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Impact of Climate Change on Soybean Crop Failure on the Local Economy: A Case Study in Pidie District, Indonesia

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Abstract

The impact of extreme climate change significantly affects the production of various world crops. It has even caused crop failures, indirectly affecting farmers' income, thereby disrupting the realization of sustainable agriculture, which will lead to difficulties in achieving the Sustainable Development Goals. This study aimed to determine the characteristics of climate change in the area of the failed soybean crop in Pidie Regency, Indonesia. The research was carried out using a quantitative descriptive method by analyzing the data on rainfall, temperature, and humidity at the research location. The results of this study indicated that there had been a change in the type of climate in Pidie Regency from type C to type B. The average rainfall for the first period was1511.1 mm/year period had increased to 2340.2 mm/year in the second period. Characteristics of climate change affect the area of crop failure with a determinant coefficient (R2) of 0.591, meaning 59.1 % of the area of crop failure was influenced by climate characteristics. The remaining 40.9% was influenced by other factors such as selecting superior seeds, good soil management, proper fertilization, and pest control.

Keywords
climate change; crop failure; soybean; sustainable agriculture

I. Introduction

Climate change is one of the natural phenomena that results in changes in the value of climate elements both naturally and accelerated due to human activities on this earth. The consequences of climate change can adversely affect various aspects of life and the development sector, especially the agricultural sector, and it is feared that it will bring new problems to the sustainability of agricultural production, especially food crops. Climate change has experienced many events that have already occurred, such as: changes in rainfall patterns and distribution, increased droughts, floods and landslides, decreased agricultural production and crop failure (Surmaini et al., 2011). Development is a systematic and continuous effort made to realize something that is aspired. Development is a change towards improvement. Changes towards improvement require the mobilization of all human resources and reason to realize what is aspired. In addition, development is also very dependent on the availability of natural resource wealth. The availability of natural resources is one of the keys to economic growth in an area. (Shah, M. et al. 2020)

The main causes of droughts and floods throughout the world are also thought to be due to extreme climate change. In the tropics, these two climatic anomalies usually cause shifts in rainfall patterns, changes in rainfall quantities, and changes in air temperature. Further consequences are the occurrence of a longer dry season, drought that stimulates forest fires in sensitive areas, floods, and increased plant disturbances (pest and disease clouds, 2006). According to Kurniawati (2012), due to global warming directly or indirectly will have an impact on climate change which in turn threatens the productivity of

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agricultural crops. Climate change has a very real impact on decreasing agricultural production and even causing crop failure, one of which is soybean crop productivity.

Based on the results of research by Basri et al (2015), within 10 years there has been a climate change in Pidie Jaya Regency, which caused a drought (1668.91 ha) to occur in 2013. From this fact, farmers and related agencies have anticipated, in including shifting cropping patterns due to changing rain patterns and crop failure due to floods and droughts. With this in mind, climate change studies on the area of crop failure are very important to anticipate in the future, especially for crop commodities that are very sensitive to climate change, such as soybeans.

Soybean (Glycine max (L.) Merrill) is the main rainfed crop that can be cultivated in various latitudes.(Mercau et al., 2007). In recent decades, soybeans have become very important in the global market and have become an important agricultural commodity due to their increasing consumption as a staple food. This increase is also due to the increasing global demand for soy-based foods(Taherzadeh & Caro, 2019).To meet the growing worldwide demand for staple foods, including soybeans, crops depend on large areas and large amounts of water resources.(Gendron St-Marseille et al., 2019; Taherzadeh & Caro, 2019).

Soybean productivity is strongly influenced by environmental aspects and cultivation methods. Inappropriate cultivation methods lead to suboptimal plant growth, resulting in low plant production. Soybean quality is also greatly influenced by climate variations(Anderson et al., 2019; Reis et al., 2020). Plant growth and quality depend on the interaction between environmental factors and plant genetic factors, while environmental factors play a role in controlling plant potential, one of which is climate/weather (Suciantini, 2015).

