YANGON UNIVERSITY OF ECONOMICS

DEPARTMENT OF STATISTICS

IMPACTS OF CLIMATE CHANGE ON CROP YIELDS IN MAGWAY TOWNSHIP

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M.Econ (Statistics)

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SEPTEMBER, 2022

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This is to certify that the thesis entitled "**IMPACTS OF CLIMATE CHANGE ON CROP YIELDS IN MAGWAY TOWNSHIP**" submitted as a partial fulfillment towards the requirements of Master of Economics (Statistics) has been accepted by the Board of Examiners.

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ABSTRACT

The world is facing problems of climate change. Climate change mostly influences rural communities' livelihood. In Myanmar, climate change mainly affects agriculture, forest, biodiversity, public health, and water resources. This study aims to describe the crops production in Magway Township and to examine the relationship between climate situations, harvested area and crop yields in Magway Township. The panel data consist of six crops for the period from 2000 to 2020. Fixed effects model and random effects model are applied to examine the impacts of climate change on crop yields. The random effects model is found as an appropriate model. When diagnostic tests are considered to examine heteroskedasticity and auto-correlation in the random effects model, it is found that there is heteroskedasticity and auto-correlation in the random effects model. Thus, feasible generalized least square model is used to remedy heteroskedasticity and auto-correlation in the model. According to the feasible generalized least square model, rainfall and harvested area are statistically significant. It is found that rainfall is negatively related to crop yields but harvested area is positively related to crop yields.

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LIST OF ABBREVIATIONS

ASEAN	Association of Southeast Asian Nation
CDZ	Central Dry Zone
CRI	Climate Risk Index
DAR	Department of Agricultural Research
DMH	Department of Meteorology and Hydrology
DOP	Department of Population
ECM	Error Components Model
FAO	Food and Agricultural Organization
FEM	Fixed Effects Model
FGLS	Feasible Generalized Least Squares
GDP	Gross Domestic Product
GHG	Green House Gas
GLS	Generalized Least Squares
LSDV	Least-squares Dummy Variable
LM	Lagrange Multiplier
MOALI	Ministry of Agriculture, Livestock and Irrigation
MPSDS	Myanmar Pulse Sector Development Strategy
OLS	Ordinary Least Squares
PCSEs	Panel-correlated Standard Errors
REM	Random Effects Model
SD	Standard Deviation
UNDP	United Nations Development Programme

CHAPTER I
INTRODUCTION

Global climate change is one of the major issues facing the world today. About seventy percent of the population lives in rural areas depends heavily on agriculture, forestry, fisheries, livestock and other climate sensitive sectors (DOP, 2020). Climate change has mostly received rural livelihoods concern because of its direct and indirect impacts on the livelihoods of rural people that it presents. It poses a serious threat to livelihood security as well as enhances risks and vulnerabilities through the increased frequency of natural disasters and extreme weather events. In recent years, climate change has been characterized by changing rainfall patterns, increasing temperatures, and extreme weather events throughout the country.

1.1 Rationale of the Study

Climate change hinders development in all sectors, not only in Myanmar but also globally, and it has substantial implications for rural development all over the world. Myanmar is exceptionally susceptible to climate change and extreme weather conditions. According to the Global Climate Risk Index (CRI) for the period 1999–2018, Myanmar ranks as the second country most affected by weather-related events, which has led to massive displacement of people and the destruction of livelihoods, crops, and other food sources. Among those cases, rural people are the most vulnerable and worst effected by those climate change events (Eckstein et al., 2019).

Myanmar is a Southeast Asian nation and is primarily an agricultural country. The importance of agriculture in Myanmar is indicated by the stated objective of having agriculture as the basis of the country’s economy and the engine for the overall development of other sectors. The annual agricultural productions in Myanmar include cereals, oilseeds, vegetables and industrial crops (including rubber, sugarcane, cotton, oil palm, coffee, and tea). Myanmar is one of the developing countries and most of the people in rural areas are working in climate-sensitive sectors. Myanmar faces many development challenges, but climate change presents the greatest challenge of all. And while the impacts of climate change are felt in many ways, it is the threat to the country’s future development that makes it so significant. Action that is swift and forceful is needed both globally and locally to safeguard Myanmar's development today and in the future (UNDP, 2020).

As agriculture is one of the sectors that is more dependent on climate factors, farmers are more prone to having the impacts of climate change. The agricultural productivity is crucial for the country, as the agricultural sector alone contributes nearly 40% of the Gross Domestic Product (GDP), making the Central Dry Zone (CDZ) an important region for national planning (Tun Oo et al., 2020). The Central Dry Zone is located in central Myanmar, and the total land area is 67,700 square kilometers. Myanmar's CDZ accounts for 56% of the country's land area. It encompasses 54 townships in 13 districts spread across 3 regions, namely Sagaing, Mandalay and Magway. It is among the region most at risk from climate change, with poor soil fertility, limited surface water availability and a high proportion of rain-fed agriculture. This area is being among the more vital areas in the Union where adverse ecosystems (the result of natural and human behavior) are adversely affecting household agriculture. According to the agro-ecological zones in Myanmar, a changing climate in the CDZ is significantly different than the other zones.

The average rainfall pattern decreased while the average temperature increased over the nearly two decades from 2001 to 2019 (Hla Tun, 2019). Drought and high temperatures are major problems facing in the Central Dry Zone. The CDZ region's low crop productivity is a consequence of the considerable rainfall variability. In addition, the most essential crops' yields are reduced by the high temperatures. Thus, it is needed to tackle the problems caused by climate change for a sustainable increase in crop production. Agriculture is the main economic development in the Central Dry Zone and small agricultural crops like as peanuts, sesame, and paddy (Khaing et al., 2016). According to the Ministry of Agriculture, Livestock and Irrigation, the major cultivated crops of groundnut and sesame, it was found that the yield of sesame and groundnut decreased from 0.57 to 0.49 MT/ha of sesame and 1.58 to 1.50 MT/ha of groundnut yield from 2011/12 to 2018/19.

Magway Township is located in the central part of Myanmar and is located in Magway District, Magway Region. The second-largest city and the capital of the

Magway Region is Magway Township. It is established between north latitude $19^{\circ}45'$ to $20^{\circ}21'$ and east longitude $94^{\circ}54'$ to $95^{\circ}22'$. It is 27 miles from east to west and 40 miles long from south to north. The estimated population is about 0.3 million in the 2019 census, with a region of 682.22 square kilometers. Magway Township is located at an average altitude of 170 feet above sea level. This township is a lowland area with few rivers. It is a Dry Zone area prone to fires and droughts, and there were 19 natural disasters during the 2019 financial year.

As Magway Township is a tropical region, it is among the largest cultivated crops: paddy, groundnut, sesame, sunflower, green gram, and pigeon pea. There are sandy soils in Magway Township as the weather is hot. Oilseeds are developing on the humid, sandy soil. Magway Township is notable for being one of the producers of oilseeds, primarily sesame, groundnut, and sunflower seeds. The main product is oilseeds, which are being exported to Japan, China, and Korea every year. Oilseeds are applicable to produce a wide range of goods, including grains, oil, and cakes that are the byproduct of the oil extraction process. Paddy is critical to food security, while groundnut, sesame, sunflower, green gram, and pigeon pea are important for the improvement of trade balances and foreign earnings, employment, income generation, poverty eradication, as well as economic growth and development.

Pulses are Myanmar's largest export, and are the second essential crop for domestic consumption. Currently, the sector is facing a rise in market for specialty cereals, pulses and oilseeds: high potential market and sub-segments for oilseeds, cereals and pulses from Myanmar (MOALI, 2017). Crop productivity in the Magway Township suffers from the high variation in rainfall. Moreover, the high temperatures can reduce the yields among the most crucial crops. Other stated obstacles to crop production include the traditional farming practices, poor quality seeds, lack of investments in inputs and their use (fertilizer, pesticide), and uncertain crop prices (Tun Oo et al., 2020). Magway Township is currently not climate resilient; it will be difficult for socioeconomic growth to proceed. It is an economically developed township with good transportation. The local people in the township are mainly engaged in agriculture. An agriculturally intensive state with varied climatic conditions has been considered for the study covering the tropical zone in Myanmar. In this study, the impacts of climate change on crop yields of the most imported and cultivated crops in Magway Township are analyzed.

1.2 Objectives of the Study

The objectives of the study are:

i. To describe the climate situations (rainfall, maximum and minimum temperatures) in Magway Township.
ii. To overview the situations of yields of selected crops (paddy, groundnut, sesame, sunflower, green gram, and pigeon pea) and harvested area in Magway Township.
iii. To examine the impacts of climate change on crop yields in Magway Township.

1.3 Method of Study

To meet the objectives of the study, descriptive statistics and panel regression analysis were used. Firstly, the descriptive statistics was used to describe the climate situations (rainfall, maximum temperature and minimum temperature), the situations of yields of selected crops (paddy, groundnut, sesame, sunflower, green gram, and pigeon pea) and harvested area in Magway Township.

Secondly, the panel regression analysis was used the fixed effects and random effects models to examine the impacts of climate change on selected crop yields in Magway Township. Thirdly, Hausman test and Breusch and Pagan Lagrangian multiplier test were used to choose the appropriate model of climate change on selected crop yields. Lagrange Multiplier (LM) test was used to diagnostic on heteroskedasticity and Wooldridge test was used to diagnostic auto-correlation in the appropriate model. Finally, feasible generalized least squares model was utilized to remedy heteroskedastic and auto-correlation in the model.

1.4 Scope and Limitations of the Study

In this study, the secondary data were used. The data on harvested area, crop yields (paddy, groundnut, sesame, sunflower, green gram, and pigeon pea) and the climatic data (rainfall, maximum and minimum temperatures) for the time span of 2000 to 2020 were used. The data on agricultural yield per acre and harvested area for the six selected crops had been received from the Department of Agriculture and the climate data on annual rainfall, maximum and minimum temperatures are obtained from the Statistical Yearbook.

