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Identification of extreme weather and their correlation on soybean production in Garut regency

Abstract. The phenomenon of extreme weather events as a result of the impact of climate change can cause threats to agricultural systems, including soybean (*Glycine max* L.). Soybean is the main source of vegetable protein, which is sensitive and vulnerable to climate change. Therefore, research has been carried out through the identification analysis of changes in extreme weather events and analyzed for their correlation with soybean crops in Garut Regency to determine the effect of extreme weather elements on soybean production. The method used in this research is descriptive quantitative, using trend analysis on extreme weather with data on extreme weather elements such as maximum rainfall, maximum temperature, minimum temperature, wet spell, dry spell, the largest wind speed, and trend analysis on soybean production and productivity. Data for the research were obtained from BUTPAAG LAPAN Garut Regency, Garut Regency Agriculture Office, and other related sources. The correlation analysis used is the Pearson correlation with a significance level of 5%. The results showed that climate change impacts extreme weather changes in the Garut Regency area, with increasing extreme weather trends. However, extreme weather changes were not significantly correlated with soybean production. In this research, only the maximum rainfall and the largest wind speed were significantly correlated with soybean productivity.

Keywords: Correlation analysis · Extreme weather · Garut regency · Soybean production · Trend analysis

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Introduction

Climate change that occurs in Indonesia can impact changes in rainfall patterns, increasing temperatures and sea levels rise, and increasing the frequency and intensity of extreme weather events because climate change disrupts the global climate system and then causes an increase in the intensity and frequency of extreme weather events (Subagiyo, 2021; Stott, 2016; Cruz & Krausmann, 2013).

Extreme weather is an atmospheric change in a fairly short time at certain locations outside normal conditions that can cause hydrometeorological disasters such as drought, heavy rain, strong winds, and extreme temperatures (Surmaini & Faqih, 2016). The phenomenon of extreme weather as a result of the impact of climate change can cause threats to agricultural systems, including soybean crops (*Glycine max* L.). Soybean, as one of the food crops that is the main source of vegetable protein, is sensitive and vulnerable to climate change because it influences the decline in soybean production (Ruminta et al., 2020).

Along with the increasing population in Indonesia, the demand for soybeans also increases yearly. However, in recent decades soybean production has fluctuated. However, it tends to decline so that soybean production in Indonesia can only meet about 40% of domestic consumption and the remaining 60% is covered by imports (Carolina et al., 2016).

Soybean production, which tends to decline every year so that it has to import from abroad, is caused by the decline in soil fertility and the conversion of agricultural land into non-agricultural land. In addition, the occurrence of global climate change that can lead to extreme weather events is thought to be a difficult factor to control (Aminah et al., 2017; Araji et al., 2018; Fodor et al., 2017).

Extreme weather events due to climate change can threaten Garut Regency as the second largest soybean producer in West Java Province, with West Java's contribution to national soybean production of around 10% (Ministry of National Development Planning of the Republic of Indonesia, 2016). Garut Regency has a tropical climate with high rainfall, many rainy days, a very fertile area with very high agricultural production capacity, and potential commodities, including soybean crops.

Identifying the number of extreme weather indicators such as maximum rainfall, maximum temperature, minimum temperature, consecutive rainy days (wet spell), days without consecutive rain (dry spell), and the largest wind speed that occurred in Garut Regency from 1982 to 2018 is important, given the fluctuations in soybean production in that year in Garut Regency because soybeans are a crop that is sensitive and vulnerable to climate change. Then also analyse the level of closeness (correlation) between the occurrence of extreme weather and changes in soybean production to help anticipate and mitigate disasters caused by extreme weather changes, such as droughts and floods, that can harm the agricultural sector, especially in soybean crops.

