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Constraints in the Primary Production of Bananas in the Davao Region, Philippines

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Abstract *— This quantitative study examines the constraints in the primary production of bananas in Davao Region, Philippines. Various studies and climate projections by PAGASA proved the existence of climate change. Climatic variables (i.e. average temperature, rainfall amount, and relative humidity), Panama disease occurrence, and government support dataset are derived from government agencies from 1990-2019. Multiple regression analysis and other statistical tests are used. Most studies imply that there is a negative relationship between banana production to climate variables and panama disease but a positive relationship to government support. Results of this study show that climate variable indicators display a negative significant relationship on the volume of banana production which adheres to past studies while Panama disease and government support indicate an insignificant relationship which contradicts other studies. This study is therefore intended to impart practical knowledge to help farmers to be prepared for the adverse risks of climate change on their crops. It is also expected that this provides policy recommendations for the government to arrive at appropriate policies based upon ground realities.*

climate, climate change, agriculture, temperature, relative humidity, rainfall, panama disease, government support, production

I. INTRODUCTION

Climate is one of the most essential factors that determine where and what kind of agricultural crops could be grown in a particular area. The massive damages from disasters each year that are generally climate-related are being experienced by the agricultural sector in the Philippines (Dikitanan et al., 2017). The Philippine Atmospheric, Geophysical, Astronomical Services Administration (PAGASA) stated that the country's climate is characterized by relatively high temperature, high humidity, and abundant rainfall.

The Davao Region experiences type II and type IV climate which means that it is not directly hit by typhoons and low-pressure systems and is rarely affected by high winds (Department of Agriculture, 2021). PAGASA mentioned that the region's climate and rainfall all year round allow for various crops to be grown in Davao. Its favorable climate and fertile soils make it a good and ideal place for tropical fruit production of one of the most popular fruits in the world, bananas (Digal, 2007; Rodeo, 2016; Calica et al., 2017). A banana has specific temperature ranges in the world where it can grow, and it prefers warm climates with high annual rainfall. Specific temperature ranges and high-water demand throughout all stages of its growth limit the range and growth of bananas since it is a water-sensitive plant (Carr, 2009; Ortiz, 2012; FAO, 2012; Devi et al., 2013).

Banana is a monocotyledonous, herbaceous, evergreen perennial that produces a typical color yellow, sweet fruit. There are two distinct sectors in the banana industry in the Philippines: one for the domestic market and the other for the country's exports. The Philippines produces six different banana cultivars: Cavendish and Buñgulan (exports); and Lakatan, Latundan, Saba, and Cuarenta Dias (domestic market) (Rodeo, 2016).

However, threats continue to emerge in the banana industry. They face market, technical, organizational, financing, environmental, and policy issues. Developing countries that are mainly dependent on agriculture are highly vulnerable to the effects of climate change since they are not equipped with technological advancements and information to help them cope with extreme climate conditions (Hanif et al., 2010). Recent years showed the presence of extreme weather conditions or climate changes which lead to widespread damage to banana crops and industry. The periodic El Nino and La Nina also affect banana and market production (Department of Agriculture, 2018). Climate change-related impacts are predicted to rise in the next decades, threatening the agricultural sector. It is projected to have negative impacts in areas of the world that will turn out to be hotter and drier (IPCC, 2007; DILG, 2011; Crost et al., 2018). Climate-related impacts are also anticipated to diminish agricultural productivity in the Philippines (Dait, 2015). Ramirez et al (2011) forecasted that banana systems will face pressure from climate change. Variations in rainfall distribution and temperatures may affect the suitability of particular regions for banana production and cause a decline in yields (Ortiz, 2012). In the study conducted by Ortiz (2012), the author revealed that Davao's climate has changed by an average of 0.02 °C every year, where the mean annual temperature in 2010 was around 1 degree warmer than it was 6 decades ago. Climate records from Davao City showed that temperatures are becoming warmer and rainfall is decreasing. On average, rainfall has been declining in the region. Furthermore, PAGASA (2011) made climate change projections in the Philippines. Their projections showed that in the Davao region, the temperature will change by 1°C- 1.2°C in 2020. While there will be 1.9°C- 2.5°C temperature changes in 2050. In terms of rainfall amount, it is projected that there will be a decrease of rainfall for the months of March to August in all provinces in the Davao region for 2020 and 2050. While there will be an increase of rainfall in the December to February months and variability in the September to November season.

Having said that, the research problem arises in the idea that the Davao Region, despite being an ideal place for banana production, may still be affected by factors like climate change which is defined as the change in the state of climate over time. Possible threats to the banana industry must be acknowledged and solved to lessen the harmful impacts in the future. There are numerous studies showing the importance of bananas to the country. For instance, many Filipino farmers rely on their banana crops as their source of income. Since bananas are also one of the major exports of the country, it is essential to maintain or improve its competitive advantage and global market position.

On the other hand, another major influence of climate change on agriculture could be changed in the incidence of crop diseases. Several studies claim that global climate change can potentially influence diseases and how they are managed. Changes in the incidence and severity of crop diseases are likely to occur (Vurro et al., 2010). Climate change influences the occurrence, prevalence, and severity of crop diseases which could induce epidemics (Ahanger et al., 2013; Zayan, 2019). Higher temperatures will also increase pest and disease risks in some plantations because some diseases thrive during hot climates and make it easier to infect close crops (Knox et al., 2021). Panama disease is prevalent in most banana-growing regions of the world. It is referred to as banana wilt, is a destructive disease of bananas caused by the soil-inhabiting fungus species Fusarium oxysporum forma specialis cubense (Garcia-Bastidas et al., 2015; Salvacion et al., 2019). The incidence of Panama disease is indicated to increase with climate change. Increasing temperatures and periods of drought will change plant physiology, causing stress, and possibly expanding the aggressiveness of F. oxysporum f. sp. cubense in susceptible cultivars (Ghini et al., 2011). The predicted changes in rainfall in the future can also increase the areas that are favorable for Fusarium wilt occurrence (Salvacion et al., 2019). These factors threaten banana production and exportations in the global market (Dela Cruz and Jansen, 2017). The disease brings lower production and higher cost of production since plantations require to have more stringent and costlier sanitary and quarantine practices to contain and control the spread of diseases (Department of Agriculture, 2018). Molina et al. (2008) asserted that there is a serious occurrence of Foc TR4 epidemics in plantations and farms in the Philippines specifically in Mindanao due to the devastating potential of the pathogen in the plantations where most bananas for export and local consumption are produced. Foc TR4 now threatens the million-dollar banana export industry in the Philippines as well as the subsistence banana producers. In the previous years, the Foc TR4 pathogen was reported in the provinces of Compostela Valley, Davao del Norte, and Davao City (Molina et al. 2008). In the Philippines, Cavendish cultivars account for about 51% of national banana production, Saba 29%, Latundan about 11%, and Lakatan 10%. More than 80% of bananas and 99% of the Cavendish cultivars are produced in Mindanao. In 2001, Cavendish bananas in the highlands were severely affected by Fusarium wilt. In 2003, periodic cases were observed in lowlands. In 2005, there was a significant increase in the lowlands. In 2013, small-scale growers were severely affected (FAO, 2015). The Department of Agriculture confirmed that the first incidence in the Davao region was in Calinan in 2009.

Due to a higher incidence of crop diseases that pose a decline in the country's crop production severed by climate change, this study used the Panama disease as an intervening variable.

This study also incorporated government support to assess if it has a significant impact on the production of bananas. Government support plays a role to develop industries such as the improvement of infrastructure and logistics support, programs and projects, incentives, marketing, financing, research, and development, etc. The governments in Southeast Asia for instance, have been providing financial and production support for farmers through input subsidies (Anderson, 2013).

With that, the researchers came up with this study because climate change, crop diseases, and government support are the major constraints in the production of crops and in agriculture. The Philippines is most at risk from these constraints. Impacts of climate change in the Philippines are extensive, including changes in rainfall patterns and distribution, droughts, sea-level rise, annual losses in GDP, threats to biodiversity and food security, public health risks, and endangerment of vulnerable groups such as women and indigenous people. Decisively dealing now with climate change and its underlying impacts is key to ensuring sustainable development, poverty eradication, and safeguarding economic growth. Scientific assessments indicate that the cost of inaction now will be costlier in the future. While in terms of crop diseases, agrarian societies are held responsible for damaged crops. Filipino farmers are having difficulties in handling damaged crops due to the lack of technological advancements and the capacity to implement disease management protocols on farms. To prevent the spread of diseases is costly and time-consuming for farmers. Once the plantation is infected, eliminating infected plants and restricting access to it is the only way to prevent it from spreading. This results in losing their productive capacity for profitable banana production (Dela Cruz and Jansen, 2017). Consequently, this may greatly affect the banana industry and therefore, will most likely affect the banana exports of the Philippines. The assessment and analysis of this study imparted practical knowledge in the banana industry by helping farmers to be prepared for the adverse risks of climate change and disease on their crops. To come up with economic and environmentally sound decisions and adaptive measures to help the industry in the possible occurrence of problems in the future will also be a great help. Government support through policies and subsidies can be further implemented by the government to improve the production of bananas which in turn can stimulate economic activity and promote the socio-economic well-being of farmers.

This study aims to assess the influence of Climate Change, Panama disease, and Government Support on banana production in the Davao Region: (1) Describe the association of 1990-2019 historical records of climate change variables and Panama disease on the volume of banana production in Davao Region, Philippines; (2) Determine the impact of government support on the volume of banana production in the Davao Region, Philippines.

II. LITERATURE REVIEW

A. Background and Agricultural Issues in the Banana Industry

The Philippines is an archipelago country with a total area of 300,000 km2 located in Southeast Asia and is situated between the West Philippine Sea (Bagtasa, 2017). Its three largest island groups are Luzon, Visayas, and Mindanao (Rodeo, 2016; Tolentino et al., 2016). Despite the plans to make it an industrialized economy by 2000, it is still heavily dependent on agriculture where many Filipinos are still living in rural areas and support themselves through agricultural works. Its main agricultural crops are rice, corn, coconut, sugarcane, bananas, pineapple, coffee, and mangoes (PSA, 2020).

The Philippine export fruit production is concentrated on the island of Mindanao (Lockie et al., 2015). The regions of Davao, Northern Mindanao, and South Cotabato, Sultan Kudarat, Saranggani, and General Santos City (SOCCSKSARGEN) are the top banana-producing areas in the country where there is a continuous increase in the number of hectares planted and volume of harvested fruits every year (PSA, 2015). Davao Region is an ideal place for banana production because of its large contiguous tracts of land available, rich soil, and abundant human resources. It has a competitive advantage in exports in the Asian region due to its strategic location (Digal, 2007). The province of Davao del Norte is known as the Banana Capital of the Philippines, with many plantations run by multinationals and local producers (Guia, 2012). In 2020, banana remained as the leading agricultural export commodity in the Philippines; banana production was estimated at 2.40 million metric tons making the country the second top exporting country for the past decade. The country was also able to make its way to the international market which includes Japan, South Korea, Hong Kong, China, and the Middle East (Rodeo, 2016). However, threats continue to arise in the banana industry. One of which is the threats of crop disease particularly the Panama disease (Vurro et al., 2010).

In the Philippine context, the spread of plant disease through blaming is being linked to existing oppositions from the land reform process and the history of agrarian relationships. Dela Cruz and Jansen (2017) studied one of the essential practices in the banana industry which is contract farming also known as contract growership. It is an agreement that exists between the farmers and marketing firms. Both parties agreed on predetermined prices for the agricultural production and supply of products. The institutional arrangement also integrates the smallholder farmers into agricultural value chains (Barrett et al., 2012). Contract farming has various advantages and one of which is that it provides access to markets and credit that would otherwise not be available for the smallholder farmers (Simmons, 2002). Apart from that, Guo, Jolly, & Zhu (2007) mentioned that contract growership arrangements ensure price stability.