To support the soybean development program, it is necessary to conduct research and analysis of the characteristics of climate change on the area of crop failure with the aim of seeing what climatic factors affect the extent of soybean crop failure, as well as seeing the relationship between the characteristics of climate change and the area of soybean crop failure in observation location in Pidie Regency. The location chosen is Pidie Regency which is one of the soybean development areas in Aceh. The determination of the location of this research is expected to include and provide information for other regions, so that the characteristics of climate change that can affect soybean crop failure can be known and become information for further conservation actions in soybean development in Pidie Regency in particular.

II. Research Method

The research was conducted in Pidie Regency, by making observations at three rain gauge stations located in three different sub-districts in two observation periods, Period I (2000 – 2009) and Period II (2010 – 2019). The three rain gauge stations are: rain gauge at Agricultural Extension Center (BPP) Keumala District (N 05013'59.1" E 0950 53' 58.5") with an area of 926.43 km2; Rain gauge station at Agricultural Extension Center (BPP) Glumpang Tiga District (N 05013'49.6" E 0960 01' 34.5") with an area of 1,804.71 km2; and a rain gauge station at the Agricultural Extension Center (BPP) Pidie District (N 050 22' 5.50" E 0950 57' 24.4") with an area of 445.31 km2.

The materials used in this study were a Pidie sheet of 1:50,000 scale, rainfall data, air temperature data, humidity and drought data, as well as yield data and crop failure areas. While the applications used for data processing are ArGis 9.3 and GPS to make map scale for Thiessen polygon analysis, as well as SPSS20 and Microsoft excel programs for data analysis.

The method used is descriptive quantitative comparatively, namely research that wants to find answers to fundamentally about cause and effect, by analyzing the factors that cause the occurrence or emergence of a certain phenomenon. The data collected was then tabulated in tabular form according to the analysis. To test hypotheses I and II can be described in the following steps: Testing Hypothesis I in the form of an analysis of the average regional rainfall; temperature and humidity; area of crop failure; and analysis of climate change types. Meanwhile, hypothesis II was tested to determine whether climate change had an effect on the area of soybean crop failure, using multiple linear regression analysis.

III. Result and Discussion

3.1 Climate Characteristics in Pidie Regency

Based on data analysis that has been carried out from the three rain gauge stations, there has been a change in the climate type in Pidie Regency from type C to type B. The complete analysis can be seen in Table 1. The results of the calculation of the average regional rainfall in Pidie Regency were carried out using the polygon method. thiessen. The 10-year average regional rainfall for Period I (2000 – 2009) and Period II (2010 – 2019) is presented in Figure 1. The average rainfall for the first period is 1511.1 mm/year and has increased to 2340.2 mm /year in the second period.

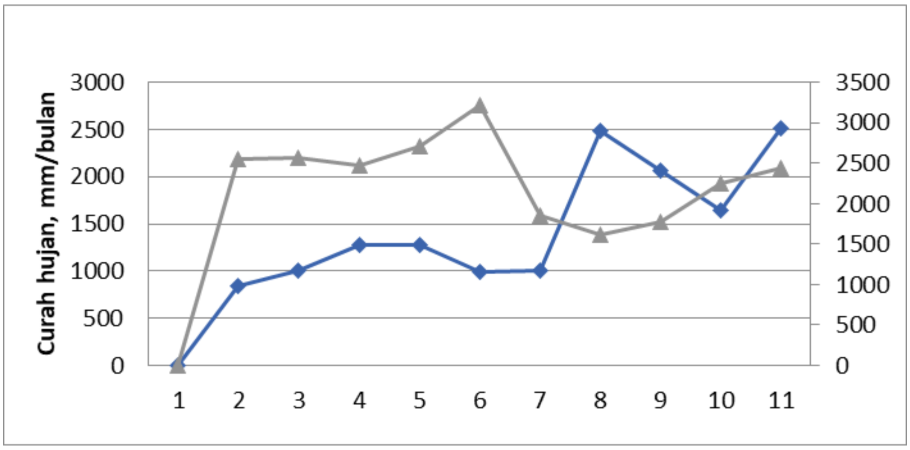


Figure 1. *The amount of rainfall in Pidie Regency per year in period 1 (2000-2009) is blue line and II (2010-2019) is green line.*

Meanwhile, based on the results of the analysis of air temperature with the Douglas HK Lee classification, which is shownin Figure 2,the average air temperature in the first period is 26oC which is classified as hot, while in the second period the average temperature is 27oC, where there has been an increase of one degree Celsius in the second period compared to the first period. Pidie has remained between 68o-86oF (20o-30oC) heat, for the last 20 years.