Materials and Methods

The research was conducted from April to August 2022. This research uses a quantitative descriptive method by using historical data in the form of extreme weather data including maximum rainfall, maximum temperature, minimum temperature, wet spell, dry spell, and the largest wind speed in 1982-2018 obtained from Balai Uji Teknologi dan Pengamatan Antariksa dan Atmosfer Garut, Lembaga Penerbangan dan Antariksa Nasional (BUTPAAG LAPAN) Garut Regency, as well as data on soybean crops including harvest area, production, and productivity obtained from the Garut Regency Agriculture Office. The climate data was divided into two periods (1982 to 2000 and 2001 to 2018) with almost the same amount of data to see climate change in both periods

The research data were analysed using trend and correlation analysis:

1) Trend line analysis (regression) using the following equation.

$$Y = b0 + b1X$$

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

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

where: Y = trend value of extreme weather data (maximum rainfall, maximum temperature, minimum temperature, wet spell, dry spell, or largest wind speed) or soybean crop data (harvest area, production, or productivity); b0 = constant value, which is the value of Y when the value of X = 0; b1 = value of the slope of the line, which is the additional value of Y, if X increases by one unit; and X = year period.

2) Analyze the degree of closeness (correlation) between the occurrence of extreme weather changes and changes in soybean production using the following formula.

$$r = \frac{\sum_{i=1}^{n} x_i y_i - \frac{1}{n}(\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} y_i)}{\sqrt{\left(\sum_{i=1}^{n}(x_i)^2 - \frac{1}{n}(\sum_{i=1}^{n} x_i)^2\right)\left(\sum_{i=1}^{n}(y_1)^2 - \frac{1}{n}(\sum_{i=1}^{n} y_1)^2\right)}}$$

where: r = correlation coefficient; xi = maximum rainfall data, maximum temperature, minimum temperature, wet spell, dry spell, greatest wind speed; yi = data on harvest area, production, soybean productivity.

Data processing and analysis in this study used Microsoft excel and Minitab software version 19. The interpretation of the analysed data will be presented in the form of tables and charts.

Results and Discussion

Analysis of Extreme Weather Changes in Garut Regency. Based on the results of statistical test analysis for the last 37 years (1982-2018) the Garut Regency area has experienced extreme weather changes, which can be seen in Table 1 below.

Table 1 above shows that Garut Regency in period 1 (1982-2000) and period 2 (2001-2018) experienced an increase in maximum rainfall of 84.7 mm. The increase in maximum rainfall occurs due to the increase in temperature on earth, which causes an increase in evaporation events and the volume of water in cloud formation so that rain with higher intensity occurs (Puspitasari et al., 2016). The maximum average temperature and minimum average temperature also increased by 0.2°C and 0.1°C. By the research of Stocker et al. (2007) and Yang et al. (2021) the climate will continue to warm or increase in temperature over a certain period due to the emission of gases and carbon dioxide that will remain in the atmosphere. The average wet spells decreased by one day, inversely proportional to the increase in the average maximum rainfall, indicating that in Garut Regency, rainfall intensity is increasing, but the rainfall time is getting shorter. The average dry spells increased by four days, indicating an increasingly dry climate in the region. The average largest wind speed decreased by 14.9 km/h, although it decreased. However, the largest wind speed was included in the extreme category in both periods because the average wind speed, according to the operational standards of the BMKG, is between 5-30 km/h. The change analysis aligns with the following extreme weather elements trend analysis.

The Trend Analysis of Maximum Rainfall. It can be seen in Figure 1 from the Y formula that a gradient of 6.82 mm is obtained, which means that the average annual maximum rainfall of Garut Regency has an upward trend of 6.82 mm each year.

Table 1. Extreme Weather Changes in Garut Regency on the period 1982-2000 and 2001-2018.

Climate Indicators	**Extreme Weather Changes**		**Magnitude of Extreme Weather Change**
	Period 1982-2000	Period 2001-2018	
Average Maximum Rainfall (mm)	153.9	238.6	84.7 mm
Maximum Average Temperature (°C)	28	28.2	0.2 °C
Minimum Average Temperature (°C)	24.8	24.9	0.1 °C
Average of Wet Spell	11	10	-1
Average of Dry Spell	23	27	4
Average Largest Wind Speed (km/hour)	52.5	37.6	-14.9 km/hour