1.5 Organization of the Study

This study comprises five chapters. Chapter I is an introduction, which deals with the rationale of the study, objectives of the study, method of study, scope and limitations of the study, and organization of the study. Chapter II is the literature reviews, which include climate change, crop production in Myanmar and reviews of related studies on changes in climate's effects on crop production. The theoretical background of panel regression analysis is described in Chapter III. The climate change's effects on crop yields are examined in Chapter IV. The conclusion is expressed in Chapter V.

CHAPTER II

LITERATURE REVIEWS

Multiple stressors are imposed by climatic change on the biophysical, social, and institutional contexts that support agricultural output (Parry, 2007). The patterns of climate change's effects on agriculture into biophysical and socio-economic effects. Climate change has several direct effects on agricultural systems such as: (a) seasonal changes in precipitation and temperature, which could impact agro-climatic conditions, altering growing seasons, planting and harvesting calendars, water availability, pest, weed and disease populations; (b) alteration in evapotranspiration, photosynthesis and biomass production; and (c) alteration in land suitability for agricultural production. The concepts of climate change and crop production in Myanmar are highlighted in this chapter. Additionally, reviews of related studies on the impacts of climate change on crop production are included in this chapter.

2.1 Climate Change

Climate change is characterized as a shift in the climate's condition that lasts for an extended period of time, usually decades or longer, and that can be detected by changes in the mean and/or variability of its attributes. It describes any climatic change over time, whether it is brought on by natural variability or human activities (Parry, 2007).

Ghali (2011) described that any long-term shift in the climate, regardless of whether it was caused by human activity or natural variability, is discussed to as climate change. Climate change, sometimes known as climate transformation, is the term used to explain modifications in the planet's typical climate (in terms of temperature, precipitation, and wind), which are mostly brought on by human activity. The sustainability of the planet's ecosystems, the future of humanity, and the stability of the global economy are all at risk as an outcome of the unbalanced weather on Earth.

Brath et al. (2015) expressed that weather patterns that vary over decades or longer are a result of climate change. Natural and human factors both contribute to climate change. Humans have influenced climate change subsequently to the Industrial Revolution by emitting GHGs and aerosols, changing how land is used, and changing their behavior, which has led to an increase in global temperatures. A rise in storms, floods, droughts, sea levels, and the thinning of ice sheets, sea ice, and glaciers are just a few of the effects that rising global temperatures may have.

Freestone (2016) recognized that the phrase "climate change" refers to a shift in the climatic that can be directly or indirectly linked to human activity that modifies the global atmosphere's chemical composition, in addition to the natural climate variability that has been documented throughout comparable time periods.

Riedy (2016) presented that climate change is designated as a long-term, statistically significant change in the average climate or in the variability of the climate that may be caused by human activities such as changing the composition of the atmosphere or using land for different purposes, as well as by natural processes, external forcing, or all of the above. The expected temperature, amount of precipitation, and wind speed are frequently used to characterize climate. Global warming is the root of climate change, which also affects changes in rainfall patterns, the frequency and location of meteorological phenomena such as storms, floods, and heat waves, along with other types of climate change. Despite the frequent confusion between the terms "climate change" and "global warming," the former refers to a broader spectrum of observable changes in the climate, including global warming. Many scientists believe that climate alteration will result in a significant negative influence on both natural and human systems.

2.2 Impacts of Climate Change

The climatic system on Earth has changed in recent decades, according to scientific observation and study. Increases in global surface and atmospheric temperatures, sea levels, and surface ocean acidity have all coincided with increases in atmospheric Greenhouse Gas (GHG) levels (Slagle, 2014). Global warming, changing precipitation standards, and increasing sea levels are the main implications of these changes. Rising GHG levels in the environment have also contributed to climate changes. Along with these core consequences, there will likely be a wide range of secondary effects, such as a rise in the frequency of extreme weather events including storms, droughts, floods, and heat waves, among other things. The synergy between these primary and secondary effects will probably result in a future with a higher rate of change.

And then, global warming only refers to the temperature component of climate change, whereas climate change includes other aspects of the weather, such as precipitation and wind patterns. Given that temperature variations are among the main causes of other climatic aberrations, this mistake is probably widespread. For instance, when warmer air and water change evaporation rates and the capacity of the air to hold moisture, rising temperatures have an effect on precipitation rates. The worldwide natural environment, human populations, and agriculture will all be impacted by all of these climate shifts. Despite differing degrees, it is anticipated that the effects of the changing climate will be felt by Myanmar, its neighbors, and Southeast Asian areas. The variations in rainfall and temperature are the climate change's impacts on crop yields (Slagle, 2014).

According to the Ghali (2011), water resources, agriculture and food security, ecosystems and biodiversity, human health, and coastal zones were just a few of the sectors in Asia that were affected by climate alteration. Climate change would make many environmental and developmental issues in Asia harder. Flood-prone areas in East Asia, South Asia, and Southeast Asia may grow as a consequence of the expected increases in rainfall across most of Asia, particularly during the summer monsoon. Crop yields in Central and South Asia were expected to decline by up to 30%, posing a very significant danger of hunger in numerous nations.

Two-thirds of Myanmar's agricultural land is located in the dry zone, which has hotter temperatures than other parts of the nation. The region's agricultural production is severely affected by climate shift. Changes in precipitation patterns can raise the chance of short-term crop failures and long-term productivity decreases. Therefore, it is imperative to do research on how climate change would affect the economy of agricultural output in Myanmar's arid zone. Less than 30 inches of rain fall on average per year in the central arid zone (762 mm). While it may range from

40°F (4.4°C) to 50°F (10.0°C) in January and February, the typical maximum temperature in the central dry zone is approximately 100°F (37.8°C) in March and April. Years of drought in the CDZ region have drastically decreased crop production, making it difficult to feed livestock and humans alike. In 2010, a severe drought dried up rural community water supplies across the nation and ruined the rice and crops outputs. Longer droughts are anticipated to alternate with brief bursts of extreme precipitation. This will make it much more difficult for the majority rural people of the nation to cultivate food and make a life. The most noticeable effects of climate change in the dry zone are unpredictable rainfall patterns, decreased crop yields, protracted droughts, and changes in cropping seasons. The climatic changes that take place in Myanmar's CDZ, including as temperature rises, frequent severe droughts, changes in precipitation patterns, and shifts in the rainy season (Tun Oo et al., 2020).

According to the Department of Meteorology and Hydrology's climate change predictions, the drought risk in the CDZ region is anticipated to increase in the future century, placing the CDZ at a high risk of experiencing a drought danger. Local farmers are particularly vulnerable to climatic variability during the start and end of the monsoon season in addition the length and timing of the mid-season rain gap because farming in the CDZ is primarily rain-fed. As a result, high variability in rainfall is an important stress on farming in the CDZ. Low seasonal rainfall totals can restrict crop choices, yields, and quality, and this issue is made worse by inadequate crop water management. Field yield of crops in the CDZ region are significantly impacted by ramifications of climate change, particularly drought and rainfall unpredictability, as well as second-order effects like pest infestation and plant diseases. Temperature affects the rate of biological matter breakdown, the availability of nutrients, and the soil's ability to retain water. While temperature changes have an effect on evaporation, variability in precipitation may also somewhat influence the amount of water available for irrigation. The loss of soil moisture content, lack of water holding capacity, and decreased soil fertility were all important effects of climatic variability brought on by rising temperature and rainfall unpredictability (Aung et al., 2017).

Agriculture and climate variations are two processes that are interconnected and occur on a worldwide scale. Firstly, agriculture is highly dependent on the climate, but secondly, it influences the climate through its many agricultural operations. As was shown, global warming is expected to have a large impact on weather variables like temperature and precipitation, which in turn affect agriculture because these variables greatly influence the ability for food and feed production. In order to prepare for and adapt farming to the changing environment while maintaining an effective agricultural production, it is essential to assess the effects of climate shift on agriculture in various regions of the world. With a predicted reduction in yield of crops in most of the tropical and subtropical regions, due to the decreasing water availability and incident of new and damaging insect pest, the poorest countries will be the hardest-hit a cause of climate change. Crop production are not only affected by change in precipitation and temperature but also influenced by human investment like irrigation system, transportation etc. In general, it may cause negative effects such as lower yield, increase yield variability and reduction of suitable production area through increased severe weather and water shortage variability (Baniya, 2018).

According to the Phillips & Moya (2011), natural climate variability and its changes with mean warming regulate the frequency of severe occurrences like drought, excessive moisture, heat waves, and these events are critical determinants of agricultural and livestock productivity. The amount of people who depend on agriculture is higher in the developing countries. Climate variability, including changes in precipitation and temperature as well as climate extremes like drought and flooding, among other things, have a significant impact on agriculture. Due to its high reliance on weather and environment, the fact that farmers have lower incomes than urban dwellers. Crop yields are directly impacted by rising temperatures and shifting rainfall patterns, as well as indirectly by changes in irrigation water supply. One of the key determining elements affecting the future food security of humanity on earth will be the effects of climate shift on agriculture. Not only is agriculture affected by climate change, but it is also one of the main contributors to it. The obstacles facing the extension of the agricultural industry as a whole include comprehending how the weather varies over time and modifying management strategies to produce better harvests. Agriculture's climate sensitivity is unknown because rainfall, temperature, crops and cropping systems, soils, and management techniques vary according to area. The inter-annual fluctuation in rainfall and temperature was much greater than the anticipated changes in both. Agricultural losses could grow if the anticipated climate change increases climate variability.

Food and Agriculture Organization (FAO, 2006) indicated that 75 percent of the world's people resides within the tropics and that agricultural accounts for two thirds of their primary employment, agriculture is more important in the tropics. Given the primitive state of technology, the abundance of weeds, diseases, and pests, the deterioration of the soil, the unequal distribution of the land, and the rapid population expansion, any impact on tropical agriculture will have an effect on their way of life. Due to its size and weather susceptibility, agriculture is the sector most at threat from climate change, which has significant economic ramifications. Climate change, including variations in temperature and rainfall, has an important effect on crop output. As a result, any impact on the crops would be detrimental to the availability of food.

