ISSN No:-2456-2165

Agricultural Productivity of Selected Philippine Crops: Effect of Climate Change in Cotabato Province

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Abstract:- This study focused on the effect of climate change on agricultural productivity. The purpose of the study was to determine the rainfall pattern in North Cotabato from 2006 to 2020, the trend of minimum and maximum temperatures in North Cotabato from 2006 to 2020, the relationship between rainfall, temperature, and crop yield, and the effects of rainfall and temperature on crop yield. Rainfall, temperature and crops (rice, corn, pineapple, banana and coconut) data were obtained for a period of 15 years from Department of Science and Technology- Philippine Atmospheric, Geophysical and Astronomical Services Administration (DOST-PAGASA) and Philippine Statistics Authority (PSA). Multiple linear regression techniques were used to evaluate the relationship between rainfall, temperatures, and agricultural yield. Maximum temperature has a negative impact on rice and pineapple yield, whereas minimum temperature has a significant impact on all crops, according to the study's findings. With the exception of banana and coconut, rainfall has a negative impact on agricultural output.

Keywords:- *Agricultural Productivity, Climate Change, Rainfall, Temperature.*

I. INTRODUCTION

A long-term change in the statistical distribution of weather patterns is referred to as climate change. Over a lengthy period of time, spanning from decades to millions of years, it's a significant and permanent shift in the statistical distribution of weather patterns (Ajetomobi & Abiodun, 2010).

Two things occurred on a worldwide scale: climate change and agriculture. Changes in temperature, carbon dioxide, glacier runoff, precipitation, and their linkages were predicted to have a considerable impact on agriculture as a result of global warming (Aondoaka, 2012).

Climate change has a massive impact on agricultural production. In the Philippines, extreme weather events such as typhoons and floods are frequently linked to climate change. Natural disasters threaten 85.3 percent of the Philippines' annual GDP of US$86 billion, and the country is positioned in high-risk zones (World Bank, 2010). During the eight months from October 1911 to May 1912, the Philippines experienced a remarkable drought. Drought has affected 40 percent of the Philippines, costing the country 82 million dollars in agricultural losses (International Federation of Red Cross, 2015). As a result, residents in the Philippines have been affected by droughts and floods, and changes in temperature and rainfall patterns have resulted in decreased agricultural production and output.

Knowing that Cotabato is vulnerable region in climate change results in the studies of one researcher. It is good opportunity to research this study kind of in Cotabato. Although there were studies in other countries examining the effects of climate change on agricultural productivity but they prioritize crops like maize, cassava, wheat and sugarcane. In this study its focus in the major crops of the area which is corn, rice, banana, pineapple and coconut.

This study will be importance in reducing vulnerability of agricultural productivity to hazardous climate change. Also, the students and other researchers will benefit greatly from this study because it will act as a benchmark for the future researcher.

The general objective of the study is to determine the effects of climate change in agricultural productivity in Cotabato Province. Specifically, established a pattern of annual rainfall in Cotabato from year 2006-2020; established a trend temperature in Cotabato from year 2011-2020; to investigate the relationship of crop yield to rainfall and temperatures.

II. THEORITICAL FRAMEWORK

Changes in temperature along with erratic precipitation may affect crop productivity and these effects may overwhelm the production methods in place. Generally, agricultural system depends on the stable water sources; but, if the pattern and scale of precipitation changes are not fully known, agriculture will be vulnerable and uncertain (Intergovernmental Panel on Climate Change,2007).

Using a statistical model, Ajetomobi and Abiodun (2010) evaluated the relationship between cowpea (Vigna unguiculata) yield and temperature, precipitation, and temporal trend in Nigeria. The study's findings differed from one geographical region to the next.

ISSN No:-2456-2165

The framework model for this study is based on empirical research conducted by Yingjie and Erda (2008), as well as Ajetomobi and Abiodun (2010). Crop yield was studied as a function of minimum and maximum temperatures as well as rainfall..

III. METHODOLOGY

The research design to be employed is the combination of descriptive and causal research design. For descriptive research design, data is describing the annual rainfall, minimum and maximum temperature and the crop yield.

For causal research design, Multiple Linear Regression analysis was applied to operate on the assumption of the relationship in climatic variables on the agricultural productivity of selected crops.

The study mainly focused on the parameters such as rainfall and temperature (minimum and maximum) and the total crop yield annually. It's used to figure out how different climatic conditions affect agricultural productivity. It only covers the 15-year period from 2006 to 2020.

Temperature, rainfall and crop yield data will be needed for the study. The researcher obtained climatological data from the Philippine Atmospheric, Geophysical, and Astronomical Service Administration of the Department of Science and Technology, as well as crop yield data from the Philippine Statistics Authority (PSA).The information covers the farming season from year 2006-2020 in Cotabato province. The major crops randomly selected were rice, corn, banana, pineapple and coconut.

