increase in rainfall in the same year. Concerning agriculture, especially food, this D1 agro-climatic zone type means that it can be planted by short-aged rice once, and the time for planting secondary crops (including maize) is sufficient (Harahap et al., 2021; Maylay, 2019).

Climogram Changes in Garut Regency. A climogram is a graph that describes the climate conditions in a location. Based on the results of the climogram analysis listed in Figure 1, it can be concluded that in the 1982-1999 and 2000-2018 periods, there has been an increase in air temperature, which is characterized by a pattern of shifting temperature numbers towards the Y axis. Rainfall in certain months is also seen to have undergone significant changes which is also evidenced by the pattern of shifting rainfall numbers towards the X axis. Climate change described by climogram has also occurred in Malang, East Java, where the area generally experienced an increase in average air temperature and rainfall characterized by a shift in the climogram to the right (Ruminta, 2015).

Hazard of Maize Production Decrease. The potential hazard of maize production decrease in Garut Regency is obtained from the analysis results assuming that changes in air temperature and rainfall are related to the potential decrease of food crops. The result of the analysis of the magnitude of the potential hazard of maize production decrease in Garut

Regency is shown in Figure 2. The potential hazard of decreased maize production due to climate change in each sub-district averaged 3%. The area with the highest potential hazard of maize production decline is Wanaraja Subdistrict, and the highest level of potential maize production decline is in Pakenjeng Subdistrict.

The potential decrease in production can occur due to climate change in Garut Regency because climate change, such as an increase in temperature, impacts crop yields. The amount of air temperature is directly related to metabolic processes such as respiration. When the air temperature increases, the respiration rate also increases. High respiration causes the decomposition of photosynthesis products, thereby reducing plant yields. Likewise with rainfall, according to the analysis, Garut Regency experienced an increase in rainfall in several months when the average rainfall reached 300 mm/month. In contrast, the rainfall needed by maize plants grown on non-irrigated land is around 85-200 mm/month (Kemendag, 2016). This could lead to a decrease in maize yields, as maize is intolerant of inundation (anaerobic conditions) (Tian et al., 2020; Chen et al., 2014; Mangani et al., 2018).

Hazard of Decreasing Maize Productivity. Productivity is a value that shows the average production yield/unit area of food crop commodities. The magnitude of the hazard of decreasing productivity of maize crops is calculated to determine the potential decrease in maize productivity/unit of land in each sub-district in Garut Regency. The amount of potential productivity decrease is calculated in the same way as the production hazard analysis, which in this analysis requires data on maize productivity from 1982 to 2018.

The results of the analysis of the magnitude of the potential hazard of decreased maize productivity in Garut Regency are shown in Figure 3. The potential hazard of decreased maize productivity in Garut Regency is moderate to very high. The high level of potential decrease dominates in almost every region in Garut Regency. Meanwhile, the region with the highest potential decrease is Pamulihan Subdistrict. Similar to production, the potential hazard of decreasing maize productivity in each sub-district in Garut Regency averages at 3%