Different crops will react to rising temperatures, shifting precipitation patterns, and CO2 fertilization differently depending on the crop and the region. When the temperature rises, the yield is observed to drop, although the impact of the increasing precipitation is likely mitigated or lessened. Agricultural type, climate scenario, and the CO2 fertilization effect all have an effect on crop productivity. Farmers' net income is seen to decline sharply as precipitation decreases or temperature rises. Because tropical crops are more susceptible to high heat and little rainfall, tropical regions are more affected by climate alteration overall. There are still a lot of unanswered questions regarding future climate shift, like how heat waves, droughts, floods, and storms may vary in frequency and intensity. These changes are predicted by worldwide climate patterns, but regional changes and their effects on agriculture are more difficult to foresee (Parry, 2007).

Climate change can happen due to increasing population levels, innovation, high living standards, technological progress, industrialization, increasing infrastructure, reduction of trees and agricultural land, etc. According to the results of IPCC (2013), the level of Greenhouse Gases has surpassed the highest levels of concentrations on earth. This greenhouse effect, in turn, is causing increased rainfall, frequent hot extremes, floods, droughts, cyclones and gradual recession of glaciers. Climate change may not always have a negative effect on agriculture, especially in case of high latitude and high-income countries where agriculture cultivation is complimented by advanced technological implements and resources, leading to higher productivity of land. However, this climate alteration is a major barrier to developing economies, like Myanmar (Kaur, 2016).

Magway Township is situated in the CDZ of Myanmar, exceptionally susceptible to climate shift and where decision-makers in the township will need to prepare for higher rainfall during a shorter monsoon season, which will result in both crop destruction and flooding in urban areas; much warmer average temperatures and more frequent extreme heat days; and water scarcity, drought risks, decreased agricultural productivity, and threats to human health. The current and anticipated climatic circumstances are the vulnerability of Magway Township's ecological, infrastructure, and socioeconomic conditions. If no adaptation and resilience-building measures are done, Magway Township will become less adaptable to the existing climate circumstances and more vulnerable to the anticipated future climatic changes. Due to the current socioeconomic, infrastructure, and ecological system conditions also the anticipated outcomes of changing climate on these systems, this is mostly the case (Nang Ei Mon The, 2012).

2.3 Crop Production in Myanmar

Myanmar has a diversity of agro-ecological conditions which are shaped by dramatic differences in rainfall temperatures, soil types, and other factors. Regions in Myanmar can be characterized into three zones for agriculture - the Hilly Zone, the Central Dry Zone and the Coastal Zone. In these zones, pulses are mostly produced in the CDZ (Haggblade et al., 2014). Pulses, defined as edible legumes including dry beans, peas and lentils are an important source of nutrition, and household and national income earnings, and play a crucial part in eradicating poverty in Myanmar. By both value and volume, pulses are Myanmar's second-most significant crop for domestic consumption and its largest export. They are an important source of vitamins, minerals, and dietary fiber in addition to providing dietary protein (such as iron, zinc, and magnesium).

Pulses are valuable for food, but they also have a substantial impact on cropping systems because of their ability to fix nitrogen in symbiosis with rhizobia, a soil bacterium, and thereby enrich the soil. Myanmar is a top five world producer for three key pulse crops (mung bean, pigeon peas and green grams). It has strong competitive advantage in pulses production due to vast resources for land, water, and manpower, as well as proximity to quickly expanding markets such as India, China and ASEAN (Raitzer et al., 2015). Approximately 68% of pulses production occurs in the post-monsoon winter season (October to January), the remaining 32% is produced during the monsoon season (June to September) Department of Agricultural Research (DAR, 2017).

Myanmar is a significant producer of pulses. It is evaluated that in 2016, Myanmar produced almost 1.2 million tons of pulses (Gumma et al., 2018). The quantity of pulses produced nationally during 2020-2021 is estimated at 2 million tones. Myanmar produces over 20 kinds of pulse plants. Black gram (or Matpe), green gram (or mung bean) pigeon peas and chickpeas are the four main pulse crops agriculture in Myanmar. The cost of production of black and green gram is high compared with other countries due to high labor requirements and fertilizer, pesticide and insecticide use. Prices of pulses are higher than that of rice. Farmer's perceive that a low selling price is the biggest challenge/difficulty their farm business face.

The Central Dry Zone, which includes Magway Township, is among the weakest and most food insecure regions of the country. It is also distinguished by a wide variety of crops, with three or more different crop varieties being grown. Peas, beans, maize, sesame, and groundnuts are the most widely farmed crops in Magway Township; rice is less widespread (since the soil type and rainfall patterns are potentially vulnerable to the production of rice). Peas, maize, sunflower, sesame and groundnut are the crops that households that plant more than two crops grow. Pulses may be cultivated in very poor soil and have very little water requirements. Pulses like mung bean, black gram, and chickpea are typically grown as an extra crop using the remaining soil moisture after the monsoon paddy harvest. In Magway Township, pulses are typically grown during the monsoon season (May to July) and the post-monsoon season (October-December). Black gram, chickpea, sunflower, sesame and groundnut are grown during the post-monsoon season, whereas mung bean, pigeon pea, and green gram are grown during the monsoon season (Cho et al., 2016).

2.4 Reviews of Related Studies on the Impacts of Climate Change on Crop Production

According to the Schmidhuber and Tubiello (2007), crop production is influenced by changing climate directly through biophysical considerations such as plant and animal growth and the physical infrastructure associated with food processing and distribution. Several studies have examined changes in climate's effects and variability on crop production using agro-economic models or statistical estimation. There is a difference in results depending on the methodology, crops under consideration, and the region. Many aspects of climatic change are directly affecting on crop production, stemming mainly from: average temperature increase, change in rainfall amount and patterns, rising atmospheric concentrations of CO2, change in climatic variability and extreme events, and sea water rise.

Nang Ei Mon The (2012) examined that the impact of climate change on rural livelihoods in Pakokku Township, Magway Region, Myanmar. This study considered multiple regression model for the time span of 1996-2011. Average maximum temperature, average minimum temperature and average rainfall were used as the explanatory variables and yield of some major crops (paddy, groundnut and sesame) are recorded as the dependent variable. The results indicate that the maximum temperature had significant and positive relationship with yield of paddy while significant and negative relationship with yield of groundnut. The results also showed that the minimum temperature had significant and positive relationship with yield of paddy and rainfall had significant and negative relationship with yield of groundnut.

Suminori et al. (2015) studied that the impacts of climate change on agricultural production in Japan. Using panel data comprises time-series data from 1995 to 2006 and a cross-section of eight regions that utilizing the framework of static panel data model and dynamic panel data model. The dependent variable is crop yields (vegetable and potato and rice) and the independent variables are three weather variables (precipitation, temperature, and solar radiation) and labor. The results show that if temperature increases by one degree, the rice production will be decreased by 5.8 and 3.9% and the vegetable and potato production will be decreased by 5.0 and 8.6% in the short term and long term, respectively.

Kaur (2016) analyzed that the impact of climate change on agricultural productivity and food security resulting in poverty in India for the years 2004-2013. Regression analysis has been used in the study. Various factors influencing productivity of agricultural variables (farm harvest price, forest area, irrigated area, number of tractors, agricultural workers and fertilizer consumption) and meteorological variables (rainfall, minimum temperature and maximum temperature) were taken to be independent variables and yield of crops in kilogram per hectare (rice, wheat, cotton, and sugarcane) was considered become the dependent variable. The results show that the farm harvest price, forest area, irrigated area and maximum temperature are negative impact to the agricultural productivity. The results also expressed that the minimum temperature, rainfall, number of tractors, agricultural workers and fertilizer consumption have a positive impact on agricultural productivity.

Kariuki (2016) evaluated that the effect of climate variability on output and yield of selected crops in Kenya was examined using the utility maximization theory and production theory between 1970 and 2014. Output supply model, agriculture crop yields model, and diagnostic tests were employed to assess the relationship between climate variability on output and yields of selected crops. The study analyzed the precipitation and temperature effects on the production response of three major crops namely maize, tea, and coffee. While dependent variable of analysis is crop yields, the independent variables are monthly rainfall and temperature. The study finds that increase in temperature has a negative effect on maize and tea yields. The findings also indicated that climate variability is expected to have both positive and negative effects on coffee yield depending on the stage of crop growth and development.

Poudel and Shaw (2016) analyzed that the relationship between climate variability and crop yield in Lamjung District, Nepal from 1980 to 2012 by using multiple regression models. In this study, summer and winter (precipitation, maximum temperature, and minimum temperature) were used as the explanatory variables and yield of five major crops (rice, maize, millet, wheat, barley) was used as the explained variable. The results revealed that as increases the minimum temperature in winter has negative impact on wheat crop. The results also found that the summer precipitation had a negative impact on maize crop. Moreover, increasing the maximum temperature in summer has positive impact on millet crop in Nepal.

Byishimo (2017) considered that the assessment of climate change impacts on crop yields and farmer's adaptation measures: a case of Rwanda over the period 1970 to 2015. This study employed regression model used to evaluate the effects of climate change on yields of major food crops in Rwanda. The study uses the yield data for 5 major food crops: maize, beans, cassava, Irish potatoes and sweet potatoes. While dependent variable of analysis is crop yields, the independent variables are area harvested, annual rainfall, maximum and minimum temperatures, floods, and droughts. The results expressed that area harvested is positively related to maize, cassava and Irish potato yields and annual rainfall is positively related to beans, maize and sweet potato yields, but dummy variables (floods and droughts) had no impacts on crop yield. The results also expressed that minimum temperature is positively related to Irish potato yield and negatively related to maize yield while a change in maximum temperature is positively related to yield of sweet potato and negatively related to yields of beans, maize and Irish potato.

Htoo (2021) investigated that the macro analysis of climate change and agricultural production in Myanmar was examined using multiple regression model for the time span of 2009 to 2019. In this study, the dependent variable is the cereal crop production in kg per hectare while the independent variables are climate variables (average annual maximum and minimum temperatures, and average annual precipitation) and agricultural variables (fertilizer and phosphate and potash). The result also established that temperature, rainfall, fertilizer, and phosphate are negatively related and potash was positively related to the production of cereal crops.