Based on the result of the study and intensive interviews conducted by Dela Cruz and Jansen (2017), they revealed that smallholder farmers are the ones liable for the spread of Panama disease due to their lack of technological knowledge and capacity to carry out disease management protocols at the farm areas. The expansion of multinational banana companies to new areas in the Philippines is also highly linked to the spread of Panama disease. With that, the Pilipino Banana Growers and Exporters Association, Inc. (PBGEA) takes the lead in Panama disease in the Philippines. The head of Research of Unifrutti Philippines said that the government did not have enough resources to conduct its own research on Panama disease protocols. Therefore, the Provincial Agriculturist of Davao agrees that the private sector or the multinational companies have more technical expertise compared to the government which makes them have the power to see themselves as the

"saviors". The little contribution of the government to this plant disease creates a little incentive for the private sector to enhance their behavior, implement more equitable contracts, and accept more risk and responsibility of Panama disease in the Davao region (Dela Cruz and Jansen, 2017).
On the other hand, in the Industry Clusters Roadmaps of Davao Region for 2014-2030 presented by Regional Development Council XI (2014), the banana industry in the region is the most recommended priority. The goal of the region is to remain the major producer of bananas and to have a significant contribution to the economy through exports. However, pests and diseases, weak relationships between the farmers and the government, and climate change are the major threats in the industry. Access to financing is the major constraint in the input provision of bananas. While in terms of primary production, weather factors and banana diseases are the major constraints. In terms of processing, the lack of government policy implementation posed a major constraint. In terms of distribution, the lack of modern port facility channels of distribution and scarcity of wood products for pallets are the major constraints. With these constraints, the industry has come up with strategies and action plans such as meeting with the banks, conducting meetings among government agencies, improving port facilities, etc.

B. Climate of the Philippines

According to PAGASA, the country's climate is characterized by relatively high temperatures, high humidity, and abundant rainfall. Generally, the Philippine Climate has two major seasons: (1) the rainy season, which sets in by late May to June and ends around November. The rainy season is subdivided into the habagat season from June to August and the transition from southwest to northeast monsoon season from September to November; (2) the dry season, which starts in December and ends in May. The dry season is also subdivided into the cool dry or amihan season from December to February and the hot dry season from March to May. During the summer season, from the month of March to May, the highest temperatures occur. Precipitation is measured between 965-4000 mm a year and the period with the highest rainfall is during the southwest monsoon season or the month of June to August. The Philippines is also vulnerable to short-term and long-term changes in climate. This includes climate change, a change in the state of the climate over time (Ortiz, 2012), and El Niño that brings an extended period of no rain, which harms crops and severely limits yields (Li et al., 2019). The Philippines' geographical location and archipelagic formation make the country vulnerable to the impacts of climate change. It is the country that is most vulnerable to tropical cyclones, third in terms of people exposed to such seasonal events, and fourth among countries most affected by extreme weather events (Sönke et al., 2016). Since 1900-2010, the country has experienced more than 480 natural disasters (Pacheco, Aquino, & Tanzo, 2010). The country also has a regional climate classification based on rainfall distribution. Davao region is classified as type IV climate which is characterized by a fairly even distribution of rainfall throughout the year (PIDS, 2005).
There are various studies that looked into the local trends and changes of temperature and rainfall in the country to explain climatic observations that play a big role in coming up with climate change adaptation measures and solutions (Bagtasa, 2017). The study conducted by Cruz et al. (2013), revealed that from 1960-2010, there is a decrease in the rainfall trend in the western portion of the Philippines during the southwest monsoon season. While in most parts of the western Philippines, there is a prolonged dry season. Villafuerte et al. (2014) use the seven extreme precipitation indices (EPI) to examine the long-term trends and the variability of rainfall extremes. Based on their findings, it revealed that there is a drying trend from January to March and an increase in extreme rainfall events from July to September. Cinco et al. (2014) revealed that there are warming trends in surface temperature and an increase in extreme temperature and daily rainfall events which were significantly distributed all over the country. While Ortiz (2012) revealed that Davao's climate has changed by an average of 0.02 °C every year, where the mean annual temperature in 2010 was around 1 degree warmer than it was 6 decades ago. Temperatures are becoming warmer and rainfall has been declining in the region.

C. Banana Production

Production is defined as an economic activity of combining inputs in order to produce something for consumption. In the context of this study, production is defined as the harvesting or refinement of something natural. In the Philippines, banana production is branched into two different systems, (i) large-scale commercial agro-export-orientated plantation estates and (ii) small-holder farms typically functioning as 'outgrowers' for the larger estates. Multinational companies usually own the latter that manages the production, transport, and distribution of bananas with high output levels supported by substantial infrastructure investment (Wiley, 2008; Robinson & Galan-Saúco, 2010).
The Cavendish is the most cultivated globally (Smith, 2015) and it became highly productive in intensively managed plantations and competent to international and domestic markets. As a result, it contributed approximately 50% of worldwide production and 99% of export markets (Kema et al., 2020). It is the most economically essential banana cultivar in the Philippines which accounts for 50% of total banana production.

Other banana cultivars such as saba, accounts for 30%, and lakatan accounts for 11% of banana production (DOST, nd). In the Davao Region, bananas dominate with a relative proportion yield estimate of 36.12% out of all agricultural commodities (PSA, 2017a). The average production in the country from 2012 to 2016 was estimated at 8,029,419 mt wherein 56.24% is Cavendish, 32.06% is Cardava banana and 11.70% is Lakatan (Calica et al., 2017). As for the last quarter of the year 2018, 51.9% of the total banana production in the Philippines is accounted for the Cavendish cultivar (PSA, 2018).

In connection, Salvacion (2019) described trends from 1991 to 2016 in banana yield in the Philippines. The yields averaged around 10.8 tons/ha, a maximum of 64.4 tons/ha, and a minimum of 0.57 tons/ha. The highest yield of bananas came from the south-central of the country-- the Davao Region. Provinces such as Davao del Norte and Davao Oriental showed a significant banana yield trend from 1991-2016 and were attributed to large banana plantations.

To measure the volume of banana production, Salvacion et al. (2019) gathered the provincial level yield data from 1981 to 2016 reported by the Philippine Statistics Authority. Simultaneously, to calculate the effect of climate, climate data such as monthly rainfall (mm), monthly maximum and minimum temperature (C), and monthly frequency of wet days (days) were collected. In the methodology, in order to determine the presence of a linear trend, a trend analysis was applied to the time series of banana yield data for each province. Then, based on the result of linear trend analysis, multiple regression analysis was used to assess the effect of climate on provincial-level banana yield.

Similarly, the relationship between banana yields and climate parameters was assessed using time series moments, correlation, and regression analyses. In addition, a process-based crop water assessment tool, FAO-CROPWAT was used to investigate the effects of intra-seasonal rainfall variations on rain-fed banana yields over different parts of Uganda. The cumulative effect of rainfall and temperature variations on banana yields can be seen from correlation and regression results [0.78 (R2 =61%)] (Sabiiti et al., 2016).

While the recent study of Shi et al. (2020) is more technical in terms of the variables and methodology because aside from climate change and agricultural output, crop disaster areas were included. To assess the impact of climate change on agricultural production, the dynamic Slacks-Based Measures (SBM) under an exogenous variable model to simulate the external environmental factors by adding extreme weather days. Also, the Dagum Gini coefficient and kernel density estimation are used to explore the regional differences in agricultural production in China.

The study of Shi et al. (2020) is similar to Tanure et al. (2019) in terms of examining the impact of climate change on agricultural production. Tanure et al. (2019) incorporated land use and food production. To evaluate changes in agricultural production and land use in the region due to climate change scenarios proposed by the IPCC (Intergovernmental Panel on Climate Change), the methods used were the Computable General Equilibrium (CGE) model and the Inter-regional General Equilibrium Model for the Brazilian Legal Amazon (REGIA).

Alboghdady and El-Hendawy (2016) used a production function model and fixed effect regression analysis to evaluate and analyze the impact of climate change on variable agricultural production. The results showed that the increase in temperature in the winter was 1%, which led to a 1.12% reduction in agricultural production.

In terms of location, the two sowing and harvesting seasons in Pakistan are Rabi and Kharif. The study of (Hanif et al., 2010) used the Rabi and Kharif mean precipitation, minimum and maximum temperature individually as climate variables. They used the Feasible Generalised Least Square technique of panel regression estimations to calculate the relationships of climate variables with agricultural land price as well as marginal climate impacts. Based on their findings, they revealed the magnitude of change in per acre agricultural land price with the change of climate variables. The study revealed that farmers may face uncertainty and threats to agricultural production, like climate variability. It confirmed their hypothesis that climate change affects the price of agricultural land which is a long-run variable for net revenues.

Shayanmehr et al (2020) addressed uncertainty and threats in a production function data distribution. Under these conditions, the stochastic production function approach and the statistical downscaling model (SDSM) are used to estimate the impacts of climate change on yield distributions of wheat in the northwest of Iran.

Besides, Devi et al. (2013) stressed the importance of water-- be it in soil or rainfall in plant growth and field crop production. This is because water deficit is one of the most important factors to limit banana productivity in the world, especially in dry and semi-dry areas where large fluctuation in the amount and distribution of the rain these areas face. The leaf area, leaf area index, and specific leaf weight served as the parameter to evaluate the impact of water deficit on growth attributes and yields of banana cultivars and hybrids.

D. Climate Change

A study by Bhat et al. (2013) defined climate change as the long-term shift in weather statistics. This agrees well with the findings reported by Hanif et al. (2010) that temperature rise can be linked to rainfall pattern changes, rise in sea level, and frequency of extreme events like cyclones and droughts, which he also referred to as climate change. Grossman (2018) defined it as the rise in atmospheric and ocean temperatures, changing patterns of precipitation, rise in the sea level, increase in oceans' acidity, and the frequency and intensity of extreme weather events. While Ortiz (2012) defined it as a change in the state of the climate over time.

In this study, climate change has three parameters: temperature, rainfall, and relative humidity. Temperature is defined as the determination of the object's sensation of warmth or coldness (Sullivan, 2008). Rainfall is the amount of precipitation-- described as the liquid or solid condensation of water vapor falling from clouds or deposited from the air onto the ground. The main forms of precipitation include drizzle, rain, sleet, snow, ice pellets, graupel, and hail. Precipitation is measured as the amount of water that reaches the horizontal ground or the horizontal ground projection plane of the earth's surface and is expressed as a vertical depth of water or the water equivalent of solid precipitation. In particular, regional rainfall is defined by observed rainfall at multiple, well-distributed stations in a given area (Yu et al, 2015). Apart from that, drought is also considered as one of the characteristics of rainfall and is defined as the lack of precipitation. The latter can be measured through annual rainfall, seasonal distribution of rainfall, and persistence (Rowntree, 1989). On the other hand, Dourte et al. (2015) discussed that extreme and very heavy rainfall are typically high-impact rains and are rare by definition.

Kong and Singh (2011) defined relative humidity in the air as the ratio of the vapor pressure of air to its saturation vapor pressure. It is a measure of how much water vapor is in a water-air mixture compared to the maximum amount possible. Relative humidity (RH) also refers to the moisture content (i.e., water vapor) of the atmosphere, expressed as a percentage of the amount of moisture that can be retained by the atmosphere (moisture-holding capacity) at a given temperature and pressure without condensation (Postharvest Technology of Perishable Horticultural Commodities, 2019). The relative humidity is tied with temperature and is usually used to determine the duration of leaf wetness. The high relative humidity is closely linked to moist leaf surfaces while low relative humidity causes a dry microclimate at the leaf surface. High levels of humidity favor crops to kill aphid virus vectors (Jones, 2016).