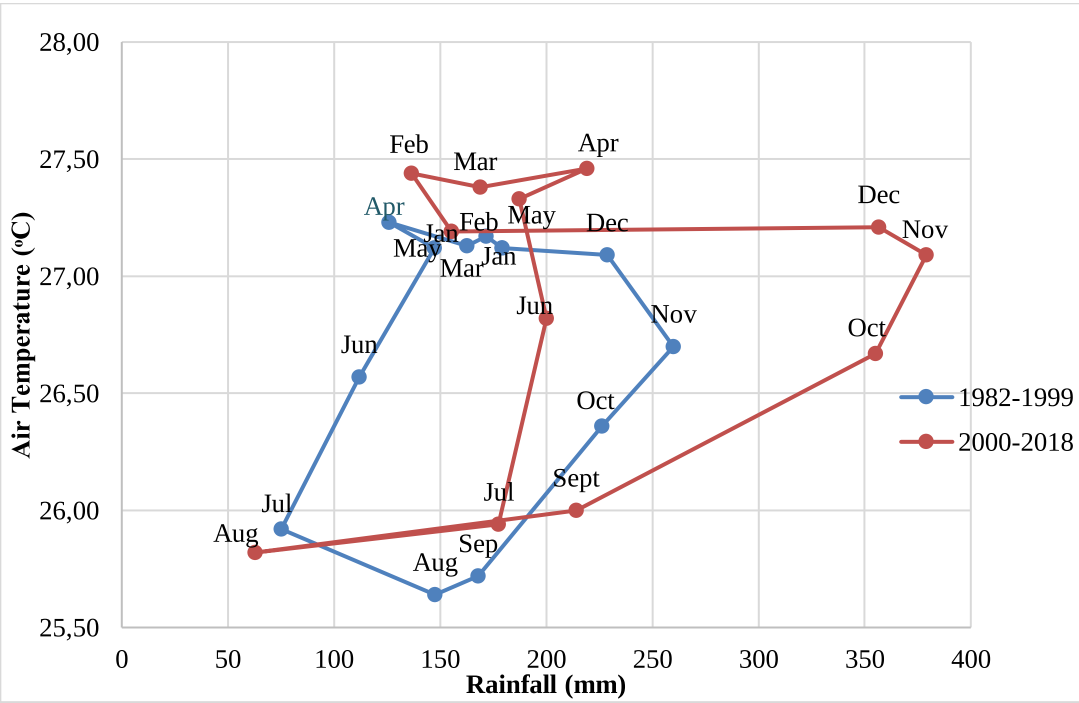

Figure 1. Climogram of Garut Regency

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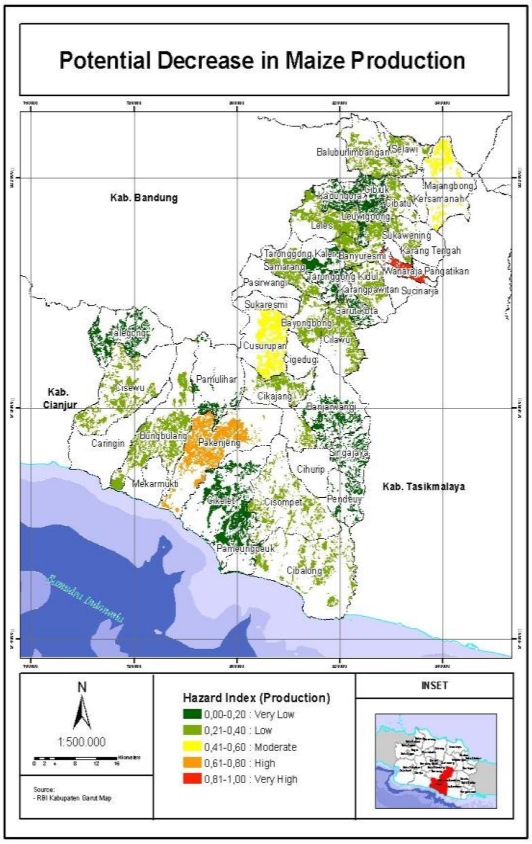

Figure 2. Map of potential decrease of maize production

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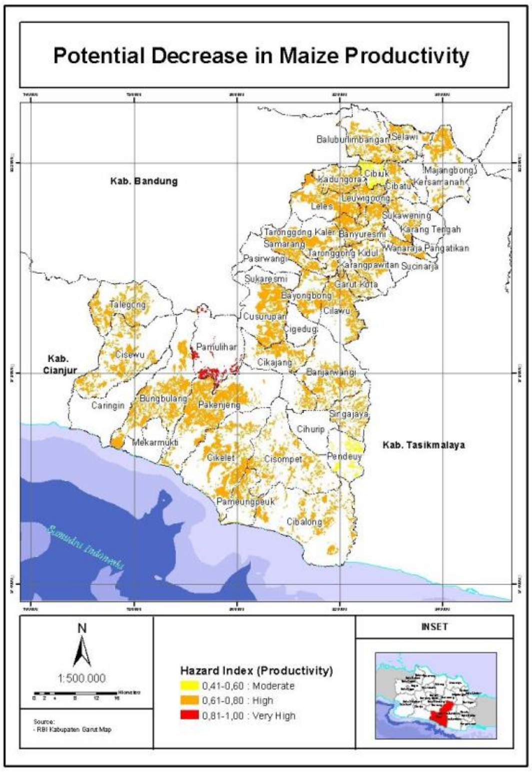