CHAPTER III

THEORTICAL BACKGROUND

In this study, panel regression analysis was used to examine the impacts of climate change on crop yields. It is presented from basic concepts to panel data and the uses of panel data regression models.

3.1 Panel Data

Panel Data are the combination of cross-sectional data and time series data, where the same cross-sectional unit is studied over time. In short, panel data have space as well as time dimensions. Other terms for panel data include pooled data (combining time series and cross-sectional observations), micro-panel data, longitudinal data (a study over time of a variable or group of subjects), event history analysis (for example, examining the progression over time of entitles through successive states or conditions), and cohort analysis.

T is the time periods (t = 1, 2, ..., T) and N is the number of individuals (i = 1, 2, ..., N), with panel data have total observation units of N x T. If sum unit time is the same for each individual, then the data is called balanced panel. An unbalanced panel is one in which the number of time units varies for every participant. The panel data are divided into short panel and long panel. The number of cross-sectional entries, N, in a short panel is more than the number of time periods, T. The number of time periods in a long panel, T, exceeds the number of cross-sectional sections, N (Gujarati & Porter, 2008).

3.2 Panel Data Regression Models

The regression models based on panel data are called panel data regression models. Panel data models examine group (individual-specific) effects, time effects, or both. There are regression analyses through fixed effects model and random effects model. A fixed effects model examines if the intercepts vary across groups or time periods, whereas a random effects model explores differences in error variance components across individual or time period (Gujarati & Porter, 2008).

3.3 The Fixed Effects Model

The basic panel data model takes the form;

$$Y_{it} = \beta_1 X_{it} + a_i + u_{it}, \qquad \text{t = 1, 2,…, T.} \tag{3.1}$$

Where, i is the individual dimension and t is the time dimension. Therefore, Y_{it} is the response of individual i at time t, a_i are the unobserved individual-specific, time-invariant intercepts, X_{it} is the explanatory variable i at time t, β_1 is a vector of regression coefficients, and u_{it} is the error term of individual i at time t . They are also known as idiosyncratic errors because they change across i as well as across t.

Fixed effects (FE) model which treats the unobserved individual effects as random variables that are potentially correlated with the explanatory variables,

$E(X_{it}a_i) \neq 0.$

The statistical properties of a_i, it can be eliminated from the model. Among various ways to eliminate a_i, the within-group transformation or deviation from mean is used (Wooldridge, 2012).

Now, for each i, average this equation over time.

$$\bar{Y}_i = \beta_1 \bar{X}_i + a_i + \bar{u}_i, \tag{3.2}$$

where $\bar{Y}_i = T^{-1}\sum_{t=1}^{T} y_{it}$; $\bar{X}_i = T^{-1}\sum_{t=1}^{T} x_{it}$; $\bar{u}_i = T^{-1}\sum_{t=1}^{T} u_{it}$ and $\bar{a}_i = a_i$. These are called time means for each unit i. The OLS estimator for β_1 obtained from (3.2) is called between estimator.

To eliminate a_i subtract equation (3.2) from (3.1) for each t gives the fixed effects transformed equation,

$$Y_{it} - \bar{Y}_i = \beta_1(X_{it} - \bar{X}_i) + u_{it} - \bar{u}_i, \qquad \text{t = 1, 2,…, T,}$$

or equivalently

$$\ddot{Y}_{it} = \beta_1 \ddot{X}_{it} + \ddot{u}_{it}, \qquad \text{t = 1, 2,…, T,} \tag{3.3}$$

where $\ddot{Y}_{it} = Y_{it} - \bar{Y}_i$ is the time-demeaned data on Y, and similarly for $\ddot{X}_{it}$and $\ddot{u}_{it}$. The fixed effects transformation is also called the within transformation.

Few changes result from including more explanatory variables in the equation. The original unobserved effects model is

$$Y_{it} = \beta_1 X_{1it} + \beta_2 X_{2it} + \cdots + \beta_k X_{kit} + a_i + u_{it}, \qquad t = 1, 2, \ldots, T. \quad (3.4)$$

The general time-demeaned equation for each i is

$$\ddot{Y}_{it} = \beta_1 \ddot{X}_{1it} + \beta_2 \ddot{X}_{2it} + \cdots + \beta_k \ddot{X}_{kit} + \ddot{u}_{it}, \quad t = 1, 2, \ldots, T, \qquad (3.5)$$

The fixed effects model is an estimation which allows for heterogeneity among subjects by allowing each entity to have its own intercept value. The fixed effects model is

$$Y_{it} = \beta_{1i} + \beta_2 X_{1it} + \beta_3 X_{2it} + \beta_4 X_{3it} + \beta_5 X_{4it} + u_{it} \qquad (3.6)$$

Where, i = 1, 2,…., n

t = 1, 2,…., t

i is the i^{th} subject and

t is the time period for the variables

Equation (3.6) is called the fixed effects (regression) model (FEM). The term “fixed effects” derives from the fact that, although the intercept may differ across subjects, each entity’s intercept does not vary over time, which means, it is time-invariant. The fixed effects model essentially looks at differences between intercepts, assuming the same slopes and constant variance across entitles or subjects. Since a group (individual specific) effect is time invariant and considered a part of the intercept, where u_{it} is allowed to be correlated to other regressors (Gujarati & Porter, 2008).

One way to estimate a pooled regression is the fixed-effect within a group estimator. It is to eliminate the fixed effect, β_{1i}, by expressing the values of the dependent and explanatory variables. It will obtain the sample mean values of each variable and subtract them from the individual values of the variables. The resulting values are called mean corrected values.

Dummy variables are not needed in a within group effect model that, however, uses deviations from group mean. Thus, the model is the OLS of $(Y_{it} - \bar{Y}_i) = (X_{1it} - \bar{X}_{1i.})\beta_2 + (X_{2it} - \bar{X}_{2i.})\beta_3 + (X_{3it} - \bar{X}_{3i.})\beta_4 + (X_{4it} - \bar{X}_{4i.})\beta_5 + (u_{it} - \bar{u}_{it})$

without an intercept. The incidental parameter problem no longer exists. The parameter estimates in the within effect model are identical to those of (LSDV).

Since this model does not report dummy coefficient, it needs to compute them using the formula $\hat{\beta}_{1i} = \bar{Y}_{i.} - \bar{X}_{1i}\hat{\beta}_2 - \bar{X}_{2i}\hat{\beta}_3 - \bar{X}_{3i}\hat{\beta}_4 - \bar{X}_{4i}\hat{\beta}_5$

$\bar{Y}_{i.}$ = dependent variable mean of group i.

$\bar{X}_{i.}$= means of independent variables (Ivs) of group i.

3.4 The Random Effects Model

A simple representative panel data regression model is,

$$Y_{it} = \beta_1 + \beta_2 X_{1it} + \cdots + \beta_k X_{kit} + a_i + u_{it}. \quad (3.7)$$

The unobserved effect, a_i has zero mean. Then, using a transformation to eliminate a_i results in inefficient estimators (Wooldridge, 2012). The unobserved effect $a_i$is uncorrelated with each explanatory variable:

$$\text{Cov}(X_{itj,} a_i) = 0, \quad t = 1, 2,\ldots, T;\ j = 1, 2,\ldots, k. \quad (3.8)$$

The random effect model presumes that individual effect (heterogeneity) is not correlated with any regressor and estimates error variance specific to groups (or times). The random effects model or the error components model is

$$Y_{it} = \beta_{1i} + \beta_2 X_{1it} + \beta_3 X_{2it} + \beta_4 X_{3it} + \beta_5 X_{4it} + u_{it} \quad (3.9)$$

The intercepts β_{1i} are assumed to be random variables with mean value

$$\text{E}(\beta_{1i})=\beta_1 \quad (3.10)$$

and the intercept value for individual i can be revealed as

$$\beta_{1i} = \beta_1 + a_i, i=1,\ldots,n \quad (3.11)$$

where $\text{E}(a_i) = 0$ and $\text{V}(a_i) = \sigma_a^2$

The equation (3.9) becomes that

$$Y_{it} = \beta_1 + a_i + \beta_2 X_{1it} + \beta_3 X_{2it} + \beta_4 X_{3it} + \beta_5 X_{4it} + u_{it}$$

$$Y_{it} = \beta_1 + \beta_2 X_{1it} + \beta_3 X_{2it} + \beta_4 X_{3it} + \beta_5 X_{4it} + v_{it} \quad (3.12)$$

Where, $v_{it} = a_i + u_{it}$

i = 1, 2,…., n

t = 1, 2,…., t

i is the i^{th} subject and

t is the time period for the variables

Equation (3.12) is called the random effects (regression) model (REM). The composite error term v_{it} consists of two components: a_i, which is the cross section, or individual-specific, error component and u_{it}, which is the combined time series and cross-section error component because it varies over-section (subject) as well as time. The other name of random effect model is called error component model (ECM) because the composite error term consists of two (or more) error components (Gujarati & Porter, 2008).

The usual assumptions made by the ECM are that

$a_i \sim N(0, \sigma_a^2)$

E $(a_i a_j) = 0$ for i ≠ j

$u_{it} \sim N(0, \sigma_u^2)$ (3.13)

E $(u_{it}\, u_{is}) = E(u_{ij}\, u_{ij}) = E(u_{it}\, u_{js}) = 0$ for i≠j; t≠s

E $(a_i\, u_{it}) = 0$

That is, the individual error components are not correlated with each other and are not auto correlated across both cross-section and time series units.

E $(v_{it}) = 0$ (3.14)

Var $(v_{it}) = \sigma_a^2 + \sigma_u^2$ (3.15)

As Equation (3.15) shows, the error term is homoscedastic. However, it can be exhibited that v_{it} and v_{is} (t≠s) are correlated; that is, the error terms of a given cross sectional unit at two different points in time are correlated. The correlation coefficient, corr (v_{it}, v_{is}) is

$$\rho = \text{corr}\,(v_{it}, v_{is}) = \frac{\sigma_a^2}{\sigma_a^2 + \sigma_u^2} \; ; \; t \neq s \qquad (3.16)$$

where $\sigma_a^2 = Var(a_i)$ and $\sigma_u^2 = Var(u_{it})$.