The predicted increasing temperatures due to climate change are also expected to increase weather variability– weather events which are moderate and extreme deviations from average such as droughts, more intense, less frequent rains, cold snaps, heat waves, and more violent storms (IPCC, 2012). With this, under predicted climate change, present agricultural practices may become unsustainable due to the rise of temperature as well as the changes in the rainfall patterns which can lessen the viability of certain crop types (Tolentino et al., 2016). It is expected that Climate change (CC) will change global crop productivity, resulting in higher world prices in the future. Beach et al. (2010) mention that its impact will differ across crops, locations, and time periods. Some crops and regions will be less affected than others; some will have an increase in agricultural productivity or will have an increase in precipitation. Countries that have multiple climate zones will have major variations in productivity impacts.

Historically, the effects of climate change are evident in economic development especially in the agrarian economies that have always depended on unexpected changes in nature and climate. Changes in temperature, averages of precipitation, and extreme climate events can cause changes in yields, income, health, sociology, and physical safety. It is closely linked to food security and poverty (Hanif et al., 2010). It also constitutes numerous threats to global stability, national security, and human welfare (Nordas and Gleditsch, 2014). Another threat of climate change is the distribution of rainfall. Chou et al. (2013) mention that climate change is already going towards wetter wet seasons and drier dry seasons. This trend is predicted by Chou and Lan (2012) to be intensified in the near future. It is supported through the study conducted by Crost et al. (2018) in which they examined the effect of rainfall by season on agricultural production as well as in civil conflict in the country. Based on their findings, they found that the forecasted shift towards drier dry seasons and wetter wet seasons will cause harmful effects to agriculture which will also strengthen the civil conflict. They also claimed that rainfall is linked to civil conflict and affects agriculture. Moreover, developing countries that are mainly dependent on agriculture are highly vulnerable to the effects of climate change (Hanif et al., 2010).

For instance, extreme weather conditions as external factors have a great impact on agricultural production like China, which is also one of the countries with the most severe climatic disasters. China's wide latitude in the north and south of their territory is the reason why all regions are faced with extreme weather, including drought, frost, flooding, and other disasters. Under extremely high-temperature weather, land surface moisture evaporates quickly, reducing soil moisture and thus badly affecting the growth of the crops. Extreme weather conditions or low temperatures, especially when co-occurring with nonstop rainfall, may reduce agricultural water; however, the cold frost can lead to winter crop output, of which in the north, the winter wheat is the primary representative crop. Thus, the cold weather there has an important intervention effect on the wheat growth cycle, which will affect the whole crop production schedule for farming (Shi et al., 2020).

In Pakistan, the 2006 share of their agricultural sector in their GDP, exports, and employment level have decreased due to the decline in agricultural productivity brought about by climate change. In 2007, they suffered heavy rainfall, high temperature, and a shortage of water in the overall irrigation system. It is one of the

countries vulnerable to climate change due to its warmer climate. The variability in monsoon rains, floods, and droughts makes their water, food, and energy security be placed under serious threat (Hanif et al., 2010).
Lastly, the Philippines is endowed with a favorable climate that is well suited for growing bananas all year round but it is also one of the countries that are vulnerable to climate change due to its increasing incidence of extreme weather events and limited resources for adaptation (Calica et al., 2017; Kreft et al., 2014; Tolentino et al., 2016). Disasters due to climate change in the country are the major cause of disruption to fruit crops and production which results in the loss of livelihoods as well as an increase in the prices of food. In the past years, the weather events in the Philippines have cost the economy an annual average of 0.3 percent of GDP (FAO, 2021). Chandra et al. (2016) also added that the productivity and sustainability of smallholder mixed farms in Mindanao are threatened by climate variability and change. The number of farmers who are displaced, the loss and damage incurred in the region will likely increase as the effects of climate change increase rapidly on smallholder agriculture.
In 2011, PAGASA, the national agency of the Philippines, made a projected seasonal climate change in 2020 and 2050 in the Philippines. To be more specific, the projected climate change in the province of Davao is summarized as follows:

Davao Region	Observed Baseline (1971-2000)				Change in 2020 (2006-2035)				Change in 2050 (2036-2065)			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
Compostela Valley	26.7	27.8	27.6	27.6	0.9	1.1	1.2	1.1	1.9	2.3	2.4	2.1
Davao Del Norte	26.7	27.8	27.4	27.4	0.9	1.1	1.2	1.1	1.9	2.3	2.5	2.1
Davao Del Sur	26.9	27.8	26.9	27.1	0.9	1.1	1.1	1.0	1.9	2.2	2.3	2.0
Davao Oriental	26.8	27.8	27.5	27.6	0.9	1.0	1.1	1.0	1.8	2.0	2.4	2.0

Table I Seasonal temperature increase (in °C) in 2020 and 2050

Davao Region	Observed Baseline (1971-2000) mm				Change in 2020 (2006-2035)				Change in 2050 (2036-2065)			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
Compostela Valley	748.1	559.0	546.7	586.6	10.2	-11.3	-2.7	0.3	6.6	-21.9	-6.5	0.0
Davao Del Norte	637.0	496.5	535.6	556.2	9.2	-12.5	-3.6	-1.5	1.1	-22.2	-7.9	-2.2
Davao Del Sur	288.1	347.1	494.1	442.3	18.1	-9.8	-7.8	-2.4	15.2	-12.0	-12.6	-4.5
Davao Oriental	827.3	611.8	540.4	599.2	12.3	-5.7	-4.7	1.2	15.9	-16.1	-9.9	4.9

Table II Seasonal rainfall change (in %) in 2020 and 2050

In table 2.4a, for example, Davao Del Norte had a baseline temperature of 27.8°C in the summer months MAM. In 2050, there is a predicted change of 2.3°C so its mean temperatures will be around 30.1°C. Furthermore, all seasons are projected to have an increase in temperatures, and the provinces are forecasted to experience about the same increase in temperature. On the other hand, table 2.4b shows the projected rainfall changes. Here, it is projected that there will be a decrease in rainfall for the MAM, JJA months in all provinces in the region for 2020 and 2050. While there will be an increase in the DJF months and variability in the SON season.

E. The Influence of Climate Change on the Occurrence of Plant Diseases (Panama disease)

Climate change will affect the occurrence of plant diseases together with other components of global change like anthropogenic processes such as water, air, and soil pollution, urbanization, and the long-distance introduction of exotic species (Regniere, 2012). Similarly, climate change influences the occurrence, prevalence, and severity of plant diseases. Projected atmospheric and climate change will affect the interaction between crops and pathogens in multiple ways (Zayan, 2019). Charkraborty and Datta (2003) claimed that a change in temperature may favor the development of different inactive pathogens, which could induce an epidemic.
Generally, plant diseases at cold average temperatures are likely to experience longer periods of temperature than if the climate is warm. This makes it suitable for the growth and reproduction of pathogens. The earlier onset of warm temperatures could result in an earlier threat from late blight with the potential for more severe epidemics and increases in the number of fungicide applications needed for control. During colder parts of the

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year, warming may relieve plant stress, whereas during hotter parts of the year it may increase stress. An example of the potential effect on the yield of crop plants in response to elevated temperature is the rice yield in the Philippines. It was estimated that there is a 10% decline for each 1°C increase in the minimum temperature during the dry season (Peng et al., 2004).

On the other hand, Salvacion et al. (2019) showed that almost a quarter of the Philippines was estimated to be favorable for the occurrence of Panama disease. In comparing the area coverage of future Fusarium wilt occurrence with the average banana production statistics from the PSA, it showed that around 67% (0.27 million ha) of the harvested area for banana might have Fusarium wilt infestation under future climate change conditions. Therefore, the projected climate change in the Philippines is expected to increase potential areas for Fusarium wilt occurrence. A decrease in rainfall amount during the driest and wettest month of the year due to climate change favors the occurrence of Fusarium wilt in a place as well as an increase in rainfall during the warmest quarter.

F. Panama Disease

Fusarium wilt in bananas (also known as Panama disease) is caused by a soil-borne fungal pathogen, Fusarium oxysporum f. sp. cubense (Foc), that invades the roots and then the vascular of the plant resulting in wilt and dieback (Garcia-Bastidas et al., 2015; Salvacion et al., 2019). According to Ploetz (2006), the pathogen travels in soil and running water, as well as on-farm implements and machinery. Soluri (2002) also added that it can also enter via root structures and travel up vascular tissues to the leaves. TR4 blocks the vascular tissue which stops the passage of supply of water and nutrients in the plants. This caused the yellowing of the banana leaves and longitudinal splitting of the stem of the plant at the base which will eventually lead to the wilting and collapse of the whole canopy. Infected foliage turned yellow-brown before wilting. Severely diseased plants seldom produced healthy fruit, if they produced any at all (Soluri, 2002). That is why horticulture experts considered this disease as one of the most devastating diseases in the world, one of the most severe threats facing the banana industry worldwide, and is considered one of the most severe plant disease epidemics in agricultural history (Ploetz, 2006; Ma et al., 2020) and it has no known remedy yet to mitigate the disease (Pérez- Vicente, Dita, & De la Parte, 2014). Currently, researchers are trying to understand and examine the genetic diversity of the pathogen itself, so that the development of methods, tools, and measurements to diagnose the disease in the field can be started before it can cause massive destruction in plantations (Ordoñez et al., 2015).

In line with this, farmers face challenges brought by various shifts in the agri-food system due to the increased incidence of diseases, particularly fusarium wilt, which is compounded by climate change (Timmusk, et al., 2020). However, Dela Cruz and Jansen (2017) reported that all varieties of bananas can be affected by fusarium Wilt and not just the Cavendish cultivar. As estimated, around 91.2% of the total highly suitable areas for bananas located in the northern and southern regions of the country have Fusarium wilt (Salvacion et al., 2019). As of 2015, the government's Philippine Information Agency gave a report about the banana plantations that have been infected with Panama disease. Based on the report, 15,500 hectares of banana plantations are infected with Panama disease and Davao del Norte is the most infected accounting for 13, 743 hectares of its banana farms (Department of Agriculture, 2015). In this case, Dela Cruz and Jansen (2017) mentioned that lands infected by the disease may be lost or need to be quarantined. Lockie et al. (2015) pointed out that growing the same plant over a wide interconnected area inevitably raises the risk of pest outbreaks and the incidence of contagious diseases, such as Sigatoka, Panama disease, and the like. Strict pest and disease control must therefore be applied consistently over the entire area to maintain the quantity and quality of bananas. Aside from that, the disease created a huge financial setback for the farmers. For instance, in order to mitigate the spread of the disease, they have to take various measures. There is a need to surround the infected banana plants with bamboo and then put the plant to the ground to be burned. This costs them Php 250 per infected banana plant, and lost profits and loss of land are excluded. There is a loss of land since the area around the infected plant cannot be replanted anymore and it needs to be quarantined. With this, it gives farmers a difficult time and a serious problem in addressing Panama disease in any sustainable way because they do not have enough resources and they are still facing increasing debts to the corporation (Dela Cruz and Jansen, 2017; Ma et al., 2020)

Historically, strains of Foc have become well-known following its appearance in Central America in about 1890 which destroyed millions of Gros Michel banana plants in the country (Stover, 1962; Hubbell and Gregory, 1996) and its English-language name originated from the place where it was first widely observed: Panama. By 1960, Panama disease had spread widely in tropical America, the Caribbean, and Western Africa, destroying 40,000 hectares of 'Gros Michel' (Ploetz 2005; Stover 1962). Clearly, the pathogen has gone outside its former Southeast Asian boundaries and is established in the Middle East (Ploetz & Evans 2015). Moreover, Ploetz & Pegg (1997) claimed that the presence of Panama disease in Australia was first discovered in 1997. TR4 was also confirmed in Jordan in 2013 but has probably been present in the country since at least 2005 (Ploetz et al., 2015). The occurrence of the disease in Jordan was apparently the first occurrence of Panama disease in the Middle East, but it also represented a considerable expansion of TR4's distribution, which had previously been restricted to the Far East. Despite some measures, Foc TR4 escaped from the infested fields and spread rapidly and widely to disease-free areas. In 2011, the fungus was first identified outside Australasia when it was detected in several plantations in the Sultanate of Oman (Ploetz et al., 2015). Soon thereafter, it was reported from Jordan, Lebanon, and Pakistan. When Foc TR4 was discovered in Mozambique in 2013, the arrival of "banana-geddon" was announced (Milmo, 2014).