Figure 3. Map of potential decrease of maize productivity

Vulnerability of Agriculture Sector in Garut Regency. The potential vulnerability of reduced maize production was analyzed using a combination of three components: exposure, sensitivity, and adaptive capacity. The indicators that makeup exposure, the magnitude of potential exposure due to climate change, are the number of maize farmers and the area of land planted with maize. The sensitivity indicators, which are the dimensions of agriculture easily affected by climate change, are rainfed land area and altitude. While the indicators used in analyzing the adaptive capacity that shows the ability of farmers to deal with climate change are education and income.

High levels of exposure and sensitivity can increase the level of vulnerability. At the same time, adaptive capacity is inversely proportional to vulnerability, meaning that the greater the level of adaptive capacity in an area, the lower the level of vulnerability. The results of the vulnerability analysis in Garut Regency are shown in Figure 4.

From the results of this analysis, it can be seen that the areas with the highest vulnerability index are only in Malangbong and Limbangan, with a value of. In contrast, areas that fall into the high vulnerability category are Cisewu, Banyuresmi, and Selaawi.

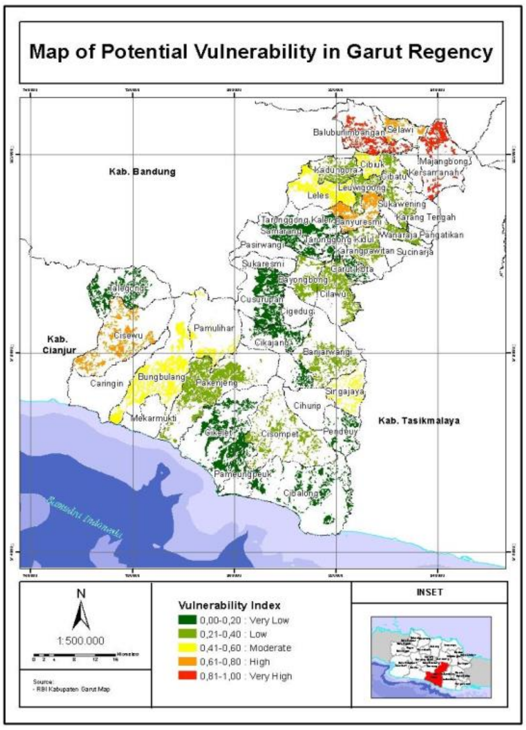

Figure 4. Map of Potential Vulnerabilities

Risk of Maize Production Decrease. Based on the results of the analysis of the potential risk of decreased maize crop production obtained from the product of hazard and vulnerability, it can be seen that two sub-districts are included in the area that has a very high level of risk of decreased production, namely Wanaraja and Malangbong. This shows that each of these areas has the highest level of hazard and vulnerability to maize production decrease among the other areas, while Cisewu, Pakenjeng, Banyuresmi, and Limbangan sub-districts are included in the high-risk areas (Figure 5).

Risk of Maize Productivity Decrease. The analysis of the potential risk of decreased productivity is calculated per unit area (ha^{-1}) planted with maize. Based on the results, the areas with the highest level of risk are Cisewu, Pamulihan, Banyuresmi, Malangbong, and Limbangan sub-districts. Areas with potentially high-risk levels are found in nine sub-districts, including Bungbulang, Singajaya, Cilawu, Bayongbong, Leles, Leuwigoong, Cibiuk, Cibatu, and Selaawi (Figure 6).