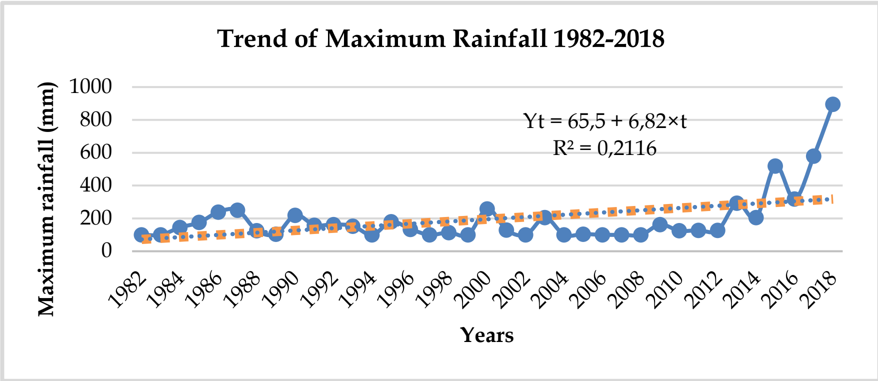
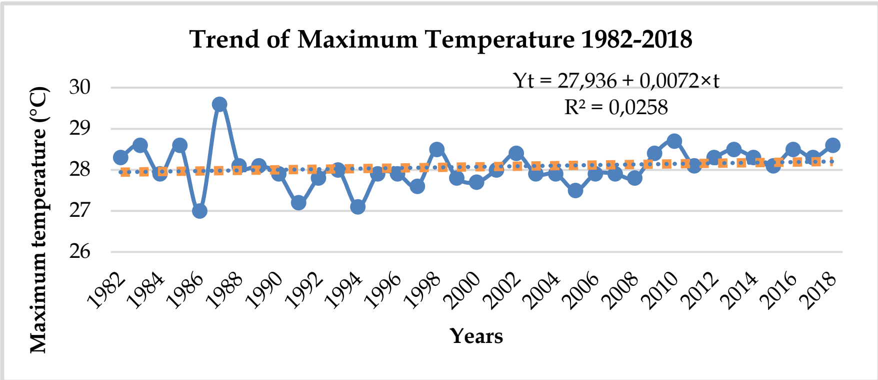
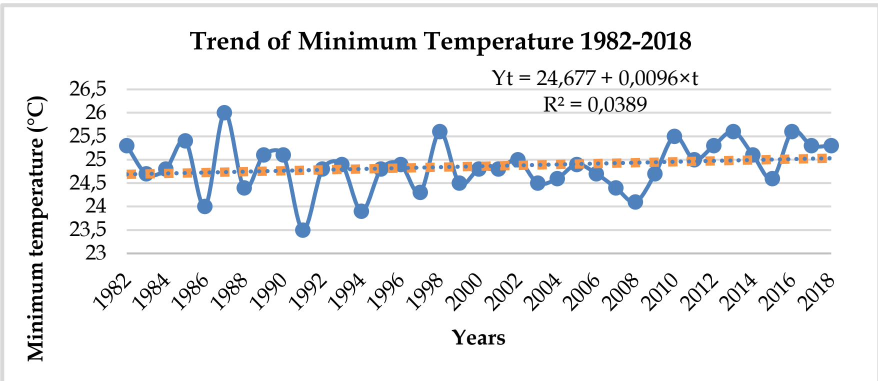


Figure 1. The trend of maximum rainfall in Garut Regency 1982-2018.



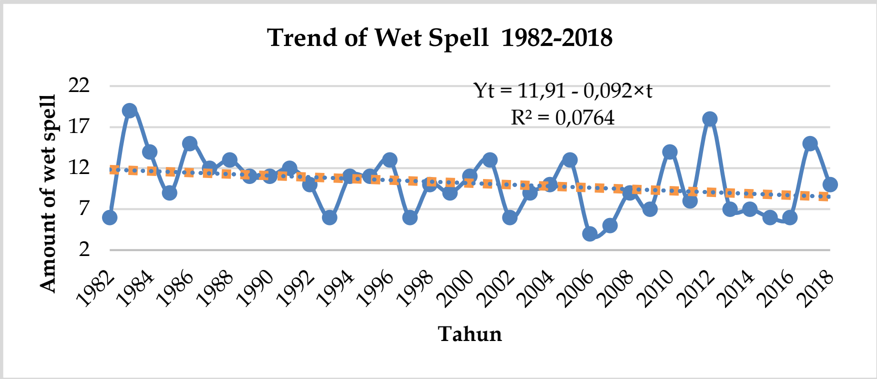
(a)