The researcher used two methods : descriptive method and multiple linear regression. To measure objectives one and two, the data to be gathered will analyzed using descriptive method.

In addition, to measure objectives three and four, multiple linear regression analysis will be employed to investigate if the climate change variables will significantly influence the agricultural productivity in terms of crop yield. The link between one variable, the dependent variable y, and a number of additional variables x, (1,2,3,.n), known as independent variables, formed the basis for this approach of analysis. This equation is written as follows:

$$Y_t=\alpha_0+ \alpha_1 Tmax_t+ \alpha_2 Tmin_t+ \alpha_3 RNF_t+u$$

where:

Y_t= Crop yield
α_1= Regressor coefficients (i=1…3)
t= 2006-2020
$Tmax_t$= Annual maximum temperature
$Tmin_t$= Annual minimum temperature
RNF= Annual rainfall

IV. RESULTS AND DISCUSION

A. Annual Pattern of Rainfall

Figure 1 shows the rainfall pattern in Cotabato Province throughout time as a bar graph. Looking at the graph, it's clear that the rainfall pattern in North Cotabato hasn't been consistent. The year 2009 had the highest rainfall, which followed by the year 2012.

This situation happens where 2009 and 2012 have the highest amount of rainfall recorded in North Cotabato which is Typhoon Ketsana (local name Ondoy), and Typhoon Bopha (local name Pablo) hit Philippines. In tropical depression Ondoy destroying about two hundred thousand tons of paddy rice (palay). According to the Philippine agriculture department, floods and strong rains drowned 124,238 hectares of rice-growing areas resulting in the loss of 180,212 metric tons palay worth 3.1 billion pesos (about 65 million USD) and also it destroyed 1,279 tons of corn and 1,571 tons of fruits and vegetables. Typhoon Pablo was the most powerful hit the Philippines (Southern Mindanao) in 2012. Winds gusted to 138 mph, with nearly 20 inches of rain falling in 24 hours. According to the Department of Agriculture in Typhoon Bopha (Pablo), the banana industry suffered at the most damage, estimated at Php20 billion(USD 500 million). Coconut farms suffered damage of Php7.22 billion (USD 193 million), while rice and corn farms suffered and losses of Php197 million (USD 5 million) and Php362 million (USD 9 million), respectively (Brown, 2012).

Based on the rainfall pattern of North Cotabato it shown that the lowest recorded of rainfall were year 2015 and 2019. In year 2015, the Mindanao experiencing a drought that reported to 100% of crop damage was reported. It reported that 70%-100% have taken damage in crops like rice, corn, coconut, banana, coffee and cacao. Crops that took the brunt of damage were rice and corn. It reported that corn worth more than P45.1 million ($1 million) and rice for P27.3 million ($612,000) were damaged. Apart from corn and rice producers, 60 coconut growers and 316 vegetable farmers also had a crop loss (Ranada,2015).

In year 2019, North Cotabato provinces suffered the brunt of drought, which a damage of crop and loses reaches at least US$12 million. The farmers have forced in selling their own farm animals in order to survived the impact of drought that cause a damage in area of about 15,000 hectares of farmland (Gamil, 2019).

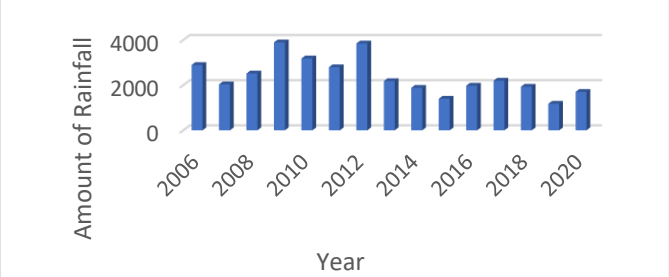

Fig 1. Rainfall pattern in Cotabato Province
Source: DOST-PAGASA, Cotabato station

B. Trend of Minimum and Maximum Temperature

Temperature change during the day, which is why two phases are used to describe it. Specifically, the maximum temperature is the greatest temperature recorded throughout the day, while the minimum temperature is the lowest temperature recorded on the same day.

The graph in Figure 2 shows the trend of minimum and maximum trend in Cotabato. From year 2006-2020 2020 there had been an unstable temperature. A line graph reveals that both minimum and maximum temperature constantly increasing from year 2006-2020. It observed that the highest temperature experienced both minimum and maximum temperature was in the year 2020 with 34.6˚C and 23.5 ˚C.