From the areas with the potential risk of decreasing maize yields in both production and productivity with high and very high levels, strategic adaptation efforts to climate change are needed so that maize yields can increase or maintain at least. If strategic adaptation efforts are not made, it is feared that maize in Garut Regency will decrease and disrupt the supply of food needs.

Strategic Adaptation Options. The adaptation is especially prioritized in areas with high or very high levels of risks from the impacts of climate change. Most maize farmers in Garut Regency have recognized the impact of climate change on agriculture. Farmers in Garut Regency have made some efforts to anticipate climate change, including the use of hybrid maize seeds of Bisi 16 and Bisi 18 varieties, which are considered to have an important role in suppressing the decrease in maize production due to climate change. This is because, in addition to having high average yields (9.2 and 9.1 ton/ha), both varieties can be planted during the dry/rainy season, which is also in accordance with the climatic conditions of Garut Regency, which has been predicted to experience increased rainfall. In addition to the use of these maize varieties, Litbang Pertanian in its Katam system also recommends using hybrid maize seeds of Pioneer 15, Bisi 9, Bisi 12, Bisi 13, and DK 3 in the Garut Regency area (Litbang Pertanian, 2020). The recommended varieties have high yield potential, can be planted in two seasons, and are early maturing. Early-maturing hybrid varieties are considered an effort to minimize crop failure due to climate change, such as short rainy periods or prolonged rains that will disrupt the growth of maize plants (Carena, 2013; Major et al., 2021).

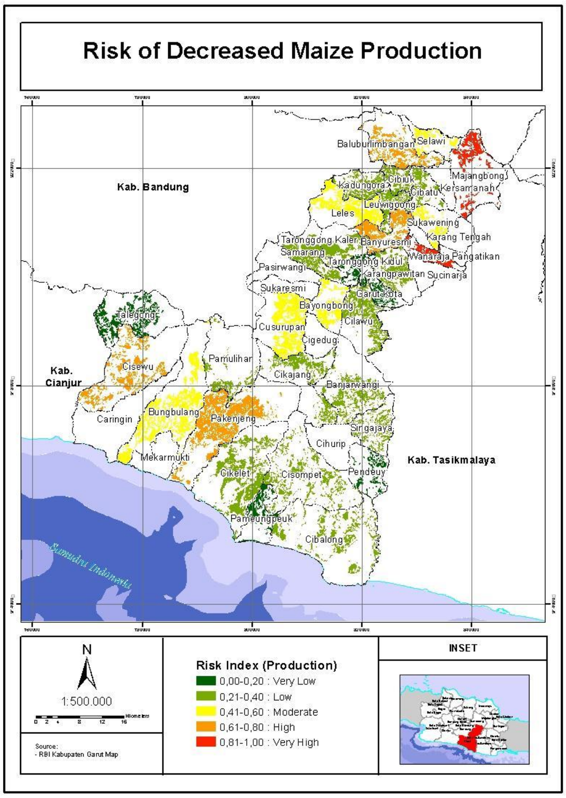

Figure 5. Maize Production Decrease Risk Map

Efforts to manage planting time also need to be made to reduce losses due to floods or droughts due to climate change. In addition, to reduce the occurrence of inundation around maize crops due to high rainfall, a good drainage system is needed so that maize growth is not disturbed, or an alternative can be made by making a bed system (Fahong et al., 2004).

To anticipate the occurrence of drought due to insufficient rainwater supply, especially when maize planting is done on rainfed or dry land, some farmers in Garut Regency have made efforts by collecting rainwater and making boreholes which the local agricultural agency also facilitates. The borehole wells have a big contribution in the effort to prevent a water crisis that is feared to lead to crop failure.

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Minimum tillage is also important to avoid soil saturation and minimize soil aggregates from damage, and minimum tillage increases the activity of microorganisms in the soil (Wahyuningtyas, 2015). The mixed cropping system that most farmers have also applied has the advantage of increasing crop yields, the diversity of plant species can also limit the spread of pests (Thornton & Herrero, 2014; Thamo et al., 2017; Ghahramani et al., 2020).