Table 1. Average Rainfall at Each Station in Pidie Regency

Year	Region									Amount		
	district. keumala			district. Glumpang Tiga			district. Pidie			Region (An)		
	Area (Km2)	Rain (mm)	A1.R1	Area (Km2)	Rain (mm)	A2.R2	Area (Km2)	Rain (mm)	A3.R3		(A1.R1 +A2.R2+A3.R3)	(A1.R1 +A2.R2+A3. R3)/An
2000	926.43	841	779127.6	1804.71	841	1,517,761	445.31	841	374,506	3176.45	2,671,394	841
2001	926.43	1001	927356.4	1804.71	1001	1.806.515	445.31	1001	445,755	3176.45	3,179,626	1,001
2002	926.43	1279	1184904	1804.71	1279	2,308,224	445.31	1279	569,551	3176.45	4,062,680	1,279
2003	926.43	1283	1188610	1804.71	1283	2,315,443	445.31	1283	571,333	3176.45	4,075,385	1,283
2004	926.43	995	921797.9	1804.71	995	1,795,686	445.31	995	443.083	3176.45	3,160,568	995
2005	926.43	999	925503.6	1804.71	999	1,802,905	445.31	999	444,865	3176.45	3,173,274	999
2006	926.43	2484	2301252	1804.71	2484	4,482,900	445.31	2484	1.106.150	3176.45	7,890,302	2.484
2007	926.43	2071	1918637	1804.71	2071	3,737,554	445.31	2071	922,237	3176.45	6,578,428	2,071
2008	926.43	1644	1523051	1804.71	1651	2,979,576	445.31	1644	732.090	3176.45	5,234,717	1,648
2009	926.43	2504	2319781	1804.71	2514	4,537,041	445.31	2504	1,115,056	3176.45	7,971,878	2,510
2010	926.43	1552	1437819	1804.71	2957	5,336,527	445.31	2957	1,316,782	3176.45	8,091.129	2,547
2011	926.43	2020	1871389	1804.71	2792	5,038,750	445.31	2785	1,240,188	3176.45	8150,327	2,566
2012	926.43	2452	2271606	1804.71	2473	4,463,048	445.31	2473	1.101.252	3176.45	7,835,906	2.467
2013	926.43	2519	2333677	1804.71	2785	5,026.117	445.31	2786	1,240,634	3176.45	8,600,428	2,708
2014	926.43	3312	3068336	1804.71	3183	5,744,392	445.31	3183	1,417,422	3176.45	10,230,150	3.221
2015	926.43	2103	1948282	1804.71	1761	3,178,094	445.31	1761	784,191	3176.45	5,910,568	1,861
2016	926.43	2174	2014059	1804.71	1374	2,479,672	445.31	1482	659,949	3176.45	5,153,680	1,622
2017	926.43	1845	1709263	1804.71	1845	3,329,690	445.31	1370	610,075	3176.45	5,649,028	1,778
2018	926.43	2484	2301252	1804.71	2484	4,482,900	445.31	879	391,427	3176.45	7,175,579	2.259
2019	926.43	2491	2307737	1804.71	2509	4,528,017	445.31	1577	702.254	3176.45	7,538,008	2,373
Total												38,513