Globally, as of 2017, the confirmed countries that have been infected by the disease are Australia, mainland China, Jordan, Indonesia, Malaysia, the Philippines, Mozambique, Oman, and Taiwan (FAO, 2014). Ordoñez et al. (2016) have also confirmed that Pakistan and Lebanon were also infected.

In the Philippines, Fusarium wilt has infested and continuously threatens vast banana plantations in the country's southern portion. Fusarium wilt was first observed in commercial plantations in the country in 1974 and caused losses of 32,340 plants from a single company between 1974 and 1991 (Magnaye, 2001; Roperos & Magnaye, 1991). The pathogen isolated from these infections was identified as Foc race 4 and later confirmed as VCG 0122 (Pegg et al., 1993). Surveys in 2005 and 2006 confirmed that the new outbreaks were caused by Foc TR4 (Molina et al., 2008). After a few years, the Department of Agriculture in Region XI reported that the first incidence in the region was in Calinan in 2009. Foc TR4 has since spread throughout Mindanao but has not been found on any other Philippine island (Molina et al., 2015). However, as reported by Aguilar-Hawod (2014), to date, no Foc TR4 was reported in Luzon and Visayas islands but the occurrence of subtropical race 4 (ST4) was reported recently in Luzon. In similar research conducted by Solpot et al. (2016) on the spread of Tropical Race 4, they were able to list the areas where Fusarium wilt in bananas is present in provinces which are 1) North Cotabato, (2) South Cotabato, (3) Saranggani, (4) Davao del Sur, and (5) General Santos City-- both in backyard and plantation areas.

Having said that, the outbreak of the Panama disease is a threat to the banana industry in the Philippines as it is responsible for more than 90% of Cavendish banana exports in Asia (Molina et al., 2015). Foc TR4 is also threatening the US$700- million banana-export industry supplied by companies and small commercial growers in the Philippines (Garcia, 2013). Of the 80,000 ha of Cavendish bananas in the Philippines, Foc TR4 has already caused the abandonment of 3,000 ha, with another 8,000 ha affected at various levels (Garcia et al., 2014). The growing number of abandoned banana areas may be due to its wide host range that can infect different host cultivars of banana particularly those intended for export (Cavendish) and for local consumption (Lakatan and Latundan) (Solpot et al., 2016).

In many studies, the vulnerability of Cavendish and local varieties to Foc TR4 was previously demonstrated. Juruena et al. (2014) confirmed that Lakatan was highly susceptible to the alarming pathogen showing higher severity of leaf yellowing and vascular discoloration both in the rhizome and pseudostem. On top of that, Molina et al. (2014) affirmed that both Cavendish and Lakatan varieties were found to be highly vulnerable to the pathogen demonstrating 100% infection in a field experiment and that Latundan variety was found to have a lower disease infection but eventually succumbed to the disease at the later stage of the plant. Conversely, the Cardava variety showed resistance against the pathogen. Dela Cueva et al. (2014) also observed infection of Foc TR4 on several banana cultivars evaluated for resistance including Cavendish and Lakatan which were found to be susceptible to the pathogen. The findings showed the vulnerability of local varieties such as Lakatan and Latundan which are grown by many subsistence farmers in the country. Therefore, if there is a constraint in the production of bananas, and if the difference cannot be made up with imported bananas, the domestic price will rise in response to the relative shortage in supply (Cook, 2015).

On the other hand, in this study, Panama disease along with the independent variables (climate variables) is considered as the intervening variable. Knox et al. (2021) asserted that higher temperatures and changes in rainfall will increase pest and disease risks. Including Panama Disease as an intervening variable gave this study more accurate findings of their impact on the banana industry.

The parameters for the Panama disease TR4 model were the following: (1) probability of entry and establishment in production regions; (2) detection probability in areas previously unaffected; (3) population diffusion coefficient; (4) area currently Infected (ha); (5) minimum area infected immediately upon entry; (6) maximum area infected; (7) Intrinsic rate of infection and density increase; (8) minimum infection density; (9) maximum infection density; (10) minimum number of satellite sites generated In a single time step; (11) maximum number of satellite sites generated in a single time step; (12) intrinsic rate of new foci generation per unit area of infection; (13) discount rate; (14) demand elasticity; (15) prevailing market price of bananas In the first time step; (16) treatment costs upon detection ($ per ha); (17) yield reduction despite control (%). The way in which banana production is affected by Foc TR4 can be described using a simple partial equilibrium framework -- partial in the sense that it only depicts one market as opposed to the broader economy (Cook et al, 2015).

To determine the occurrence of Panama disease in bananas, Solpot et al. (2016) went through the following steps: (1) Survey and collection of infected plants; (2) Isolation and Generation of Single Spore Culture of Foc; (3) Molecular Detection of Foc TR4 Isolates DNA Isolation; (4) PCR Amplification with Specific Foc TR4 Markers; (5) Pathogenicity Test of Foc TR4 Isolates; (6) VCG Analysis and Further Molecular Detection of Foc TR4.

Salvacion et al. (2019) assess banana suitability and the potential distribution of fusarium wilt in the Philippines under current and future climate conditions and the author used fuzzy logic and a maximum entropy approach.

Briefly, it can be proved that climate change as an independent variable can be represented by main climatic indicators such as temperature, rainfall, and humidity. The maximum and minimum temperature (C), monthly rainfall (mm), and relative humidity (%) are used (Salvacion et al., 2019; Saengpook et al., 2007). With Panama disease as an intervening variable, it can be shown in total farm area validated with the incidence of Foc Disease (has) (Cook et al., 2015). Meanwhile, banana production can be presented in yield levels, or its volume of production (mt) in a form of time-series data (Salvacion et al., 2019; Sabiiti et al., 2016).

G. Government Support

Agricultural production has been shaped by government policies. The government has been involved in giving support to the agricultural sector by providing support to farmer livelihoods and food security (Lencucha et al., 2020). The governments in Southeast Asia for instance, have been providing financial and production support for farmers through input subsidies (Anderson, 2013).

In the Banana Industry Cluster Roadmap of Davao Region for 2014-2030 presented by Regional Development Council XI (2014), it was mentioned that the Department of Agriculture (DA) allocated funds and built infrastructure to help the local banana farmers in meeting the standards in the export market. There is also the Presidential Social Fund of P50 Million to help the region with its infrastructure projects and training for the farmers. The department also allocated P100 million for the construction of packing houses for the farmer cooperatives in the Davao region. Other national government agencies such as NGOs, DTI, DOST, SMARRDEC, and SUCs have provided technical support and training to strengthen the quality control in banana production. Aside from that, the Department of Science and Technology through the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD), Department of Agriculture, SMARRDEC, and SUCs have united to fight the fusarium wilt race 4 in the banana industry. The PCAARRD allocated funds in managing the Panama disease. The Department of Agriculture-Regional Field Unit (DA-RFU) XI is also in partnership with the Pilipino Banana Growers and Exporters Association (PBGEA) in giving information materials and protocol briefings about the disease. Generally, the Department of Agriculture is the one that facilitates the provision of financial and non-financial support services to further improve the competitiveness of the banana industry. They facilitate (1) crop insurance through the Philippine Crop Insurance Corporation (PCIC) program; (2) credit assistance through the High-Value Crop Development Fund (HVCDF); (3) Credit Guarantee by the Quedan and Rural Credit Guarantee Corporation (QUEDANCOR); (4) Grace period on the lease of government lands payments; (5) Tax exemption; (6) Market linkage between the agribusiness cooperatives with the consumers' cooperatives, and exporters to assure relatively higher and stable prices of bananas; (7) Technical and infrastructure support by the Department of Agriculture, Department of Trade and Industry, Department of Science and Technology, Cooperative Development Authority, state universities and colleges and other government agencies; (8) Post-harvest facilities for the establishment of post-harvest, processing and storage facilities; (9) Providing good seeds and planting materials to farmers, and; (10) Fiscal incentives.

H. Relationship of Climate Change and Banana Production

Climatically, the year-round production of bananas preferred warm and moist conditions. They are also cultivated and managed with locally adapted practices in changing climates. (Calberto et al., 2015). Climate change affects agricultural crops and harms their production, since it is dependent on light, heat, water, and other climatic factors (Rosenzweig & Liverman, 1992) so an increase in climate change results in a drop in banana production. This is because specific temperature ranges and high water demand throughout all stages of its growth limit the range and growth of bananas (Ortiz, 2012).

Hanif et al. (2010) mentioned that developing countries are vulnerable to the effects of climate change. An example of a developing country that is greatly affected by climate change is Pakistan. There was a decline in agricultural production in 2016 due to the climatic changes that the country faced. Pakistan is vulnerable to the effects of climate change comparatively due to its warmer climate and has a larger risk of variability in monsoon rains, floods, and droughts which makes their water security, food security, and energy security be placed under serious threat. This agrees with the study conducted by Ghini et al. (2011) where climate change will increase uncertainty in the production of many crops in tropical countries, including many developing countries where these crops may form an important basis of the gross domestic product. The frequent occurrence of extreme weather conditions will certainly increase stress on future climate and increase damage to crops as time progresses. They further explained that temperature, precipitation, CO2, and O3 must be integrated to determine the climate change on crops. Another study similar to this was conducted by Gupta and Mishra (2019) in which they investigated the impact of climate change on rice production in India using a crop simulation model and Global Climate Model (GCMs) outputs. Based on their findings, in 2006-2035, the rice yield is expected to vary from 1.2 to 8.8%; in 2036-2065, it will vary from 0.7 to 12.6%, and in 2066-2095, it will vary from 2.9 to 17.8% due to climate change. The increasing variation shows the possible effect of climate change on the production of rice. Similar findings by Shayanmehr et al. (2020) show that changes in yield are expected to increase in response to future climate scenarios. While in Brazil, their agriculture is also vulnerable to climatic conditions. The possible consequences of the impact of climate change on the economy in Brazil involve reducing crop productivity in some regions (Assunção & Chein, 2016).

The latest study by Brown et al. (2018) revealed that across the many different climatic zones where bananas are produced, banana growers use practices to manage the negative effects of current climate variability – both seasonal changes in average, moderate weather conditions, and extreme weather events. Bananas are known to thrive in warm and moist weather conditions, even in high temperatures they will survive. However, an increase in temperature also indicates an increase in other climates such as more droughts, more intense, less frequent rains, cold snaps, heat waves, and more violent storms (IPCC, 2012). Extreme events like this will most likely cut the profitability and production of bananas. The distribution of rainfall is also one of the threats brought by climate change and this can damage crops if heavy rainfall continues in a certain plantation.