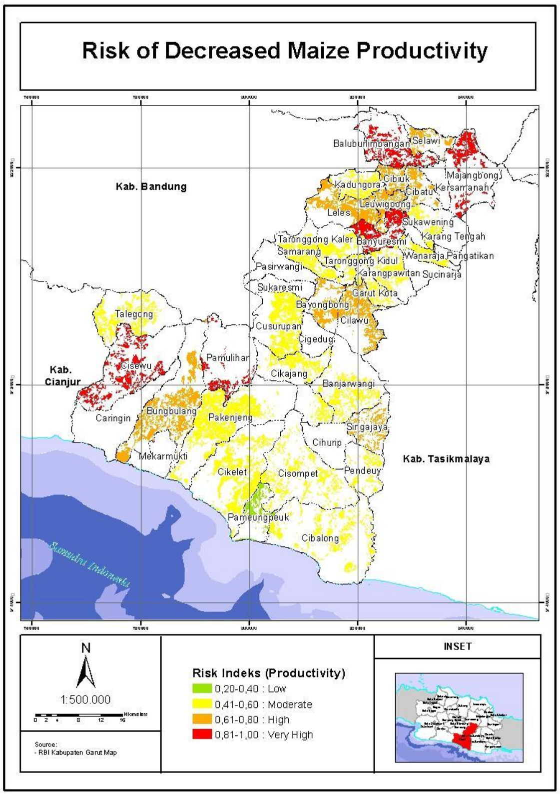

Figure 6. Maize Productivity Decrease Risk Map

Conclusion

1. Garut Regency experienced climate change characterized by an increase in average air temperature of 0.2°C and an increase in rainfall of 519.78 mm, and there was a climogram shift to the right and upward in the 2000-2018 period accompanied by a change in climate type from D2 to D1.
2. An increase in average air temperature by 0.2°C and rainfall by 519.78 mm in Garut Regency can decrease maize production and productivity by 3% on average.
3. Areas with a very high risk of maize production decrease are located in Wanaraja and Malangbong sub-districts; high level is located in Cisewu, Pakenjeng, Banyuresmi, and Limbangan sub-districts, while areas with a very high risk of maize productivity decrease are located in Cisewu, Pamulihan, Banyuresmi, Malangbong, and Limbangan sub-districts; high-risk level is located in Bungbulang, Singajaya, Cilawu, Bayongbong, Leles, Leuwigoong, Cibiuk, Cibatu, and Selaawi sub-districts.
4. Adaptation strategies that can be recommended to deal with climate change, some of which have also been implemented by local farmers, including the use of high-yielding seeds that can be planted during droughts or prolonged rains, such as the hybrid varieties BISI 16 and BISI 18. Litbang Pertanian also recommends using early-maturing and high-yielding varieties such as Pioneer 15, BISI 9, BISI 12, BISI 13, and DK 3. Other adaptation strategies that can be carried out are proper planting time management, rainwater harvesting or drilling wells, minimum tillage, and mixed cropping.

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References

BPS Garut Regency. 2019. Garut Regency in Numbers 2019. Badan Pusat Statistik Kabupaten Garut.

Carena MJ. 2013. Developing the next generation of diverse and healthier maize cultivars tolerant to climate changes. Euphytica, 190(3), 471–479. https://doi.org/10.1007/s10681-012-0849-z

Chen Y, Chen X, Wang H, Bao Y, Zhang W. 2014. Examination of the leaf proteome during flooding stress and the induction of programmed cell death in maize. Proteome Science, 12(1), 33. https://doi.org/10.1186/1477-5956-12-33

Estiyaningsih W, Syakir M. 2017. The effect of climate change on rice production in rainfed areas. Jurnal Meteorologi dan Geofisika, 18 (2):83–93.