Deriving the GLS transformation that eliminates serial correlation in the errors requires sophisticated matrix algebra. But the transformation is simple.

Define, $$\theta = 1 - [\frac{\sigma_a^2}{\sigma_a^2 + \sigma_u^2}]^{1/2}, \quad (3.17)$$

which is between zero and one. Then, the transformed equation turns out to be

$$y_{it} - \theta\bar{y}_i = \beta_1(1-\theta) + \beta_2(x_{1it} - \theta\bar{x}_{1i}) + \cdots$$
$$+\beta_k(x_{kit} - \theta\bar{x}_{ki}) + (v_{it} - \theta\bar{v}_i), \quad (3.18)$$

where the overbar again denotes the time averages. It involves quasi-demeaned data on each variable.

3.5 Fixed Effects Versus Random Effects Model

This section presents the choice between the fixed effects model and the random effects model.

1. If T (the number of time series data) is large and N (the number of cross-sectional units) is small, there is likely to be little difference in the values of the parameters estimated by FEM and REM. Hence the choice here is based on computational convenience. On this score, FEM may be preferable.
2. When N is large and T is small, the estimates obtained by the two methods can differ significantly. In REM,$\beta_{1i} = \beta_1 + a_i$, where a_i is the cross-sectional random component, whereas in FEM, β_{1i} treats as fixed and not random. In that case, FEM is appropriate. If the cross-sectional units in the sample are regarded as random drawings, then REM is appropriate.
3. If the individual error component a_i and one or more regressors are correlated, then the REM estimators are biased, whereas those obtained from FEM are unbiased.
4. If N is large and T is small, and if the assumptions underlying REM hold, REM estimators are more efficient than FEM estimators.
5. Unlike FEM, REM can estimate coefficients of time-invariant variables. The FEM does control for such time-invariant variables, but it cannot estimate them directly, as is clear from the LSDV or within-group estimator models.

If it is assumed that a_i and X's are uncorrelated, REM may be appropriate, where as if a_i and X's are correlated, FEM may be appropriate. In FEM each cross-sectional unit has its own (fixed) intercept value, in all N such values for N cross-sectional units. In REM, the common intercept represents the mean value of all the (cross-sectional) intercepts and the error component a_i represents the (random) deviation of individual intercept for this mean value (Gujarati & Porter, 2008).

3.6 Hausman Test

The Hausman specification test compares the fixed versus random effects model. The null hypothesis is that the individual effects are uncorrelated with the other regressors in the model. If correlated (H_0 is rejected), a random effect model generates biased estimates, which violating one of the Gauss-Markov assumptions; thus, the fixed effects model is preferred (Gujarati & Porter, 2008). Hausman's essential result is that the covariance of an efficient estimator with its difference from an efficient estimator is zero.

Test hypotheses are:

Null Hypothesis : The random effects model is appropriate.

Alternative Hypothesis: The fixed effects model is appropriate.

$$H = (\hat{\beta}_{FE} - \hat{\beta}_{RE})'(V_{FE} - V_{RE})^{-1}(\hat{\beta}_{FE} - \hat{\beta}_{RE}) \quad (3.19)$$

The test statistic is produced by the Hausman test has an asymptotic Chi-square distribution.

3.7 Breusch and Pagan Lagrangian Multiplier Test

The Breusch and Pagan Lagrangian multiplier test examine if there is any random effect in the model. The null hypothesis is that individual-specific or time-specific error variance components are zero. The alternative hypothesis is that individual-specific or time- specific error variance components are not zero. If the null hypothesis is rejected, random effects model is appropriate. If the null hypothesis is not rejected, the ordinary least squares model is appropriate (Gujarati & Porter, 2008). The statistic follows the chi-squared distribution with one degree of freedom. The test statistic is

$$LM = \sqrt{\frac{NT}{2(T-1)}}\left\{\frac{\sum_{i=1}^{N}(\sum_{t=1}^{T}\hat{e}_{it})^{2}}{\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{e}^{2}{}_{it}} - 1\right\} \quad (3.20)$$

3.8 Heteroskedasticity

The standard error component of appropriate model presumes that the regression disturbances are homoscedastic with the same variance across time individuals. This may be a restrictive assumption for panels. In the existence of heteroskedasticity, the standard errors of the estimates will be biased. The robust standard errors need to be computed to correct for the possible presence of heteroskedasticity. The situation in which the error process is homoscedastic within cross-sectional units, but its variance differs across units is called group-wise heteroskedasticity.

Lagrange Multiplier LM test is used to calculate heteroskedasticity in the residuals of a random effect regression model. The null hypothesis that $\sigma_i^2 = \sigma^2$ for i=1,…,n, where n is the number of cross-sectional units. The resulting test statistic is distributed Chi-squared under the null hypothesis of homoscedasticity (Wooldridge, 2012).

3.9 Auto-correlation

The relationship that lies between an error and the immediate previous error in data is called first-order correlation. Ignoring auto-correlation may well lead to inefficient parameter estimates which will lead to the incorrect analysis of a variable's contribution to the variation in the dependent variable. In fact, auto-correlation can introduce bias in the standard errors. Wooldridge's method is used in the model. Woolderdge's method applies the residuals from a regression in first-differences (Wooldridge, 2012). The first-differencing data removes the individual level effect, the term based on the time-invariant covariates and the constant,

$$Y_{it} - Y_{it-1} = (X_{it} - X_{it-1})\beta_1 + \varepsilon_{it} - \varepsilon_{it-1} \tag{3.20}$$

$$\Delta Y_{it} = \Delta X_{it}\beta_1 + \Delta\varepsilon_{it} \tag{3.21}$$

Where Δ is the first-different operator.

3.10 Feasible Generalized Least Squares Estimator

Feasible Generalized Least Squares (FGLS) determines for the data with heteroskedasticity as well as for temporal and spatial dependence in the residual of time-series cross-section models. FGLS affords an efficient estimation for the case in which the number of t (time period) is greater than or equal to the number of N (cross-sections) (Tobechukwu & Azubuike, 2020).

The FGLS estimation method provides into consideration heteroskedasticity and auto-correlation. The equation from the model is given by

$$y_{it} = X_{it}\beta + \varepsilon_{it}$$

where i = 1,…,N is the number of units and t = 1,…,T is the number of time periods for panel i. This model can be expressed similarly as

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix} = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_N \end{bmatrix} \beta + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_N \end{bmatrix}$$

The variance matrix of the disturbance terms can be recorded as

$$E[\varepsilon\varepsilon'] = \Omega = \begin{bmatrix} \sigma_{1,1}\Omega_{1,1} & \sigma_{1,2}\Omega_{1,2} & \cdots & \sigma_{1,N}\Omega_{1,N} \\ \sigma_{2,1}\Omega_{2,1} & \sigma_{2,2}\Omega_{2,2} & \cdots & \sigma_{2,N}\Omega_{2,N} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{N,1}\Omega_{N,1} & \sigma_{N,2}\Omega_{N,2} & \cdots & \sigma_{N,N}\Omega_{N,N} \end{bmatrix}$$

Where
$$\Omega_{i,j} = \begin{bmatrix} 1 & \rho_j & {\rho_j}^2 & \cdots & {\rho_i}^{t-1} \\ \rho_i & 1 & \rho_j & \cdots & {\rho_i}^{t-2} \\ {\rho_i}^2 & \rho_i & 1 & \cdots & {\rho_i}^{t-3} \\ \cdots & \cdots & \cdots & \ddots & \cdots \\ {\rho_i}^{t-1} & {\rho_i}^{t-2} & {\rho_i}^{t-3} & \cdots & 1 \end{bmatrix}$$

In the FGLS model, the estimation of regression applies regular OLS. In order to estimate assumed error AR (1) serial correlation coefficientρ, the estimation residuals are utilized. This coefficient is used to transform the model to eliminate error serial correlation. $\widehat{\Omega}$ is substituted for Ω, using estimated ρ and σ^2, then the FGLS estimator of β is derived as

$$\hat{\beta}_{FGLS} = (X'\widehat{\Omega}^{-1}X)^{-1}X'\widehat{\Omega}^{-1}y.$$

CHAPTER IV

ANALYSIS OF PANEL DATA REGRESSION MODELS

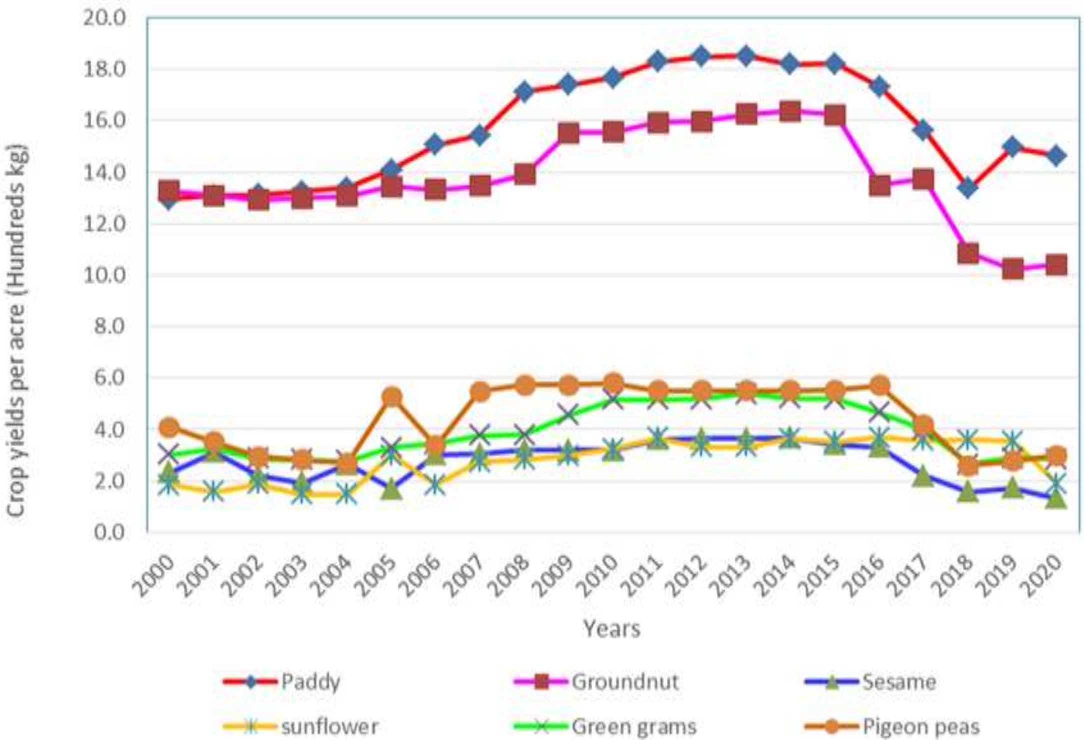
The impacts of climate change on crop yields are studied in this chapter. The climate change situations (minimum temperature, maximum temperature, and rainfall), the situations of crop yields per acre (paddy, groundnut, sesame, sunflower, green gram, and pigeon pea) and harvested area describe descriptive statistics. Moreover, it also includes the results of fixed effects model, random effects model, hausman test, Breusch and Pangan Lagrangian multiplier test, diagnostic checking on random effects model and feasible generalized least squares model.