Furthermore, various studies were conducted to assess the relationships between climate change and crop production. For instance, a study by Chou et al. (2013) pointed out that Sabiiti et al. (2016) examined the linkages between banana yields and rainfall and temperature variability in the central and western regions of Uganda. They observed the banana yields, rainfall, and air temperature covering the period from 1979-2008. Based on their findings, there are relatively strong linkages between banana yields and climate parameters over various locations in Uganda. They also found that air temperatures have direct and indirect effects on banana yields making the air temperature variations strongly linked to banana yields. Moreover, rainfall effects on banana yields may be lagged. The result shows varying levels of moisture deficits across banana-growing areas in Uganda. These moisture deficits are said to be connected to the reductions of banana yields by up to 46%.

Moreover, Brown et al. (2018) conducted 500 survey forms among different banana experts located in Asia, Africa, and Latin America where 137 completed the survey. This was used to determine if banana production will be affected under common and extreme weather conditions per region. The study showed that excess rain and drought-affected banana plantations the most, and other climate conditions were not mentioned as frequently as others. Asseng et al. (2015) added that the effects of extreme events on bananas present a challenge to scientists, and instead of survey forms, models should be used to project changes in short-term high temperature and water availability.

On the other hand, moderately strong rainfall, averagely high temperature, and good relative humidity are associated with the high productivity of bananas (Salau et al, 2016). The right amount of climate that a banana requires is a rainfall of approximately 1500-2500mm, mean temperature of 27°C, and within 25°C to 30°C in a preferably tropical humid lowland (Turner, 1983). On average, the mean temperature of about 26°C and an average rainfall of around 1891mm with a relative humidity of approximately 77% will lead to a good annual production. While excessive rainfall, high temperature, and low humidity can cause the productivity of bananas to decline and damage production (Calberto et al., 2015). However, climate change projections from global climate models predict that banana-growing will face pressures from higher temperatures and changing rainfall patterns (Ortiz, 2012).

Salvacion (2019) determined climate change from 1991-2016 in the Philippines and results showed that there was 2559 mm/year in average annual rainfall with a minimum of 970 mm/year and a maximum of 5848 mm/year. Trends in other climatic conditions were also measured and showed only 10% of the banana-producing areas in the Philippines are significantly affected by climate. Among climatic variables, temperature seasonality has more impact than rainfall on provincial-level banana yield in the country. The northern part was observed to have the highest annual rainfalls than in other parts of the country while a higher frequency of wet days (FWD) was observed in the Southeastern part of the country with an average of 176 days in FWD, with a minimum of 97 days, and a maximum of 284 days.

Generally, there is an inverse relationship between climate change in general and the volume of production. Climate change is already going towards wetter wet seasons and drier dry seasons soon. This can harm plantations like bananas that need a warm or high temperature to produce (Chou et al., 2013). With that, it is fundamental to measure the impact of climate change at the most disaggregated regional level possible because the effects of climate change are heterogenous regionally and among economic sectors (Tanure et al., 2019). Therefore, as climatic factors change in the long term, a host of consequences will ripple through the agricultural system as humans respond with decisions involving farm management, storage facilities, transportation infrastructure, regional markets, and trade patterns (Salau et al., 2016).

I. Relationship of Temperature and Banana Production

Salvacion et al. (2019) pointed out that an increase in temperature will favor areas that have lower temperatures than the optimum for growing bananas while a negative effect is expected on regions with climate hotter than the optimum. Depending on market demands, the temperature is used during ripening to control the desirable combination of peel color, pulp texture, and eating quality of bananas (Nunes et al., 2013). There will be damage to the plant and fruit when bananas are exposed to high temperatures while the growth and its quality may be affected by low temperatures (Ortiz, 2012). This is supported by the study of Ravi & Vaganan (2016) in which the authors mentioned that the growth and development of bananas are highly influenced by temperature. Extreme, higher, and lower temperatures have a negative influence on the growth and development of bananas.

A study by Dell et al. (2012) revealed that higher temperatures have wide-ranging effects, reducing agricultural output. An increase in extreme temperature in plantations will also not simply affect the level of output but also the growth rates and crop conditions. It could also affect soil quality, health, and water tables that would cause long-term effects and larger impacts to the agricultural sector. In another study conducted by Solomon et al. (2007), it was discussed that agricultural production is reduced in some regions due to extreme levels of temperature. Higher temperatures lead not only to a decline in agricultural output but also to the political instability of a country that could potentially reduce economic growth rates especially in poor countries (Dell et al., 2012). Similar to this is the study by Salau et al. (2016) in which the authors also revealed that extremely high temperatures can reduce banana productivity while low temperature with poor humidity will result in a small production. On average, the mean temperature of about 26°C- 27°C- with a relative humidity of approximately 77% will lead to a good annual production.

Research by Salvacion (2019) stated that bananas are susceptible to hot weather conditions and are usually found in tropical countries, however, as mentioned, high temperatures can damage banana plantations and hinder their production. The Philippines is usually experiencing extreme droughts which are caused by El Niño that damages crops and affect food security in the country. The study showed that extreme, higher, and lower temperatures harm banana growth and development. The optimum temperature for banana growth is only around 27°C and anything higher than that can harm the growth and production. While in determining the significance of variables, banana production was used to calculate the provincial level yield data from 1991 to 2016. The data that was collected was gathered from the Philippines Statistics Authority and any province that is missing 5 years of data was excluded from the analysis. As for climate data, Climate Research Unit Times Series (CRU-TS) data were used to determine the monthly rainfall (mm), monthly maximum and minimum temperature (C), and monthly frequency of wet days (days) per region. Based on the results, in the Philippines, higher monthly temperature variation within the year favors banana yield in the province of Bohol while the opposite occurs in the province of Capiz. The study further proved that significance between variables was observed and among the climate conditions, the temperature has the highest effect on banana production; the temperature has a greater impact on banana yield compared to rainfall. This result is similar to the study of Tanure et al. (2019) in which they found that in Brazil, there is an inverse relationship between temperature and volume of production. He projected that the increase in average temperature during the years 2030 and 2049 will result in agricultural productivity loss. He also added that beyond that, it will also affect the economy, impacting GDP, employment, income, consumption, migration flows, and food security. Brown et al. (2018) added that the predicted increasing temperature due to climate change is also projected to increase the frequency of weather events which are moderate or extreme deviations from average – more droughts, more intense, less frequent rains, cold snaps, heat waves, and more violent storms. Such events have serious implications for the productivity and profitability of bananas. While based on findings of Shayanmehr et al. (2020), using two different models namely linear and non-linear models, the result showed that using a linear model, the result shows that minimum temperature is negatively related to average yield while using the nonlinear model, the relationship of minimum temperature and average yield is positive. In contrast, maximum temperature gives positive effects on the yields in the linear model and negative effects in the non-linear model.

However, with all of these findings, Calberto et al (2015) mentioned that bananas will still thrive even under higher temperatures associated with climate change. Desk studies on projected temperature and rainfall changes confirm that land areas suitable for banana production will likely increase over the next decades with only a few areas crossing the upper-temperature threshold by 2070. Similarly, De-Graft and Kweku (2012) use the Just-Pope Production function to evaluate the impact of climatic variables on yield in Ghana. Based on the result of their study, it reveals that the level of yield is positively related to temperature.

On the other hand, in relation to the occurrence of diseases, a change in temperature may favor the development of different inactive pathogens, which could induce an epidemic (Charkraborty and Datta, 2003). Higher temperatures will increase pest and disease risks in some plantations. Some diseases thrive during hot climates and make it easier to infect close crops (Knox et al., 2021). This is also supported by Zayan (2019) who pointed out that high levels of temperature can cause infection and the spread of disease among crops. The yields will decline if the temperature exceeds the crop's optimum temperature and worse, the existence and infestation of pathogens might occur. Climate change can cause interaction in crops and pathogens, certain levels of temperature cause the host/crops to have higher resistance to plant diseases, changes in weather conditions and patterns, and the limit of water availability can hurt agricultural production. Also, soil causes crops to lose their biological function and become prone to certain diseases and pests that are caused by insufficient water levels and dryness due to extreme temperature.

J. Relationship of Rainfall Amount and Banana Production

In certain parts of Southeast Asia, for instance, in the Philippines, high amounts of rainfall are either beneficial to farmers for their plantations or harmful since it can damage their crops, depending on when it will occur (Crost et al., 2018). This is supported by Ramirez, et al. (2011) who pointed out that in a specific place, an increase in rainfall can be positive to those areas with limited rainfall while negative to those areas receiving higher than optimum. Roberts et al. (2009) conducted a study to determine when above-average rainfall is beneficial to the county. It showed that above-average rainfall for May to October showed a negative effect on agricultural production and a positive effect during November to April since this is considered the dry season in the country. During the wet season, farmers are faced with challenges in flooding and extreme weather events like typhoons since crops are at greater risk during this period. On average, the country experiences 20 storms per year and usually makes landfall on Eastern Visayas and Northern Luzon, above average in this season is linked with lower agricultural production. In contrast, in the dry seasons, the crops pose a greater risk due to doubt which results in a higher agricultural production brought by above-average rainfall in this season.

Crost et al. (2018) conducted a study regarding climate change and agricultural production in the Philippines. In this study, it was stated that rainfall by season has a significant effect on the country's agricultural production. They examined the effect of rainfall by season on agricultural production as well as in civil conflict in the country. Agricultural data were gathered from the Philippine Bureau of Agricultural Statistics and is publicly available through the CountryStat database; rainfall measurements per province were constructed using the Tropical Rainfall Measuring Mission's 3B43 algorithm. It provides monthly participation using various microwave satellite estimates and rain gauge estimates. Based on their findings, they found that the forecasted shift towards drier dry seasons and wetter wet seasons will cause harmful effects to agriculture which will also strengthen the civil conflict. The relationship between rainfall and agricultural production seasonality was confirmed and claimed that rainfall is linked to civil conflict and affects agriculture. Similarly, Salau et al. (2016) revealed that excessive rainfall can reduce banana productivity and production is also small when rainfall is very low with poor humidity. They further added that average rainfall of around 1891mm with a relative humidity of approximately 77% will lead to a good annual production. Apart from that, Dell et al., (2012) also added that changes in precipitation have relatively mild effects on national growth in both rich and poor countries. While Alboghdady and El-Hendawy (2016) showed that precipitation variability during summer seasons had a negative impact. However, in contrast to this, De-Graft and Kweku (2012) pointed out that the level of yield is positively related to precipitation.

On the other hand, plants respond to drought stress through alteration in physiological and biochemical processes (Devi et al., 2013). Bananas are sensitive to water shortages and waterlogging (Ortiz, 2012). The study of Knox et al. (2021) determines the significance between increasing water stress and banana production. Banana cultivation and management are based on the climate conditions of a region to provide the crops the attention that it needs. The study presented water scarcity as a major threat to global agriculture and showed water shortage in some areas resulting in reduced crop yield. Devi et al. (2013) made a similar study and found that water deficit in plantations can reduce growth attributes in all stages. A deficit of 100 mm monthly rainfall during the banana crop cycle can reduce bunch weight up to 9%, and regions with less than 1100mm per year can cause losses between 20–65 % compared with other years that experienced more rainfall. Soil water deficit limits plant growth and field crop production more than any other environmental stress (Zhu, 2002; Almeselmani et al., 2011). It remains an ever-growing problem that severely limits banana production worldwide and results in significant horticultural and agricultural losses specifically in dry and semi-dry areas (Kallarackal et al., 1990). Bananas are found to have high demands of water to obtain maximized production and it was discovered that a water shortage can cause a delay in the growth of plantations. Knox et al. (2021) mentioned that commercial and smallholder production is affected by increasing rainfall variability and competition for water resources; it yields losses of up to 65 % due to loss in bunch weight in moderate to low rainfall areas.