Source: Data Analysis Results, 2020

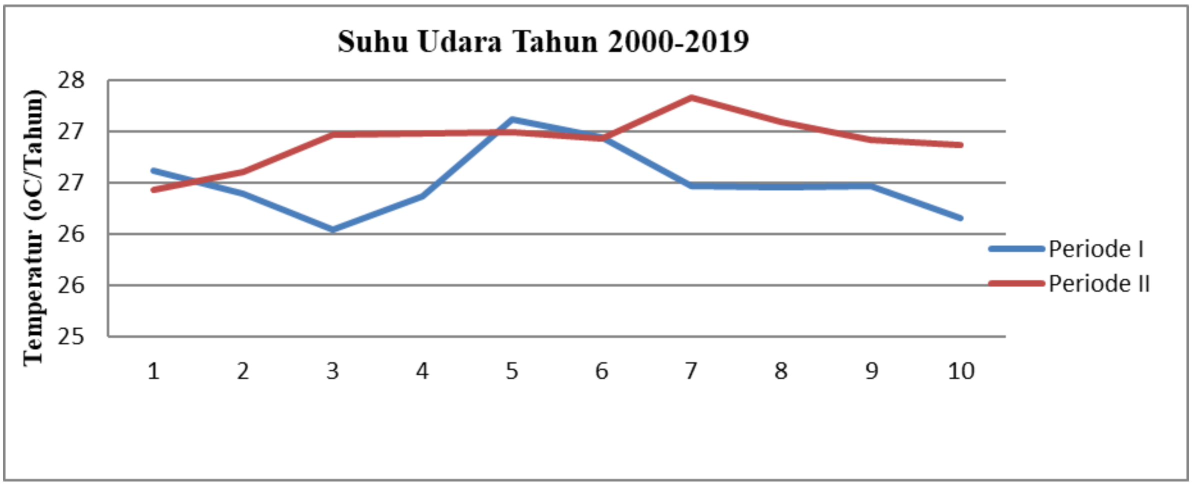


***Figure 2**. Average air temperature per year in periods 1 (2000-2009) and II (2010-2019).*

The results of the analysis of air humidity with the Douglas HK Lee classification, that the average air humidity in the first period is 76.7 percent (with classification B, which is wet), while in the second period the humidity is still in classification B or wet with an average of 79.7 percent. This provides information that the humidity in Pidie Regency has increased by about 3 percent in the second or last 10 years, as can be seen clearly in Figure 3.

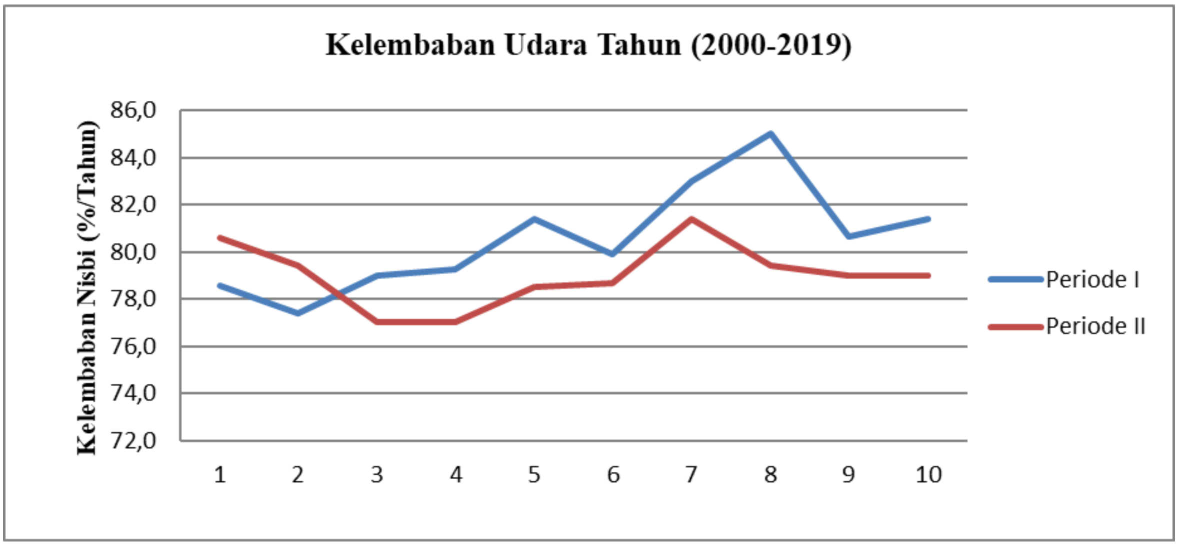


Figure 3. *Average humidity per year in periods 1 (2000-2009) and II (2010-2019).*