4.1 Descriptive Analysis

The descriptive statistics of crop yields per acre, rainfall, maximum temperature, minimum temperature, and harvested area of Magway township from 2000 to 2020 are described the following sections.

4.1.1 Crop Yields per Acre

Crop Yields per Acre (kg) of Magway Township from 2000-2020 are shown in Figure (4.1).



Source: Department of Agriculture (2000-2020)

Figure (4.1) Crop Yields per Acre (kg) in Magway Township, 2000-2020

Figure (4.1) demonstrates that based on the annual crop yield over the period 2000-2020, the highest yield came from the Paddy crop, and followed by Groundnut, Sesame, Sunflower, Green grams and Pigeon peas. Among them paddy and groundnut crops produced the higher yields. These crops took four times higher yield than other crops. The lowest yield among them was from the sesame crop with 131.6 kg per year in 2020. In comparison among rainfall, temperature and crop yield, the temperature has lowest response to the crop yield. In contrast, the rainfall is the highest influence on crop yield. After 2005, the crop yields are highly responded to the rainfall, as they followed more or less on the rainfall situation, i.e., the lower the rainfall, the lower the crop yield (See Appendix – A).

Descriptive statistics of selected crop yields in Magway Township from 2000 to 2020 are described in Table (4.1).

Table (4.1)

Descriptive Statistics on Yields per Acre (kg) of Selected Crops in Magway Township

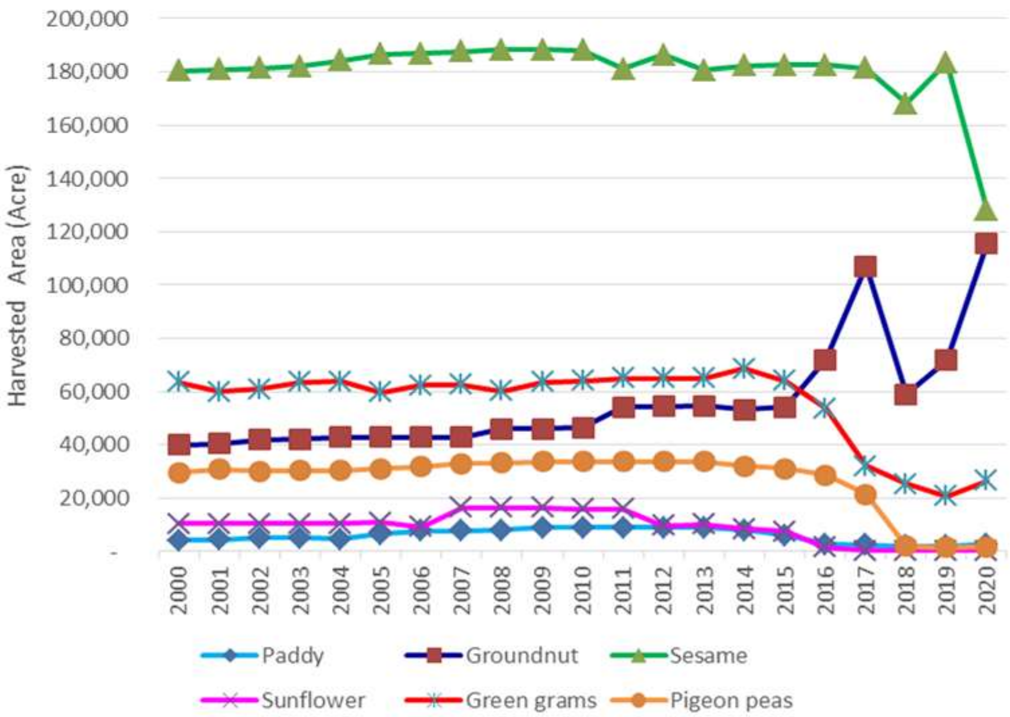
Crops	Mean	Standard Deviation	Minimum	Maximum
Paddy	1572.4864	211.0334	1295.4060	1851.9508
Groundnut	1381.1858	187.2737	1022.4698	1637.6670
Sesame	274.0150	77.1306	131.565	365.785
Sunflower	278.7214	83.2701	146.10	369.45
Green gram	389.5467	100.8388	265.28	537.60
Pigeon pea	443.8791	128.1045	259.638	580.425

Source: Department of Agriculture (2000-2020)

The results given in Table (4.1) show that the paddy yield per acre is a minimum of 1295.4060 kg in 2000 and a maximum of 1851.9508 kg in 2013, while the average is 1572.4864 kg (SD = 211.0334). The groundnut yield per acre is a minimum of 1022.4698 kg in 2020 and a maximum of 1637.6670 kg in 2014, while the average is 1381.1858 kg (SD = 187.2737). Similarly, the sesame yield per acre is a minimum of 131.565 kg in 2020 and a maximum of 365.785 kg in 2014, while the average is 274.0150 kg (SD = 77.1306). The sunflower yield per acre is a minimum of 146.10 kg in 2004 and a maximum of 369.45 kg in 2016, while the average is 278.7214 kg (SD = 83.2701).). The green gram yield per acre is a minimum of 265.28 kg in 2018 and a maximum of 537.60 kg in 2013, while the average is 389.5467 kg (SD = 100.8388). Furthermore, the pigeon pea yield per acre is a minimum of 259.638 kg in 2018 and a maximum of 580.425 kg in 2010, while the average is 443.8791 kg (SD = 128.1045).

4.1.2 Harvested Area of Selected Crop Yields

Harvested Area (Acre) of Selected Crop Yields of Magway Township from 2000-2020 are shown in Figure (4.2).



Source: Department of Agriculture (2000-2020)

Figure (4.2) Harvested Area (Acre) of Selected Crop Yields in Magway Township, 2000-2020

As illustration in Figure (4.2), it shows that the largest harvested area among them is the Sesame and it has more than three times higher than the rest. Before 2015, the lowest harvest area was the Paddy, but after that it was changed to the Sunflower until 2020. The variation between the lowest and the highest harvested areas is 20 times as the lowest and over 6000 times as the highest. Though, all crops were harvested at the similar area with the same situation until 2015, changed into different situations during 2016 till 2020, except for Sunflower and Paddy. The harvested areas of the Sesame, Green grams and Pigeon peas are dropped down after 2015. Their future situations are predicted to be decreased as well. The only one rising of harvested area after 2015 is Groundnut and its growing rate is three time larger. Its future situation is expected to be increased as well. Over the period 2000-2020, the minimum harvested area is 20 acres of the Sunflower which was harvested in 2020. In contrast, the maximum harvested area is 188,391 acres of the Sesame in 2009 (See Appendix – A).

Descriptive statistics of harvested area of selected crop yields in Magway Township from 2000 to 2020 are presented in Table (4.2).

Table (4.2)

Descriptive Statistics of Harvested Area (Acre) of Selected Crops in Magway Township

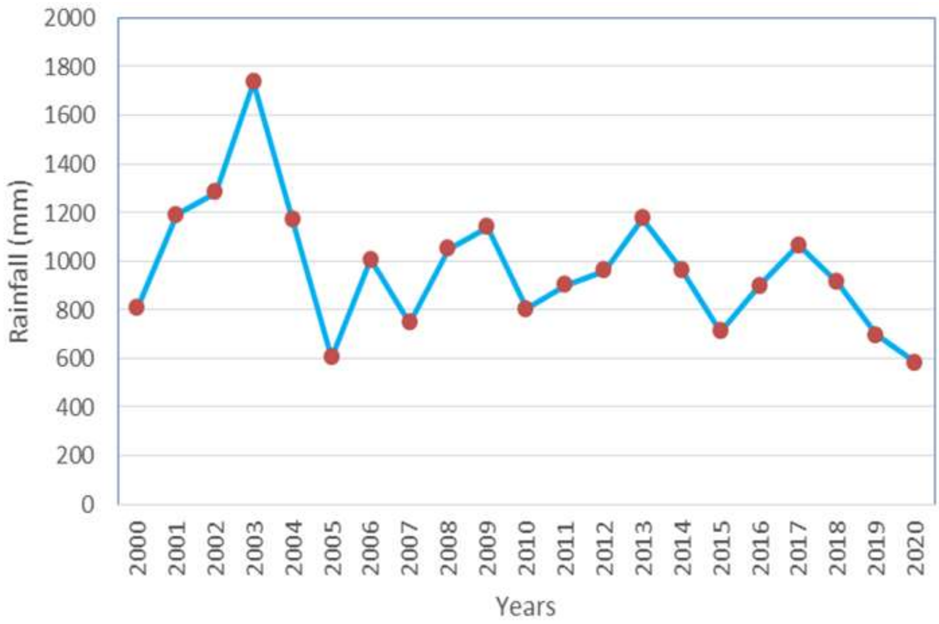
Crops	Mean	Standard Deviation	Minimum	Maximum
Paddy	5891.24	2584.652	2026	9048
Groundnut	55686.81	20679.639	40050	115473
Sesame	180552	12787.841	128226	188391
Sunflower	9081.43	5672.811	20	16501
Green gram	55653.90	15074.487	20776	68457
Pigeon pea	27014.19	10910.945	1489	33752