In relation to the occurrence of plant diseases, Perez-Vicente et al. (2014) stated that a decrease in rainfall during the driest and wettest quarter can cause deficit water stress condition making the plant highly susceptible to intense disease infection while an increase in precipitation during the warmest quarter can provide condition (warm and wet) that is conducive for disease infection (Salvacion et al., 2019).

K. Relationship of Relative Humidity and Banana Production

The study conducted by Salau et al. (2016), shows that the banana production is high at moderately high humidity while the production declines as the relative humidity reduce. Poor humidity, associated with low rainfall and temperature will result in the low quality of bananas. Turner (1983) added that within 25°C to 30°C in a preferably tropical humid lowland, bananas will grow well.

The low relative humidity is pointed to as one of the factors that cause banana finger drop. Finger drop is defined as the weakening of the pedicel that causes the banana to fall from the crown and limits its shelf life (Ketsa, 2007). The study of Semple & Thompson (1988) discovered that banana fruit is usually ripened at a relative humidity (RH) of more than 90%, which will prevent early browning and splitting of the peel. Once the required humidity does not meet, it can cause bananas to ripen faster that will hurt the growth and production of the plantations. Saengpook et al. (2007) also made a study between relative humidity and finger drop in bananas and discovered that there was a significant relationship between variables. The resistance of bananas to a finger drop is seen in high levels of relative humidity than in bananas at low relative humidity. Another study by Blankenship and Hederman (1995) that is aligned with the study of Saengpook et al. (2007) pointed out that relative humidity on the quality of bananas, during production, the temperature should be more than 15 ◦C to control the relative humidity in the area. Weight loss and the condition of banana peels are the only variables that are affected when tested with different levels of relative humidity.

L. Relationship of Panama disease and Banana Production

Any disruption to production caused by plant diseases will impact the economy and society, with far-reaching implications beyond simple production losses (Ghini et al., 2011). Numerous pests and diseases pose constraints to yields (Ortiz, 2012). According to Strange & Scott (2005), 10% of the losses on global food production are caused by pests and diseases which are a threat to food security. Agrios (2005) estimated that annual losses by disease cost $220 billion; these should be added to 6–12% losses of crops after harvest, which is particularly high in developing tropical countries lacking infrastructure. Bananas have been the source of food and income in some countries. As mentioned in the previous section, in the Philippines, banana is the leading fruit grown and remained the top dollar earner with an estimated total production of 8, 884.63 thousand metric tons (mt) in 2014 (PSA 2015). However, in the last few years, pests and diseases are hindering banana cultivation and expansion in some regions causing production constraints. One of these is Panama disease (Fusarium oxysporum f. sp. cubense) (Ploetz et al., 2003) which is considered the most devastating disease that affects banana production and distribution in plantations. Panama disease is also a threat in the banana export sector becoming a historical footnote. This disease once caused Gros Michel cultivar in the banana industry to be extinct and now this disease made its way back to Cavendish cultivar. Tropical Race 4 (TR4) once again threatens banana production and exportations in the global market (Dela Cruz and Jansen, 2017). A similar idea was discussed by Salvacion et al. (2019) in which it was mentioned that coincidence between areas with high and medium suitability for bananas and occurrence of Fusarium wilt can pose a significant impact on the banana industry in the country (Salvacion et al., 2019). A study by Soluri (2002) mentioned Claude Wardlaw during his tour in Central America in 1927, Claude mentioned that as Panama disease spreads throughout the soil, this will lead to the abandonment of farms. Therefore, there will be a decrease in output. Apart from that, the cost associated with the disease will also affect the ability of local growers to supply the market (Cook et al., 2015).

Furthermore, Solpot et al. (2016) explain that there is a negative relationship between Panama disease and banana production. They also discovered that fusarium wilt is present in both small- and large-scale plantations in areas where banana production is expanding. Information on Panama in regions was gathered through survey and collection of bananas that showed symptoms of the said disease in SOCCSKSARGEN and some areas of Davao del Sur and Maguindanao. Moreover, similar results were suggested by Salau et al. (2016) in which the occurrence of pests and diseases resulted in declining banana production. Both studies revealed that Panama disease and volume of banana production show a negative relationship (Solpot et al., 2016 and Salau et al., 2016).

In relation to the international market, the spread of the fungus not only decimates affected plantations but might restrict export markets in the future, thereby affecting the income of producers (FAO, 2017a). If fusarium wilt continues to spread in banana plantations, this can pose a serious threat to the banana industry. TR4 has a wide host range and can infect different host cultivars of bananas particularly those intended for export and local consumption (Solpot et al. 2016).

M. Relationship of Government Support and Banana Production

A subsidy is a way of helping farmers to overcome financial constraints. This may also increase technical efficiency through advancements in technology (Zhu & Lansink, 2010). In terms of inputs support from the government which includes seeds, fertilizers, and other equipment subsidies, these inputs resulted in an increase in agricultural production (Bardhan & Mookherjee, 2011; Andri et al., 2011; Muncan & Bozic, 2013; Hosseingholizadeh, 2014; Yi et al., 2015). When agricultural input subsidies like fertilizer are provided, this leads to an increase in the income of farmers (Mason & Smale, 2013; Yin et al., 2014). In contrast to this, Lu & Guan (2017) found a negative relationship between input support and production due to inefficient use of resources in the subsidy program. While Onumah (2014) found that input subsidies have no effect on production. In terms of financial support which includes cash subsidies, insurance aid, loan aid, etc., these financial supports are associated with an increase in crop production (Lencucha et al., 2020). This is also supported by Laiprakobsup (2019) in which the author claimed that government subsidies give farmers more incentive to increase their productivity.

Specifically, in the banana industry, Clegg (2002) discussed the importance of government support to banana cultivation, shipment, and distribution to Europe. Government assistance even caused a rapid expansion of the banana industry and made it the most significant export commodity in the region. Financial assistance of tens of thousands of pounds was given by the government for items such as disease control, fertilizers, and training of agricultural officers in banana cultivation and production. The contribution of government support and private industries caused an increase in banana production and exports.

Strong government support in bananas resulted in the availability of funds, land, and other government support necessary to boost the industry. In the Philippines, government agencies have been regularly providing support services to enhance the market orientation and competitiveness of banana farmers. The results showed that there has been an increase in areas planted with bananas (Cavite and Abamo, 2017). It is similar to that of Malaysia. Despite the challenges associated with their banana industry, banana cultivation stays due to the positive support of the government (Molina and Roa, 2000). Based on a survey method collected from fifty banana farmers in Indonesia, the results revealed that access to government support had helped them in growing bananas, leading to a higher production of bananas compared to those who did not have access to similar government support (Wulandari et al., 2017).

N. New Solutions to Carry Out in the Environmental and Economic Sphere

Several authors proposed their own recommendations and solutions to improve agricultural and living conditions in regions of the Philippines. Salau et al. (2016) suggested strengthening agricultural policies in plantations to prepare them for future climatic conditions and weather patterns. Farmers should have adequate education and equip them with the capacity to cope with climate change, information should be easily available, and provide them with solutions to improve crop production (Debela et al., 2015). Improving irrigation in plantations with the proper use of fertilizer can help control the crop conditions and prevent the disease from spreading from one crop to another. Production of bananas will also increase under well-monitored weather conditions. Transportation and storage of harvested bananas should be under controlled temperature and humidity to prevent the rotting of peals. Chandra et al. (2016) made similar recommendations to improve crop areas that are vulnerable to climate change. They stressed that plantations that are involved with the effects of climate change should be addressed immediately through broader coverage of insurance, subsidy, and other compensation support for vulnerable farmers. Insurance should not be given to major crops like corn and rice, but rather should be distributed to commodities. In doing this policy, small and marginal farmers are safe from bigger risks and potential losses from damaged crops and plantations. In a study made by Cole et al. (2012), the Agri-Agra Reform Credit (2009) scheme and Micro-insurance Regulatory Framework (2010) were called for reform by the government. This gives farmers financial support that helps them improve agricultural plantations, and private sectors are given the opportunity to invest in agricultural insurances. If climate change will worsen in the future and farmers are not equipped with the necessary information, this could hurt the county's food supply and security. While Brown et al. (2018) mentioned that to prevent climate impact in the agricultural sector, they suggested irrigation for droughts to block flood waste contaminating crops. Improved drainage will cause water to evacuate more quickly than blocking entry into the field. Therefore, understanding the impacts of climate change on agricultural production can help policymakers to come up with appropriate policies to improve production and are expected to support and develop crop resistance from expected levels of temperature.

In terms of crop disease, Coakley & Scherm (1996) said that soilborne pathogens will remain more difficult to control than foliar pathogens because of fewer management options. Pathogens that are soilborne can survive for years and will infect future plantations. Quarantine measures on soils are essential in controlling the disease. Ghini et al. (2011) also stressed that quarantine measures have an important role in controlling pests and prevent the spread in new areas. The latest study by Dita et al. (2013) stated measures to prevent the spread of fusarium wilt in banana plantations. Scientists are still developing a cure for fusarium wilt in bananas, and the only way in

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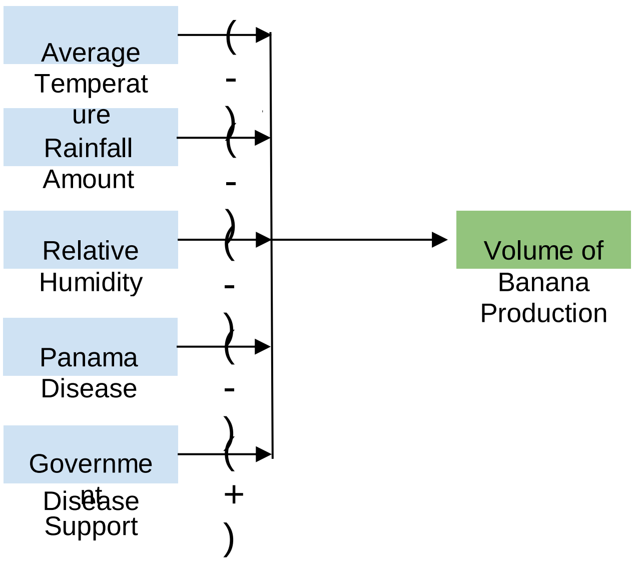
preventing the spread of the disease in plantations is to burn the crop which is time-consuming and costly. They discussed that prevention is better than cure, pre-border and on-border to on-farm measures should be conducted to spot infected crops. Awareness and farm biosecurity is essential in maintaining a productive plantation.

O. Hypotheses Statement

H_0: Climate change variables and Panama disease have no significant impact on the volume of banana production in the Davao Region, Philippines.

H_0: Government support has no significant impact on the volume of banana production in the Davao Region, Philippines.

P. Simulacrum



III. METHOD

A. Method, Statistical Tools, Regression Model, and Statistical Treatment

The variables used in the study are (1) climate change; (2) Panama disease; (3) government support; (4) volume of banana production. Climate change is determined through the following independent variable indicators: (1) average temperature, (2) rainfall amount, and (3) relative humidity. Panama disease is an intervening variable that is represented by 0 in its absence, and 1 in its presence. The government support is determined through the allocation of government funds in the high-value crops in the Davao region. The volume of bananas produced is the dependent variable.