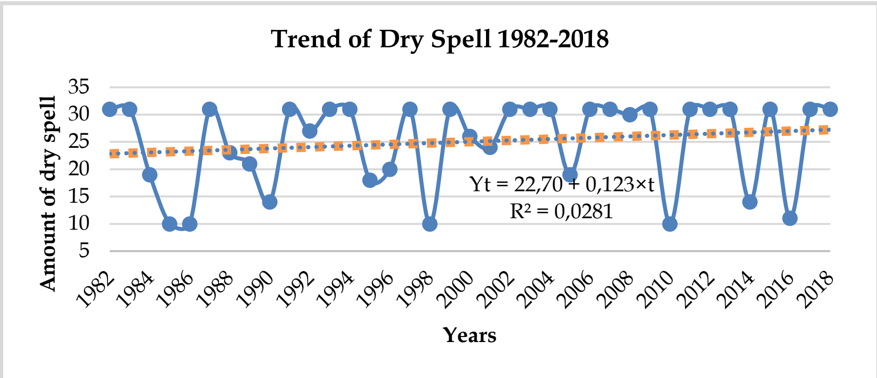
(b)

Figure 2. The trend of maximum temperature (a) and minimum temperature (b) in Garut Regency 1982-2018.

The Trend Analysis of Wet Spell and Dry Spell. It can be seen in Figure 3 (a) that the wet spell has a decreasing trend every year by 0.092 days. While the dry spell in Figure 3 (b) has a trend that continues to increase every year by 0.123 days.



(a)



(b)

Figure 3. The trend of wet spell (a) and dry spell (b) in Garut Regency 1982-2018.

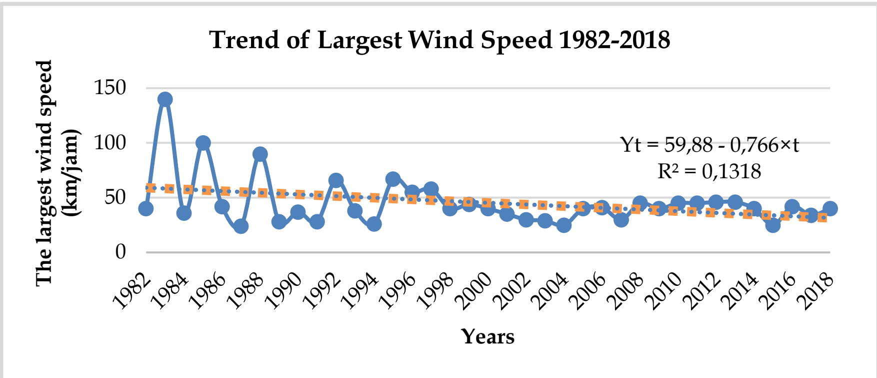


Figure 4. The trend of the greatest wind speed in Garut Regency in 1982-2018.

The Trend Analysis of Maximum Temperature and Minimum Temperature. It can be seen in Figure 2 (a) that the maximum air temperature in Garut Regency has an increasing trend of 0.007°C each year, and the minimum air temperature in Figure 2 (b) is 0.009°C each year.

The Trend Analysis of the Largest Wind Speed. It can be seen in Figure 4 that the most significant wind speed for 37 years in Garut Regency has a downward trend of 0.766 km/h each year.

Analysis of Changes on Soybean Production and Productivity in Garut Regency. Based on the analysis results, which are divided into two periods, period 1 in 1982-2000 and period 2 in 2001-2018 in Garut Regency, it has experienced fluctuating changes which can be seen in Table 2 below.