The increase in air humidity in Pidie Regency in the second period was 3 percent. This increase is considered normal and balanced according to Mohr's opinion, because the amount of rainfall in the second period obtained at three rain breeding stations in Pidie Regency ranged from 60 mm to 100 mm per month.

3.2 Analysis of Climate Type Change

To find out whether there has been a change in climate type in several areas in Pidie Regency, a Schmidt Ferguson classification analysis was carried out, by calculating the average dry and wet months for the first 10 years. The source of climate data was obtained from the breeding station located in Keumala District, Glumpang. Tiga and Pidie at the Agricultural Extension Center.

The climate in Keumala Subdistrict, Pidie Regency in the first period (2000 to 2009) was classified as a class C climate type with a Q value of 39.28% percent. The average annual rainfall is 1,510mm with an average rainy day of 151 mm, while in the second period (2010 to 2019) it belongs to class B climate type with an average annual rainfall of 2,295 mm (191.2 mm/month). Rainfall data for the last 20 years.

Climate change also causes changes in the amount of rain and rain patterns that result in a shift in the beginning of the season and the planting period. The decrease in rainfall has reduced the potential for one period of soybean planting (Runtunuwu and Syahbuddin, 2007).

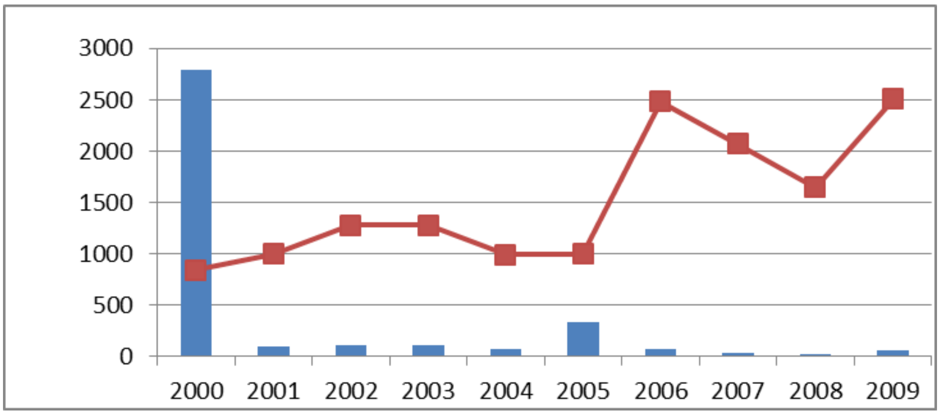
Based on the results of a 20-year rainfall study in Pidie Regency, it shows that the area has fairly stable or normal rainfall during the two observation periods. Because the area has an altitude of 201 mdl which has its own microclimate, this shows that the area is a forest cover area that is still classified as good.

Rainfall for the last 20 years in Pidie Regency (2000-2019). The highest rainfall occurred in 2014 with 3,183 mm of rain/year (265.3 mm/month) while the lowest rainfall occurred in 2000 with a total rainfall of 841 mm/month. years (70.08 mm/month). The climate in Pidie Regency in the first period (2000 to 2009) was classified as a class C climate type with a Q value of 39.28 percent. The average annual rainfall is 1,510 mm (125.8 mm/month) while in the second period (2010 to 2019) it is classified as a class B climate type with a Q value of 25 percent. The average annual rainfall is 2,125 mm (177.1 mm/month). Boer (2010), stated that the start of the rainy season also tends to be backwards compared to current conditions. The frequency with which the start of the rainy season is at least one month away from normal conditions will become more frequent. Similar shifts have also been felt on the island of Java. These patterns have the opportunity to continue. In the future, some parts of Indonesia, especially those located south of the equator, may experience a longer dry season and a shorter rainy season but with high rainfall.