Source: Department of Agriculture (2000-2020)

The results given in Table (4.2) indicate that the paddy harvested area is a minimum of 2026 acres in 2019 and a maximum of 9048 acres in 2010, while the average is 5891.24 acres (SD = 2584.652). However, the groundnut harvested area is a minimum of 40050 acres in 2000 and a maximum of 115473 acres in 2020, while the average is 55686.81 acres (SD = 20679.639). The sesame harvested area is a minimum of 128226 acres in 2020 and a maximum of 188391 acres in 2009, while the average is 180552 acres (SD = 12787.841). In addition, the sunflower harvested area is a minimum of 20 acres in 2020 and a maximum of 16501 kg in 2009, while the average is 9081.43 acres (SD = 5672.811). The green gram harvested area is a minimum of 20776 acres in 2019 and a maximum of 68457 acres in 2014, while the average is 55653.90 acres (SD = 15074.487). Moreover, the pigeon pea harvested area is a minimum of 1489 acres in 2019 and a maximum of 33752 acres in 2012, while the average is 27014.19 acres (SD = 10910.945).

4.1.3 Climate Change Situations

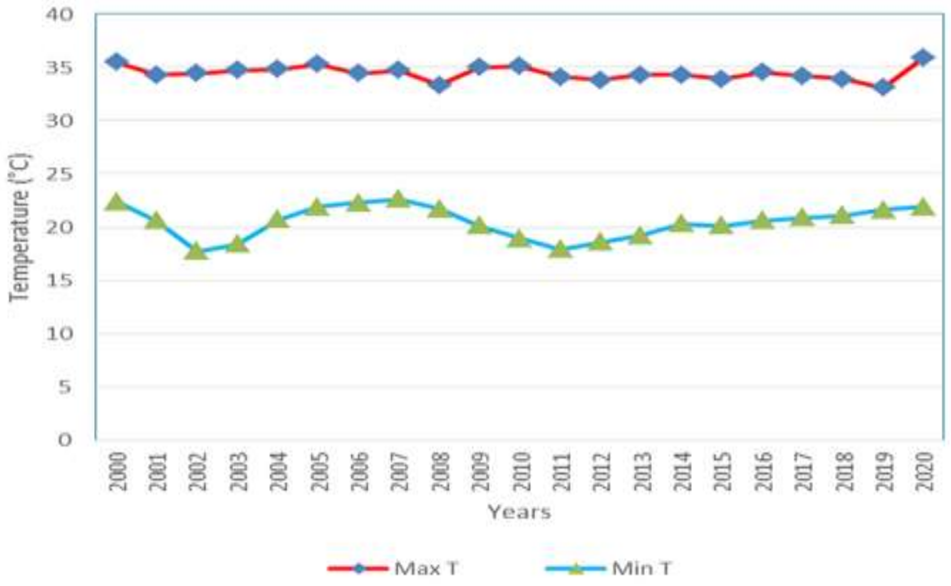
Climate Change Situations (Rainfall and Temperature) of Magway Township from 2000-2020 are shown in Figures (4.3) and (4.4).



Source: Statistical Year Book (2000-2020)

Figure (4.3) Rainfall Situations (mm) in Magway Township, 2000-2020

Figure (4.3) displays that annual rainfall has a large fluctuation over the period 2000-2020. The highest amount of annual rainfall was received in 2003 with 1735 mm. In contrast, the lowest annual rainfall was happened in 2020 with 584 mm. The wet years (higher annual rainfall years) are 2001, 2002, 2003, 2004, 2008, 2009, 2013 and 2017. The dried years (lower annual rainfall years) are 2005, 2007, 2015, 2019 and 2020. Based on the observations, rainfall will be expected to gradually fallen in future (See Appendix – A).



Source: Statistical Year Book (2000-2020)

Figure (4.4) Temperature Situations (°C) in Magway Township, 2000-2020

Figure (4.4) indicates that annual mean temperature is fluctuating over the period 2000-2020 and it has a slightly change in situation. The highest mean temperature is 35.9 °C in 2020, whereas the lowest mean temperature is 17.7 °C in 2002. The largest difference between the minimum and maximum temperatures was found in 2002 and it was a net difference of 16.7°C. Hence, 2002 has the highest variation range in mean temperature while conducting the study. The mean minimum temperature has a bi-model shape which has two times of the lowest temperature happened in 2002 and 2011. The mean maximum temperature has no distinct variation, but the lowest of it happened in 2008 and 2019. In future, the mean temperature will be slightly increased, based on the previous situation (See Appendix – A).

Descriptive statistics of climate change situations in Magway Township during 2000 to 2020 are displayed in Table (4.3).

Table (4.3)

Descriptive Statistics of Climate Change Situations in Magway Township

Variable	Mean	Standard Deviation (SD)	Minimum	Maximum
Rainfall (mm)	972	264.748	584	1735
Maximum temperature (℃)	34.452	0.6831	33.1	35.9
Minimum temperature (℃)	20.452	1.5098	17.7	22.6

Source: Statistical Years Book (2000-2020)

The rainfall, maximum temperature, and minimum temperature of Magway Township during 2000-2020 are presented in Table (4.3). The average rainfall was 972 mm (SD = 264.748), the average maximum temperature was 34.452℃ (SD = 0.6831) and the average minimum temperature was 20.452℃ (SD = 1.5098) during 2000-2020.

4.2 The Fixed Effects Model for the Impacts of Climate Change on Selected Crop Yields

The linearity of the relationship between dependent variable (crop yields per acre) and independent variables (rainfall, maximum temperature, minimum temperature, and harvested area in acre) was checked using the scatter plot matrix (See Appendix-B). It is indicated that the relationship is non-linear. Therefore, the dependent variable and independent variables are used in the form of log transformation.

The dependent variable and the independent variables are analyzed by using fixed effects model. The fixed effects model for crop yields per acre, selected climate indicators, and harvested area in acre is as follows.

$$Ln\ (Yield_{it}) = \beta_{1i} + \beta_{2i}Ln\ (Rainfall_{2it}) + \beta_{3i}Ln\ (Maxtem_{3it}) + \beta_{4i}Ln\ (Mintem_{4it}) + \beta_{5i}Ln\ (Area_{5it})$$

where,

i = Crops (1,2,…,6)

t = Time (1,2,…,21)

β_1= Intercept

β_2 = Slope of the Rainfall

β_3 = Slope of the Maximum Temperature

β_4 = Slope of the Minimum Temperature

β_5 = Slope of the harvested area in Acre

Ln (Yield) = log of Crop Yields per Acre

Ln (Rainfall) = log of Rainfall

Ln (Maxtem) = log of Maximum Temperature

Ln (Mintem) = log of Minimum Temperature

Ln (Area) = log of Harvested Area in Acre

The fixed effects model for crop yields per acre, selected climate situations, and harvested area in acre in Magway Township are presented in Table (4.4).

Table (4.4)

Summary Results of Fixed Effects Model for Crop Yields

Variables	Coefficient	Std.error	t	P-value
Constant	9.6115***	1.9132	5.02	0.000
Ln(Rainfall)	-0.3178***	0.1018	-3.12	0.002
Ln(Maximum Temperature)	-2.9827**	1.1640	-2.56	0.012
Ln(Minimum Temperature)	-1.1565***	0.3529	-3.28	0.001
Ln(Harvested Area)	0.0369	0.0249	1.48	0.141
Sigma U	0.3538			
Sigma e	0.1071			
Rho	0.9161			
F (4, 116)	5.54***			
P-value	0.0004			

Source: STATA output from APPENDIX-C, Table (C-1)

***Statistically significant at 5% level and 1% level

According to the result of Table (4.4), the overall model is statistically significant at 1% level. It designates that all the coefficients in the model are different than zero and it explains the goodness fit of the model.

The results also showed that Rainfall, Maximum Temperature, and Minimum Temperature are statistically significant at 5% level and 1% level. But, Harvested Area is not statistically significant. The estimated fixed effects model for crop yields per acre in Magway Township can be indicated as follows.

$$Ln(Yield_{it}) = 9.6115 - 0.3178\, Ln(Rainfall_{it}) - 2.9827 Ln(Maxtem_{it}) - 1.1565\, Ln(Mintem_{it}) + 0.0369\, Ln(Area_{it})$$

From the above equation, rainfall, maximum temperature, and minimum temperature have negatively related with crop yields. If rainfall increases by 1%, yields per acre will be decreased by 0.3178% when maximum temperature, minimum temperature, and harvested area are constant. If maximum temperature increases by 1%, yields per acre will be decreased by 2.9827% when rainfall, minimum temperature, and harvested area are constant. If minimum temperature increases by

1%, yields per hectare will be decreased by 1.1565% when rainfall, maximum temperature, and harvested area are constant. Thus, it can be concluded that rainfall, maximum temperature, and minimum temperature increase, yields per acre will be decreased. The Rho value is 0.9161. This means that 91.61% of the variance is due to differences across panels.

4.3 The Random Effects Model for the Impacts of Climate Change on Selected Crop Yields

The explained variable (crop yields per acre) and the four explanatory variables (rainfall, maximum temperature, minimum temperature, and harvested area in acre) are analyzed by using random effects model. The random effects model for crop yields per acre, selected climate situations, and harvested area in acre is as follows.

$$Ln\ (Yield_{it}) = \beta_{1i} + \beta_{2i} Ln\ (Rainfall_{2it}) + \beta_{3i} Ln\ (Maxtem_{3it}) + \beta_{4i} Ln\ (Mintem_{4it}) + \beta_{5i} Ln\ (Area_{5it})$$

The random effects model for crop yields per acre, selected climate situations, and harvested area in acre in Magway Township are presented in Table (4.5).