The quantitative method of research was used to find patterns and make analyses. The study also applied a correlational research design to measure and test the relationships between the dependent and independent variables. Through statistical techniques, this study found out whether there is a positive, negative, or zero correlation among variables. This method of research was used by different authors like Cinco (2014), Villafuerte et al. (2014), and Salvacion (2019). Salvacion (2019) used this research design to assess the effect of climate on banana yield in the Philippines by conducting time-series and regression analysis.

Moreover, this study was conducted on a regional scale, particularly in the Davao Region in the Philippines since it is the top banana producer in the country (PSA, 2020). It composed of the following provinces: (1) Davao del Norte, (2) Davao del Sur; (3) City of Davao; (4) Davao Oriental; (5) Compostela Valley; and, (6) Davao Occidental which were assessed as a whole. This study has a scope of 30 years ranging from 1990-2019. The period covered by this study is due to the limited availability of data.

Secondary data that were gathered from different government agencies are essential to adequately capture past climate patterns and their effect on banana production in the study area, in this case, the Davao Region, Philippines.

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The data on climatic indicators such as average temperature, rainfall amount, and relative humidity, were obtained through data request to the official website of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA): Climate and Agrometeorological Division (CAD). The historical climate data ranges from 1990-2019 (30 years) in a yearly measure of average temperature (°C), rainfall amount (mm), and relative humidity (%). In this study, seasonal variations were not taken into account. Hence, a limitation of the study.

The data on the government support was obtained through the official website of the Department of Budget and Management (DBM). This was measured through the budget allocated by the government and it ranges from 1990-2019 (30 years) in pesos.

The data on the volume of banana production was accessed through the official website of the Philippine Statistics Authority (PSA): Crops Statistics Division. It ranges from 1990-2019 (30 years) in metric tons.

The data on the presence of Panama disease in the Davao Region was requested from the Department of Agriculture: DA 11- High-Value Crops Development Program (DA XI- HVCDP) which was measured by 0 in its absence, and 1 in its presence.

In this study, a multiple regression analysis was performed to identify and analyze the relationship between the dependent variable (volume of banana production) and independent variable indicators (average temperature, rainfall amount, relative humidity, Panama disease, and government support). Through a multiple regression equation, the coefficients described the correlation between the dependent variable and independent variables which allowed the researchers to determine the strength of the outcome and of each predictor variable and the significant impact of each predictor on the dependent variable.

Multiple regression analysis was applied by Lobell et al. (2007), Lobell (2009), Cinco (2014), Villafuerte et al., (2014) and Salvacion (2019). Specifically, this study adapted the multiple regression model by Salvacion (2019).

$$\text{Volume of Banana Production} = \beta 0 + \beta 1 \text{ average temperature} + \beta 2 \text{ rainfall amount} + \beta 3 \text{ relative humidity} + \beta 4 \text{ Panama Disease} + \beta 5 \text{ Government Support} + e$$

where Y is the volume of banana production, X is different climate variable indicators (average temperature, rainfall amount, and relative humidity) with an intervening variable (Panama disease), government support, and an error term which shows what the model does not fully represent on the actual correlation between the dependent and independent variables.

Heteroskedasticity is a condition where the parameters and standard errors are said to be biased and inefficient when the variance of the regression residuals of the model is time-varying. If it is uncorrected, it could lead to wrong conclusions and decisions. To detect the presence of heteroskedastic disturbances in the residuals, the White Heteroskedasticity Test and Breusch-Pagan Test will be used.

ARCH or Autoregressive conditional heteroskedasticity is a statistical model for time series data that is used to analyze volatility to forecast future results. This was designed to improve different econometric models by replacing assumptions of constant volatility with conditional volatility. The variance of the current error term or innovation was used as a function of the actual size of the previous time periods' error terms.

The normality of residuals is the assumption that the underlying residuals are normally distributed. The null hypothesis will be rejected when the p-value is less than the level of significance and thus, the residuals are not from a normal distribution. While the null hypothesis will be accepted when the p-value is greater than the level of significance.

Autocorrelation is a mathematical representation of a given time series and a lagged version of itself over successive time intervals in the degree of similarity. This refers to the degree of correlation of the values of the variable's current value and its past values in the data. The Durbin-Watson test is the most common method of autocorrelation test that detects autocorrelation from a regression analysis.

Specification error test is manipulating the model by including irrelevant variables, excluding relevant variables, or the functional form of the model. The test creates bias or inconsistency in regression estimators, and the inconsistency can still be present even when sample observation increase

B. References

- example of a journal article in [2,4,5,8]
- example of a website in [19]
- example of a master’s thesis in [118]

IV. RESULT AND DISCUSSION

Table 4.1 shows the summary statistics for all the variables from 1990-2019. In terms of temperature, the mean temperature for the past 30 years is 28.17°C. The maximum temperature recorded during this period is 29.3°C, recorded in 2016 and the minimum is 27.6°C recorded in 1995 and 1996. The 2016 average temperature was 29.3°C, an increase of more than 1 degree since the 1990 average of 27.9°C.

In terms of rainfall amount, the mean annual rainfall was 1834.9 mm. The highest annual rainfall was 2671.3 mm in the year 2017 and the year that received the least annual rainfall was 1992 with 1176.3 mm.

In terms of relative humidity, the mean relative humidity for the past 30 years is 80.63%. The maximum relative humidity recorded during the observed periods is 85%, recorded in 2011 and the minimum is 76% recorded in 2018 and 2019.

The favorable climate for bananas is a rainfall of approximately 1500-2500mm, mean temperature of 27°C, and within 25°C to 30°C (Turner, 1983). On average, the mean temperature of about 26°C and an average rainfall of around 1891mm with a relative humidity of approximately 77% will lead to a good annual production. The results of data shows that all values resulted to be within the range of good annual production– that also remained consistent in the past 30 years. However, there are noticeable differences in the average rainfall amount in which the average annual amount was less than the preferred amount of around 1891mm. This may impact the production of crops in the region, particularly the production of bananas since it requires large amounts of water throughout their growth and is sensitive to temperature changes. Large plantations have irrigation systems and this may not be a big issue for them. However, small farmers who rely on rain to water their crops could pose a severe constraint to their production due to water deficit and heat stress. While the data showed that the temperature has increased, the temperature in Davao region may not likely have imposed a major constraint to banana production since it still falls in the range for optimal growing. However, increasing temperature could have had an impact on the quality of the fruit, especially in sugar development and ripening (Ramirez et al., 2011). Increase of temperature in the future could push current temperatures higher to the levels where heat stress and injury to fruit can take place. As listed in Chapter 2, when the temperature is high, it has an impact on the crop at different points in its growth, which includes the stage of harvest and during packing where cooling systems are required to prevent fruit from ripening prematurely before distribution. Higher temperatures could also affect the prevalence and range of banana pests and diseases.

In terms of government support, there has been an upward trend for the past 30 years. The highest government support recorded during the observed period is in 2016 and the lowest recorded is in 1993.

In terms of banana production, the mean volume of banana production for the past 30 years is around 2,529,400mt. The maximum volume of banana production during the covered periods is around 3,854,800mt, recorded in 2011 and the minimum is around 1,045,100mt recorded in 1990. Historical data shows that the volume of banana production is increasing over time. A significant change in the banana industry occurred during the administration of President Gloria Macapagal-Arroyo, from 2001 to 2010 (Hasanah, 2019).

Table 1. Summary Statistics
Observations: 1990-2019

Variable	Mean	Median	Minimum	Maximum	Std. Dev
Average Temperature	28.167	28.100	27.600	29.300	0.41384
Rainfall Amount	1834.9	1817.1	1176.3	2671.3	344.91
Relative Humidity	80.633	81.000	76.000	85.000	2.2967
Panama Disease	0.36667	0.00000	0.00000	1.0000	0.49013
Government Support	6.4623e+007	2.9604e+007	7.4745e+006	3.7844e+008	9.5032e+007
Banana Production	2.529e+006	2.491e+006	1.045e+006	3.855e+006	9.9307e+005

Using the Ordinary Least Squares, Table 2 shows the regression results. The annual volume of banana production in the Davao Region served as the dependent variable while the independent variables used are the average temperature, rainfall amount, relative humidity, Panama disease, and government support from 1990-2019. The p-value of constant, average temperature, and relative humidity are significant at 0.01 alpha which means that they have a 99% level of significance to the volume of banana production. The p-value of rainfall amount is significant at 0.05 alpha which means that it has a 95% level of significance to the dependent variable. Meanwhile, the Panama disease and government support are insignificant. The coefficient of determination (R2) was 0.82, which relates to a strong relationship between the independent variables and the volume of banana production. The Durbin Watson has a value of 1.11; the p-value of Durbin Watson is 0.000633368 which is less than the alpha of 0.05. The negative relationship between the climate variable indicators and the volume of banana production might be due to the increase in both typhoons and droughts in the region that significantly affected the volume of production of bananas. For instance in 2012, Typhoon Pablo was the strongest cyclone that hit the Philippines which caused widespread destruction and Davao Region experienced the most damage.

Moreover, statistically, all climate variable indicators with a dummy variable (Panama disease) and government support have negative relationships with the volume of banana production. However, it also shows that only climate variable indicators have a negative significant relationship with the volume of banana production. This is supported by the studies of Ghini et al. (2011), Sabiiti et al. (2016), and Salau et al. (2016). Specifically, in terms of temperature, Ravi & Vaganan (2016), Salau et al. (2016), and Salvacion (2019) mentioned that higher temperatures will affect the growth of bananas. There is only a specific optimum temperature required (Dell et al., 2012; Ortiz, 2012; Salau et al., 2016; Salvacion, 2019). Calberto et al. (2015) mentioned that on average, the mean temperature of about 26°C will lead to a good annual production. In terms of rainfall amount, the findings of this study contrasted the study of Tanure et al. (2019), Ramirez, et al (2011) and Devi et al. (2013) which showed that there is a direct relationship between rainfall and banana production especially in areas with limited rainfall amounts. Bananas are found to have lower growth attributes at all stages due to water deficit. While the study of Salau et al. (2016) found that excessive rainfall can reduce banana production. The ideal rainfall amount for a good annual production is ideally around 1891mm or approximately 1500-2500mm (Banana Production Manual, 2001). In terms of relative humidity, this study contrasted the findings of Saengpook et al. (2007) and Salau et al. (2016) that there is a positive relationship between relative humidity and the volume of banana production. On the other hand, Salau et al. (2016), Solpot et al. (2016), Dela Cruz and Jansen (2017), and Salvacion et al. (2019) found that there is an inverse relationship between the occurrence of Panama disease and the volume of banana production whereas, in this study, the researchers have found no significant relationships between the two variables. The same results applied with the relationship of government support and banana production although Bardhan & Mookherjee (2011), Andri et al. (2011), Muncan & Bozic (2013), Hosseingholizadeh (2014), and Yi et al. (2015) found that government support has a positive relationship with the volume of banana production. The insignificance of relationships of these two independent variables must be further analyzed and studied in the future.

The negative significant relationship among climate variable indicators and the volume of banana production is due to the following reasons: 1) bananas are sensitive to changes in climate and it requires specific optimum temperature, water amount, and relative humidity to grow. A decrease in banana production shows the increase and/or presence of climate change, as explained in the previous analysis; 2) because the threat of climate change in the agricultural industry is foreseeable, as is the rising presence of pests and illnesses in the region, the region faces great challenges in maintaining its position as the top banana producer both domestically and globally.

While the insignificant relationship between the panama disease and government support to the volume of banana production may be due to other other factors that were not able to be controlled by this research. For instance, the presence of data constraints in panama disease. In the past 30 years, there has been a stagnating trend in government support and a high peak for only a few years. Therefore, more research is needed to reconcile these differences.