In Indonesia the rainy season occurs between October-April and the dry season occurs in April-October. In October-April the sun is in the southern hemisphere, so the Australian continent gets more solar heating than the Asian continent. low air pressure and in Asia there are centers of high air pressure. This situation causes wind currents from the Asian continent to the Australian continent. In Indonesia this wind is the northeast monsoon in the northern hemisphere and the west monsoon in the southern hemisphere. Therefore, these winds pass through the Pacific Ocean and the Indonesian Ocean, so they carry a lot of water vapor so that in Indonesia there is generally a rainy season (Iswanto, 2007).

3.3 Harvest Failed Land Area Against Rainfall

The area of land that failed to harvest for the last 20 years, namely from 2000 to 2019. The area of land that failed to harvest in the first period was3,703ha with rainfall of 1511.1 mm/year. The second period of crop failure area was 5,410 ha with rainfall of 2340.2 mm/year. This illustrates that there has been an increase in rainfall of 829.1 mm/year and caused the area of crop failure in the second period to be 1,707 ha (Figure 4).



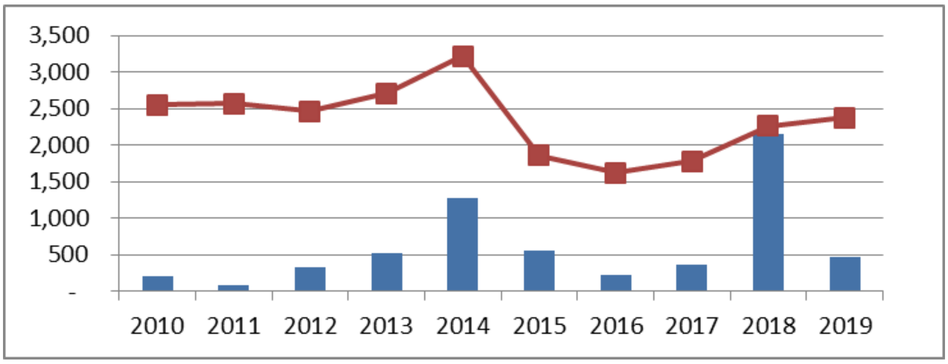


Figure 4. *Soybean crop failure area (stem diagram) and annual rainfall (lines) in: a) period I (years 2000-2009) above and b) period II (years 2010-2019).*

3.4 Changes in the Type of Climate on the Area of Crop Failed Land

In the partial analysis of changes in climate type to the area of soybean crop failure, there is one dependent variable and three independent variables, namely soybean harvest failure (Y), regional average rainfall (X1), air temperature (X2) and air humidity (X3). For more details on the effect of climate change on soybean crop failure in Pidie Regency, see Appendix 15, and is shown in Table 2.

Table 2. Value of Regression Coefficient of Climate Type Change on the Area of Failed Harvest

Variable	Regression Coefficient	t count	Sig
constant	-244,003	-1,259	0.226
X1 Region Average Rainfall	0.007	2,270	0.037
Air Temperature X2	14,505	2,955	0.009
Humidity X3	-1,742	-1,389	0.184

Judging from the influence or relationship between the average regional rainfall (X1), air temperature (X2) and air humidity (X3) climatic factors have a positive relationship with the area of crop failure, because erratic rainfall causes flooding and drought and result in crop failure. The higher the air temperature, the soil will quickly evaporate and dry which causes an increase in the area of crop failure in Pidie Regency. This can be seen from the total area of crop failure from 2000 to 2019.

IV. Conclusion

There has been a change in the type of climate in Pidie Regency from type C to type B. The average rainfall for the first period of 1511.1 mm/year has increased to 2340.2 mm/year in the second period. Climatic characteristics affect the area of crop failure with a determinant coefficient (R2) of 0.591 meaning 59.1% of the area of crop failure is influenced by climate characteristics while the remaining 40.9% is influenced by other factors such as selection of superior seeds, good soil management, fertilization proper pest and disease control.

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