Crops complete their growing cycle more quickly when average temperature are higher (Hatfield et al., 2011). Reproductive failures are more frequent when there is less time to reproduce, and yields will suffer to decline (Craufurd & Wheeler, 2009).

Extremely high temperatures of more than 30 degrees Celsius can permanently injure plants, while temperatures of more than 37 degrees Celsius can harm seeds during storage. Temperature, its persistence, and the rate at which it rises, as well as the crop's ability to react, define the type of damage (Wahid, Gelani, Ashraf & Foolad, 2007). It also depends on the plant's species and stage of development. As the climate changes, the number of occasions when temperatures rise above critical limits for corn, rice, and wheat is predicted to rise (Gourdji, Sibley & Lobell,2013).

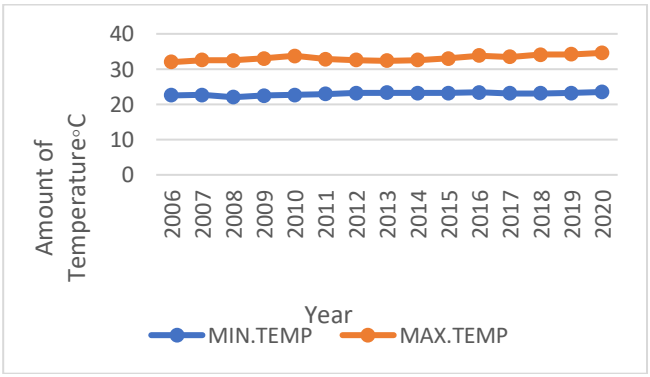

Fig 2. Trend of Temperatures in Cotabato Province
Source: DOST-PAGASA, Cotabato station

C. Relationship of Crop Yield to Rainfall and Temperatures

Multiple regression used to determine the link between crop yield and rainfall and temperatures, which was the goal of this study. To establish the link between rainfall and temperatures, annual yields of rice, corn, pineapple, banana and coconut were regressed. As a result, the regression given in Table 1 yielded the results.

D. Rainfall and Temperatures Relationship to Rice Crop yield

Rice is the Philippines' main staple food, with 90% of the people eating it. In 2012, rice consumption per capita was expected to be around 114.6 kilos in the developing world. Given that resources required for rice cultivation and constantly declining, the ongoing population expansion of around 2% per year may result in food insecurity (Portilla, 2014).

The results were presented in Table 1, which showed that the effects minimum temperature and maximum temperature are contributed positively thus minimum temperature is significantly affect rice crop yield while maximum temperature is not.

Rice is a tropical crop that thrives in temperatures ranging from 20 to 27 degrees Celsius during the growth season, therefore the minimum temperature was significant for the crop. A favorable impact of minimum temperature on rice production has been identified, which could lead to plant growth (Abbas & Mayo,2021).

The annual rainfall had a negligible and insignificant impact on the rice crop yield. Rainfall has a detrimental impact on crop productivity because, as the typhoon in North Cotabato demonstrated, it damages grain crops and causes farmers to lose money. Rainfall has a negative impact on rice plants at the heading and blooming stages, as well as at the milking stage during the ripening phase, according to the study (Abbas & Mayo,2021).

Heat- and drought-resistant high-yielding varieties must be created to cope with and mitigate the negative effects of climate change, ensuring food security in the country (Ali et al.,2017).

E. Rainfall and Temperatures Relationship to Corn Crop yield

Corn is one of the most important crops in the Philippines. It is second only to rice in terms of agricultural use. Because it is used not only for human consumption but also for animal feed and industrial applications, it is an important crop in the growth of the livestock and manufacturing industries (Exconde,1974).

Both maximum temperature and rainfall were shown to have a negative and non-significant effect on maize production, according to the findings and conclusions reported in Table 1. As a result, the minimum temperature had a statistically significant impact on corn crop output.

The minimum temperature resulted significantly affect corn yield because a low temperature was needed in growing and breeding of the corn. To support, corn yield was significantly correlated with the daily minimum temperature. According to the regression analysis, at 1˚C increased in minimum temperature will lead to increase in corn yield (Chen, Lie, Deng & Qian, 2011).

To support, it revealed that the maximum temperature found negatively and non-statistically affect the corn yield because the excessive temperature occurrences occur during pollination the corn productivity was lowered. Warm temperatures above the upper threshold during grain-filling stage reduce yield. The model revealed that every 1˚C increased in temperature results in a nearly 10% drop in yield (Hatfield & Dold,2018).

F. Rainfall and Temperatures Relationship to Pineapple Crop yield

One of the most important crops in the Philippines is pineapple. With an estimated 70,000 hectares cultivated with the crop, which is mostly exported and provides roughly 17% to global supply, the country ranks second in the world, behind Costa Rica, in terms of pineapple output (Barona,2005). The majority of production occurs in Mindanao, with the rest of Luzon following closely behind. However, 85 percent of the output is controlled by large transnational corporations such as Del Monte and Dole Philippines.