As a whole, this partially rejects the first null hypothesis that climate change variables have no significant impact on the volume of banana production in the Davao Region, Philippines, and partially accepted that including Panama disease, it has no significant impact on the volume of banana production in the Davao Region, Philippines. This accepts the second null hypothesis that government support has no significant impact on the volume of banana production in the Davao Region, Philippines.

Table 2. Regression Results
Dependent Variable: Volume of Banana Production
Sample: 1990- 2019

Variable	Coefficient	Std. Error	t-Ratio	P-value
Constant	-118.769	25.5582	-4.647	0.0001***
Rainfall Amount	0.679782	0.254893	2.667	0.0135**
Average Temperature	25.8226	5.89508	4.380	0.0002***
Relative Humidity	9.54348	2.01875	4.727	8.30e-05***
Panama Disease	0.165160	0.139209	1.186	0.2471
Government Support	0.0103145	0.0760765	0.1356	0.8933

R-squared	0.823597	Mean dependent var	14.65628
Adjusted R-squared	0.786847	S.D. dependent var	0.442606
S.E. of regression	0.204345	Akaike criterion	-4.834841
Sum squared resid	1.002161	Schwarz criterion	3.572343
Log-likelihood	8.417421	Hannan-Quinn	-2.145311
F statistic	22.41049	Durbin-Watson	1.112851

Since Table 2 shows that the two independent variables are insignificant to the volume of banana production, further regression results were obtained to maintain the precision of the model. Table 3 shows the new regression results. It shows that all independent variables, namely average temperature, rainfall amount, and relative humidity are significant at 0.01 alpha, which means that they have a 99% level of significance to the volume of banana production. The coefficient of determination (R2) was 0.81, which relates to a strong relationship between the independent variables and the volume of banana production. The Durbin Watson has a value of 1.37; the p-value of Durbin Watson is 0.0148885 which is less than the alpha of 0.05. Moreover, statistically, all climate variable indicators have negative significant relationships with the volume of banana production. This rejects the null hypothesis that climate change variables have no significant impact on the volume of banana production in the Davao Region, Philippines.

Table 3. Regression Results
Dependent Variable: Volume of Banana Production
Sample: 1990- 2019

Variable	Coefficient	Std. Error	t-Ratio	P-value
Constant	-142.481	17.2479	-8.261	9.64e-09***
Rainfall Amount	0.825984	0.220435	3.747	0.0009***
Average Temperature	31.5187	3.38040	9.324	8.92e-010***
Relative Humidity	10.4189	1.85250	5.624	6.53e-06***

R-squared	0.811314	Mean dependent var	14.65628
Adjusted R-squared	0.789542	S.D. dependent var	0.442606
S.E. of regression	0.203049	Akaike criterion	-6.815324
Sum squared resid	1.071947	Schwarz criterion	-1.210534
Log-likelihood	7.407662	Hannan-Quinn	-5.022304
F statistic	37.26495	Durbin-Watson	1.365479

Table 4 shows the diagnostic results of the regression. P-values are greater than 0.05 alpha which means that the null hypothesis is accepted. It shows that heteroskedasticity is not present using White's test and Breusch-Pagan's test. There is no ARCH effect present, the error is normally distributed, no autocorrelation error, and no specification error test using Ramsey's reset test.

Table 4. Diagnostic Test Results

White's Test for heteroskedasticity	Null hypothesis: heteroskedasticity not present Test statistic: LM= 4.8039 With p-value= 0.851057
Breusch-Pagan test for heteroskedasticity	Null hypothesis: heteroskedasticity not present Test statistic: LM= 0.46021 With p-value= 0.927542
Test for ARCH	Null hypothesis: no ARCH effect is present Test statistic: LM= 1.03432 With p-value= 0.309145
Test for normality of residual	Null hypothesis: error is normally distributed Test statistic: Chi-square (2) = 1.49999 With p-value= 0.472368
LM test for autocorrelation	Null hypothesis: no autocorrelation Test statistic: LMF= 1.02854 With p-value= 0.320218
Reset test for specification	(squares and cubes) Test statistic: F= 2.968926 With p-value= 0.0705 (squares only) Test statistic: F= 0.789209 With p-value= 0.383 (cubes only) Test statistic: F= 0.821688 With p-value= 0.373

V. CONCLUSION

The Davao Region Industry Clusters Roadmap shows that the banana industry is the recommended priority of LGUs and NGAs. Some of the major constraints on the banana value chain are the issues and concerns regarding weather factors, banana diseases, and access to financing. The results show that climate variable indicators namely average temperature, rainfall amount, and relative humidity have a negative significant relationship to the volume of banana production. Meanwhile, Panama disease and government support have been found to be insignificant to the dependent variable.

Socio economic impacts of climate change could be substantial especially to agricultural productivity, depending on the increase of temperature and crop location. Economic losses are expected as climate change progresses particularly in the tropics and high latitudes. Changes in climate could potentially increase the incidence of drought and flood events that leads to a decrease in livestock production and agricultural productivity, particularly among subsistence farmers in tropical regions. Another impact that is caused by climate change to the socio economic system is the decline in labor productivity. The increase of temperature can cause heat stress among farmers that affect economic activities, loss of production that will lead to economic loss. Poverty among farmers is another socio economic impact of climate change. Climate change has the potential to disrupt crop productivity and affect domestic agricultural production, consumption, and food security. With typhoons brewing up and rising temperature at a more erratic pace, Filipino farmers find it harder to produce food for the nation. Farmers are also expected to shoulder financial losses or take up loans which will be the last resort.

Moreover, there is not enough national climate change research agenda, nor is there appropriate research information, expertise, scientific guidelines, standards, or indicators for monitoring climate change and identifying associated hazards to different crops. The initiative to create a well-organized national and local climate risk information network aimed at farmers and other important sector stakeholders has stagnated.

Farmers can then adapt to climate change once they successfully know and perceive that there are environmental changes happening. Even though farmers have the ability to adapt autonomously to environmental changes, it may still happen that climate change brings conditions out of the farmer's normal range of experience. Therefore, sufficient support and knowledge sharing for adaptation needs to happen successfully in order to prepare local communities for climate change. Climate-proof systems are in everyone's interest for better growth and sustainability of crops. There is a need to understand how local farmers can adapt. It is found that there are profound impacts on the global markets and production if there are no changes in banana production. Plant breeding should be considered to select and breed cultivars that are found with higher resistance to diseases, heat, and drought to overcome the negative impacts of climate change to the banana sector, while high productivity under the conditions of more variable water supply should be maintained.

Irrigation is also not an option for everyone and the water supply may change in the next few years. During dry months, irrigations are unavailable, especially for small growers. Water-saving techniques like mulching or rainwater collection are important for seasons with less rainfall. A common technique used by many farmers to increase and expand their production is intercropping; this allows other crops to benefit from one another. On hot sunny days, intercropping with coconuts and durian will help decrease local temperatures and provide shade for other crops. As for commercial farmers, there is a need for irrigation systems to be maintained and optimized to use water wisely. There is a window for adaptation to occur: the Philippines and Davao region should include climate change adaptation in the development of plans and policies. There is a need to conduct further studies and research to elaborate the climate risk on the production of bananas in the country.

The research findings helped to solve socio economic issues such as threats in banana production which can affect the country's total production and market position globally due to climate change. Davao region is enormously challenged to carry on its identity as the top producer of bananas domestically and globally due to the threat of climate change in the agricultural industry that is absolutely inevitable with increasing occurrence of pests and diseases in the area. With this, there is a need for the creation of a strong relationship between the farmers and the government and vice versa. There are some opportunities for the farmers that are overlooked like the protection of production areas as to the implementation of peace and order in the community. With that, the DA could conduct more training on Good Agricultural Practices (GAP) to give proper education to farmers on how to manage damaged crops and handle them. This can achieve inclusive growth and reduce poverty among farmers.

There are various programs that evaluate climate-related issues. For instance, the Climate Change Commission continues to monitor climate action at the national level, publishing papers such as the Monitoring and Evaluation Report and the National GHG Inventory. It has also strengthened its monitoring capacity with the improvement of the National Integrated Climate Change Database and Information Exchange System (NICCDIES). At the local level, the Project Climate Twin Phoenix is a comprehensive and long term capacity development program for cities and municipalities to manage climate change risks in the impacted areas in Mindanao's Regions 10 and 11. The project will fund an information, education, and communication campaign to raise public awareness of climate change and its effects, as well as strengthen the competencies of local government units responsible for mainstreaming climate/disaster risk management into local land use and development planning and regulatory processes. The project will also promote the development of climate resilient livelihoods and risk sharing/transfer mechanisms to help disadvantaged communities become more resilient.

To address the risks in banana production, the Department of Agriculture can support the supply of financial and non-financial support services required to boost the banana industry's competitiveness, such as:

A. To boost extension support, education and training services (ESETS) to banana farmers since this only started in 2014.

B. Technical assistance in research and development. The Department of Agriculture, Department of Trade and Industry, Department of Science and Technology, Cooperative Development Authority, state universities and colleges, and other relevant government entities will provide infrastructural development, financial, and market information.

C. The Philippine Crop Insurance Corporation's insurance scheme (PCIC) shall be broadened to include high-value crops. The premium rates will not be determined based on the results of previous rice and corn initiatives. This is provided by the government to safeguard agricultural producers against crop loss due to natural disasters, plant pests and disease, and/or other risks.

D. The High Value Crop Development Fund (HVCDF) shall be used to make loans to farmers. CARP recipients, as well as other farmers' groups, associations, and cooperatives, are subject to the current Land Bank interest rates.

E. To ensure high yield and good quality product, the Department of Agriculture, in collaboration with state universities and colleges (SUCs), the Department of Trade and Industry, and farmers groups, will make good seeds and materials commonly accessible to farmers/farmers' cooperatives. However, subject to quarantine laws and the Seed Industry Development Act of 1992, project proponents may be authorized to import good quality seeds/planting materials duty-free.

As a whole, this study contributes to having an understanding of the need for an agricultural transformation emerging from the problems of climate change and plant diseases which connect environmental, economic, and socio-political landscapes. There is a need to work with provincial and local government units to strengthen their awareness and capacity to integrate this climate and plant disease risk data and analytical insights into their planning processes to help address the further impact on food security and livelihoods of the community in the future. Understanding the key risks and vulnerabilities such as through this highly localized analysis of climate-related impacts on critical value chains and livelihood groups is a first, yet very important, step in order to identify the most appropriate policies and programs that the Philippine government and partners should consider in their effort towards building resilient food systems. Coordination from the local level to national governments will help in arriving at the optimal level of annual government budget in the banana industry.

Further studies must be conducted to have a deeper understanding of the relationships between each of the independent variables to the volume of banana production. The lack of data about the potential factors that influence the relationships of the variables may lead to insufficient information which may lead to inefficient decisions. The Department of Agriculture reported that banana production could have been better in terms of quality and quantity; however, there are some factors to consider that contribute to its depletion, such as a lack of entrepreneurial capabilities and continued traditional farming practices for small growers and farmers, dispute on land acquisition, labor issues, as well as ineffective pest and disease management. Production has also been limited as a result of high input and transportation costs, all of which can have a significant impact on banana output levels in different Philippine provinces. These can therefore be analyzed in the future. Moreover, the frequency of extreme events was not included and analyzed which could be useful information in climate change adaptation planning. Because future climate conditions are likely to differ substantially from continent to continent and from developed to emerging countries, research must be done in tropical regions that take into account their unique environmental variables.

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