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Table 2. Changes in production, harvest area, and productivity of soybean in Garut Regency in the periods of 1982-2000 and 2001-2018.

Changes	Period 1982-2000	Period 2001-2018	Magnitude of Change
Production (tons)	32324.1	14522.8	-17801.3
Harvest area (ha)	25074.9	9406.6	-15668.3
Productivity (tons/ha)	1.231	1.526	0.295

Table 3. Correlation of extreme weather to soybean production in Garut Regency

Correlation	Production	Harvest area	Productivity
Maximum Rainfall	-0.086	-0.157	0.360 *
Maksimum Temperature	-0.293	-0.203	0.116
Minimum Temperature	-0.167	-0.136	0.188
Wet Spell	0.138	0.156	-0.212
Dry Spell	-0.168	-0.108	0.106
Largest Wind Speed	0.034	0.074	-0.362 *

Notes: (*) Significant

Table 2 above shows that soybean production decreased by 17,801.3 tons in 2 periods due to a decrease in soybean harvest areas during the two periods of 15,668.3 ha. The decline in the harvest area in the two periods was due to the conversion of agricultural land into non-agricultural land and the number of farmers who did not want to cultivate soybeans in Garut Regency because soybean farming was considered less profitable than other crops caused by inadequate soybean prices (Harsono, 2008). This is inversely proportional to the increase in productivity in the two periods of 0.295 tons/ha. The increase in soybean productivity in Garut Regency can cause some farmers

there have begun to apply Integrated Crop Management (ICM) cultivation technology, such as most farmers always use the superior Anjasmoro variety, farmers also fertilise NPK according to the recommended dose, and weed control carried out by farmers has been carried out optimally.

Correlation of extreme weather changes to soybean production. The correlation technique used in this research is Pearson correlation, with a significance level of 5%. Correlation measures the strength and direction of the linear relationship between two variables: extreme weather and soybean crop. The results of the correlation analysis can be seen in Table 3 below.

Table 3 shows that only the extreme weather elements of maximum rainfall and largest wind speed are significantly correlated with soybean crop productivity in Garut Regency. This is because some farmers in Garut Regency, although they have limited land area due to land conversion, have drainage channels on irrigated land that are good enough. So even if the rain intensity increases, it will not interfere with the growth of soybean plants, which causes their productivity to remain good. Supported by the research of Perdinan & Santikayasa (2006), Yang et al. (2020), and Kulig & Kopyra (2023) that the decreasing rainfall causes a decrease in soybean productivity in Bandung Regency by almost 50%, meaning that in Garut

In the district itself, maximum rainfall does not cause problems for soybean productivity as long as the drainage conditions on the land are good enough. While the decreased wind speed will minimise the risk of flower fall so that many pods are formed, which can increase soybean productivity because wind speed can affect the pollination process and determine the number of pods that will be formed (Kinasih et al., 2015; Zhang et al., 2017; Brittain et al., 2013).

None of the extreme weather elements in this research was significantly correlated with the decline in soybean crop production, it happened because the decline in soybean crop production in Garut Regency was mostly caused by the conversion of agricultural land, as happened in 2010 when rice fields decreased by 3 ha from 2009 and non-field land decreased by 649 ha compared to 2010 (Garut Agricultural Department, 2010). In addition, the decline in soybean production in Garut Regency is also caused by the low interest of farmers in cultivating soybean crops because soybeans are only considered intercrops and are considered less profitable because the production costs are not comparable to the selling price when compared to other food crops such as rice and corn. Another influence is the effect of extreme weather such as flood or drought which increases the cost of soybean production.

Conclusion

There have been changes in extreme weather events due to the impact of climate change in Garut Regency with an increasing trend in maximum rainfall, maximum temperature, minimum temperature, and the number of days without rain in a row (dry spell) in two periods between 1982-2000 and 2001-2018, while extreme weather elements that have experienced a decreasing trend are wet spell and the largest wind speed. However, the occurrence of extreme weather in Garut Regency is not significantly correlated with changes in soybean crop production.

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