Table 1. Multiple Linear Regression showing the results of rainfall, temperatures and crop yield

Variables	**Major Crops**				
	Rice	**Corn**	**Pineapple**	**Banana**	**Coconut**
Max. Temp	0.034 (0.058) **0.565**	-0.089 (0.063) **0.188**	11.184* (2.775) **0.002**	-2.310* (1.236) **0.088**	-0.362* (0.118) **0.011**
Min. Temp	0.219* (0.116 **0.086**	0.325* (0.127) **0.027**	0.112 (5.541) **0.984**	0.458 (2.468) **0.856**	-0.635* (0.235) **0.021**
Rainfall	-0.00003 (0.00005) **0.553**	-0.00001 (0.0006) **0.842**	-0.003 (0.003) **0.269**	0.001 (0.001) 0.199	0.00007 (0.000001) **0.515**
Constant	-2.271 (2.716) **0.420**	-1.568 (2.976) **0.609**	-355.495* (129.317) **0.019**	99.834 (57.587) **0.111**	30.779* (5.499) **0.0000**

*represents level of statistical significance at 5% and 10%
( ) represents the standard error

In Table 1 revealed that maximum temperature and minimum temperature contributed positively toward pineapple crops and rainfall contributed negatively to pineapple yield. It shows that maximum temperature was significantly affect the pineapple crop yield because the optimum temperatures of pineapple growth range between 20-30˚C. In study of Williams et. al (2017) showed that rainfall and temperature exhibited different effects on productivity, with the minimum temperature accounting for up to 82% of yield variability. Despite persistent reports of rainfall impacting growth phases and subsequently affecting fruit quantity and quality, the relationship between rainfall and yield have been proven to be statistically insignificant

G. Rainfall and Temperatures Relationship to Banana Crop Yield

The banana industry in the Philippines is currently one of the top agricultural export earners. The growing demand for banana around the world has resulted in a wider growth of banana plantations, especially those in environmentally sensitive areas. Banana production technologies that employ a lot of chemicals have been shown to have considerable environmental and public health consequences (Calderon & Rola, 2003).

Based on the Table 1 presented the results that maximum temperature contributed negatively towards yield of banana but this variable has a significant effects on the banana crop. Apart from that, the minimum temperature and rainfall contributed positively to the yield of banana but not significantly effect on banana yield. To support, it's range and growth are limited by specific temperature ranges and high water needs throughout all phase's development. High temperature can harm the plant and its fruit, while low temperature impede growth and influence the quality of the fruit (Ortiz, 2012).

H. Rainfall and Temperatures Relationship to Coconut Crop Yield

Coconut is one of the most important crops in the Philippines, which is the world's second largest producer (Food and Agriculture, 2021).

The highest and minimum temperatures both contributed to a negative result, as seen in Table 1. Even if the results are negative, each temperature has a statistically significant impact on coconut output. Otherwise, rain played a positive role, with higher rainfall leading to an increase in coconut yield. Temperatures are statistically relevant since they are a major weather factor affecting coconut development and yield. Increased temperatures and fluctuating rainfall, according to Garmage (2009), could affect coconut productivity by influencing fruit formation and nut development.

V. CONCLUSIONS

Based on the summary of results, it concludes that the highest recorded of rainfall in 2009 and 2012 experiencing a crop damage especially the rice and corn yield. In the lowest recorded of rainfall were 2015 and 2019, the drought experienced in Mindanao include the Cotabato, it reported a damage of crops like rice, corn, coconut and banana. Between 2006 and 2020, there was a consistent increase in both minimum and maximum temperatures. This indicates that there was a yearly fluctuation in temperature in Cotabato, which could affect the yield of particular crops. Temperatures, both minimum and maximum, have a considerable impact on Cotabato's principal crops. Climate change has a negative

impact on key crop yields. Whereas, the minimum temperature has significantly and positively influenced the rice yield, it caused positive growth of the corn. The minimum temperature was significant and positively influenced to the corn yield, it also a requirement to the growth of the corn and lead to high quality of production. The maximum temperature also is an important factor to the pineapple. Moreover, the maximum temperature was significantly affecting the yield of banana, it revealed in the studies that high temperature harm the banana production while the low temperature brings a good impact to the growth and quality of banana fruits. Further, the maximum and minimum temperatures have significant and negatively affected the development of coconut, whereas the rainfall has positively and insignificant influence to the coconut yield.

ACKNOWLEDGMENT

First and foremost, praises and thanks to the **God, the Almighty** and to all who have extended support in the study.

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