Fahong W, Xuqing W, Sayre K. 2004. Comparison of conventional, flood irrigated, flat planting with furrow irrigated, raised bed planting for winter wheat in China. Field Crops Research, 87(1), 35–42. https://doi.org/10.1016/j.fcr.2003.09.003

Ghahramani A, Kingwell RS, Maraseni TN. 2020. Land use change in Australian mixed crop-livestock systems as a transformative climate change adaptation. Agricultural Systems, 180, 102791. https://doi.org/10.1016/j.agsy.2020.102791

Harahap IS, Matondang IZ, Suryanto, Indah EK, Fitri I. 2021. Mapping Climate Classification of Oldeman in Agricultural Resources Management in South Tapanuli District. IOP Conference Series: Materials Science and Engineering, 1156(1), 012002. https://doi.org/10.1088/1757-899X/1156/1/012002

Herlina N, Prasetyorini A. 2020. Effect of climate change on planting season and productivity of maize (*Zea mays* L.) in Malang Regency. Jurnal Ilmu Pertanian Indonesia, 25(1): 118–128. https://doi.org/10.18343/jipi.25.1.11

Kemendag. 2016. Corn Commodity Profile. [referred to 2022 Agustus 31]. Avaible at: https://ews.kemendag.go.id

Litbang Pertanian. 2020. Integrated planting calendar. [referred to 2022 Agustus 31]. Avaible at: https://www.litbang.pertanian.go.id

Major DJ, McGinn SM, Beauchemin KA. 2021. Climate change impacts on corn heat unit for the Canadian Prairie provinces. Agronomy Journal, 113(2), 1852–1864. https://doi.org/10.1002/agj2.20574

Mangani R, Tesfamariam E, Bellocchi G, Hassen A. 2018. Growth, Development, Leaf Gaseous Exchange, and Grain Yield Response of Maize Cultivars to Drought and Flooding Stress. Sustainability, 10(10), 3492. https://doi.org/10.3390/su10103492

Maylay S, Rauf A, Hanum C, Hanum H. 2019. Upland Rice Growth Performance Grown under Different Planting Times and Biochar Applications at Zone D1 Oldeman Agroclimate in North Sumatra. 235–240. https://doi.org/10.5220/0008552302350240

Nuryati L, Budi W, Akbar, Roch W. 2016. Corn Food Crop Agricultural Commodity Outlook. Pusat Data dan Sistem Informasi Pertanian Kementrian Pertanian.

Prasetyo S, Hidayat U, Haryanto YD, Riana NF. 2021. Variations and trends in surface air temperature on Java Island. Jurnal Geografi, 18 (1), 60-68. https://doi.org/10.1594/jg.vl8il.27622

Ruminta, Handoko. 2012. Study of Risk and Adaptation to Climate Change in the Agricultural Sector in South Sumatra. Laporan Penelitian. KLH. Jakarta.

Ruminta. 2011. Study of vulnerability, risk and adaptation to climate change in the agricultural sector in Bandung Regency, West Java. Laporan Penelitian. Universitas Padjadjaran.

Ruminta. 2015. The impact of climate change on apple production in Batu Malang. Kultivasi, 14(2): 42–48. https://doi.org/10.24198/kultivasi.v14i2.12064

Thamo T, Addai D, Pannell DJ, Robertson MJ, Thomas DT, Young JM. 2017. Climate change impacts and farm-level adaptation: Economic analysis of a mixed cropping–livestock system. Agricultural Systems, 150, 99–108. https://doi.org/10.1016/j.agsy.2016.10.013

Thornton PK, Herrero M. 2014. Climate change adaptation in mixed crop–livestock systems in developing countries. Global Food Security, 3(2), 99–107. https://doi.org/10.1016/j.gfs.2014.02.002

Tian L, Bi W, Ren X, Li W, Sun L, Li J. 2020. Flooding has more adverse effects on the stem structure and yield of spring maize (Zea mays L.) than waterlogging in Northeast China. European Journal of Agronomy, 117, 126054. https://doi.org/10.1016/j.eja.2020.126054

Wahyuningtyas R. 2015. Conserve soil with conservation tillage. Jurnal Galam, IV(2): 81–96.