Table (4.5)

Summary Results of Random Effects Model for Crop Yields

Variables	Coefficient	Std.error	t	P-value
Constant	9.6093***	1.9144	5.02	0.000
Ln(Rainfall)	-0.3169***	0.1015	-3.12	0.002
Ln(Maximum Temperature)	-2.9769***	1.1610	-2.56	0.010
Ln(Minimum Temperature)	-1.1590***	0.3520	-3.29	0.001
Ln(Harvested Area)	0.0355	0.0247	1.44	0.151
Sigma U	0.3773			
Sigma e	0.1071			
Rho	0.9255			
Wald χ^2	22.13***			
P-value	0.0002			

Source: STATA output from APPENDIX-C, Table (C-2)

***Statistically significant at 1% level

According to the result of Table (4.5), the overall model is statistically significant at 1% level. It indicates that all the coefficients in the model are different than zero and it explains the goodness fit of the model.

The result also expressed that Rainfall, Maximum Temperature, and Minimum Temperature are statistically significant at 1% level. However, Harvested Area is not statistically significant. The estimated random effects model for crop yields per acre in Magway Township can be demonstrated as follows.

$$Ln(Yield_{it}) = 9.6093 - 0.3169\, Ln(Rainfall_{it}) - 2.9769\, Ln(Maxtem_{it}) - 1.1590\, Ln(Mintem_{it}) + 0.0355\, Ln(Area_{it})$$

From the above equation, rainfall, maximum temperature, and minimum temperature have negatively related with crop yields. If rainfall increases by 1%, yields per acre will be decreased by 0.3169% when maximum temperature, minimum temperature, and harvested area are constant. If maximum temperature increases by 1%, yields per acre will be decreased by 2.9769% when rainfall, minimum temperature, and harvested area are constant. If minimum temperature increases by 1%, yields per hectare will be decreased by 1.1590% when rainfall, maximum temperature, and harvested area are constant. Thus, it can be concluded that rainfall, maximum temperature, and minimum temperature increase, yields per acre will be decreased. The Rho value is 0.9255. This means that 92.55% of the variance is due to differences across panels.

4.4 Hausman Test for the Impacts of Climate Change on Selected Crop Yields

The Hausman test is used to decide appropriate model between fixed effect model and random effect model. Table (4.6) presents the results of Hausman test.

Table (4.6)

Estimate the Results of Hausman Test

Variables	Coefficients		(b-B) Difference	Standard Error
	(b) Fixed Effects Model	(B) Random Effects Model		
Ln(Rainfall)	-0.3178	-0.3169	-0.0009	0.0075
Ln(Maximum Temperature)	-2.9827	-2.9769	-0.0057	0.0842
Ln(Minimum Temperature)	-1.1565	-1.1590	0.0024	0.0257
Ln(Harvested Area)	0.0369	0.0355	0.0014	0.0029

Source: STATA output from APPENDIX-C, Table (C-3)

The null hypothesis is that the coefficients estimated by random effects model is appropriate. Conversely, the alternative hypothesis is the coefficients estimated by fixed effects model is appropriate. According to the result of Appendix-C, Table (C-3), the test statistic is $\chi^2 = 0.23$ with P-value = 0.9936. The Hausman test, P-value 0.9936 is greater than 0.05. It means that the null hypothesis is failed to reject. Hence, it can be concluded that the random effects model is more appropriate for this study.

4.5 Breusch and Pagan Lagrangian Multiplier Test for Random Effects

Breusch and Pagan Lagrangian multiplier test is used to determine appropriate model between ordinary least squares model and random effects model. The null hypothesis is that the ordinary least squares model is appropriate. The alternative hypothesis is the random effects model is appropriate. According to the result of Appendix C, Table (C-4), the test statistic is $\chi^2 = 974.52^{***}$ with P-value = 0.0000. The Hausman test, P-value 0.0000 is less than 0.05. It means that the null hypothesis is rejected. Therefore, it can be concluded that the random effects model is appropriate.

4.6 Diagnostic Checking on Random Effects Model

If there is heteroskedasticity and auto-correlation in the model, the result can't represent actual situation. Therefore, heteroskedasticity and auto-correlation diagnostic tests for random effect model are done in this study. Lagrange Multiplier LM test and Wooldridge test are used to examine equal variance of residuals and auto-correlation in the random effect model.

4.6.1 Diagnostic Testing on Heteroskedasticity

Lagrange Multiplier LM test is used to analyze the heteroskedasticity in the random effects model. The null hypothesis is a statistical hypothesis that states that the random effects model is homoscedasticity. The alternative hypothesis is the random effect model is heteroskedasticity. According to the result of Appendix C, Table (C-5), the test statistic is $\chi^2 = 2198.6558^{***}$ with P-value = 0.0000. The Lagrange Multiplier LM test P-value 0.0000 is less than 0.05. It denotes that the null hypothesis is rejected. Thus, it can be concluded that there is heteroskedasticity in the model.

4.6.2 Diagnostic Testing on First-order Auto-correlation

The Wooldridge test is used to examine for first-order auto-correlation in the model. The null hypothesis specifies that there is no first-order auto-correlation in the model. Reversely, the alternative hypothesis states that there is first-order auto-correlation in the model. According to the finding of Appendix C, Table (C-6), the test statistic is $F(1, 5) = 7.138^{**}$ with P-value = 0.0443. The Wooldridge test P-value 0.0443 is less than 0.05. It means that the null hypothesis is rejected. Hence, it can be indicated that there is first-order auto-correlation in the model.

4.7 Feasible Generalized Least Squares (FGLS) Model

According to Hausman test and Breusch and Pagan Lagrangian multiplier test results, random effects model was defined as appropriate model. After diagnostic with Lagrange Multiplier LM test and Wooldridge test, it was established that there are heteroskedasticity and first order auto-correlation in the random effects model. Thus, random effects model should not use for this study. And then, Feasible Generalized

Least Squares (FGLS) model is used to remedy heteroskedasticity and auto-correlation in the model.

$$Ln\ (Yields_{it}) = \beta_{1i} + \beta_{2i} Ln\ (Rainfall_{2it}) + \beta_{3i} Ln\ (Maxtem_{3it}) + \beta_{4i} Ln\ (Mintem_{4it}) + \ \beta_{5i} Ln\ (Area_{5it})$$

The feasible generalized least squares (FGLS) model for crop yields per acre, selected climate situations, and harvested area in acre in Magway Township are presented in Table (4.7).

Table (4.7)

Summary Results of Feasible Generalized Least Squares (FGLS) Model for Crop Yields

Variable	Coefficient	Std. error	t	P-value
Constant	3.0611***	0.9379	3.26	0.001
Ln(Rainfall)	-0.0877*	0.0501	-1.75	0.080
Ln(Maximum Temperature)	-0.2741	0.5236	-0.52	0.601
Ln(Minimum Temperature)	-0.0993	0.2457	-0.40	0.686
Ln(Harvested Area)	0.1324***	0.0394	3.36	0.001
Wald χ^2	14.36***			
P-value	0.0062			

Source: STATA output from APPENDIX-C, Table (C-7)

***Statistically significant at 10% level and 1% level

According to the result of Table (4.7), the overall model is statistically significant at 1% level. It shows that all the coefficients in the model are different than zero and it explains the goodness fit of the model.

The result also discovered that Rainfall and Harvested Area are statistically significant at 10% level and 1% level. Although, Maximum Temperature and Minimum Temperature are not statistically significant. The feasible generalized least squares (FGLS) model for crop yields per acre in Magway Township can be revealed as follows.

$$Ln(Yield_{it}) = 3.0611 - 0.0877\ Ln(Rainfall_{it}) - 0.2741\ Ln(Maxtem_{it}) - 0.0993\ Ln(Mintem_{it}) + 0.1324\ Ln(Area_{it})$$

From the above equation, it is found that Rainfall has negative effects and Harvested Area has positive effects on crop yields per acre. If rainfall increases by 1%, yields per acre will be decreased by 0.0877% when maximum temperature, minimum temperature, and harvested area are constant. Thus, it can be concluded that if rainfall increases, yields per acre will be decreased. Studies have shown that an increase in the rainfall during ripening can have serious implications on the growth of the crops. It can lead to a rise in the moisture level in the tissue giving way to crops growth. Moreover, it can destroy the harvest leading to a low yield. Numerous factors, including as direct physical damage, delayed planting and harvesting, constrained root growth, oxygen insufficiency, and nutrient loss can all be attributed to excessive rainfall's negative effects on crop output. Another reason could be the seasonal variations in the rainfall which may impress the sowing and harvesting schedule of crops, disturbing the production of crops patterns leading to low yields of productivity.

If harvested area increases by 1%, yields per acre will be increased by 0.1324% when rainfall, maximum temperature, and minimum temperature are constant. Hence, it can be achieved that if harvested area increases, yields per acre will be increased. According to the review, an increase in the harvested area would lead to greater productivity of crops. Thus, the more the harvested area, the higher will be the area under crops cultivation, leading to greater productivity. Installment of irrigation systems, creating canals, and training farmers on the application involve a great amount of investment by the government to raise the production of crops. Gradual changes in the climate are leading to precipitation variations, temperature variations and thus, increase in the harvested lands and rather than relying on varying weather conditions will increase the productivity of crops.

CHAPTER V

CONCLUSION

This chapter presents the findings and discussions for the impacts of climate change on crop yields in Magway Township, recommendations and needs for further research.

5.1 Findings and Discussions

In this study, the impacts of climate situations (rainfall, maximum temperature, and minimum temperature) and harvested area on crop yields (paddy, groundnut, sesame, sunflower, green gram, and pigeon pea) are analyzed by using the panel regression analysis over the period from 2000 to 2020 in Magway Township.

Then descriptive analysis are used and it is established that the crop yields per acre in Paddy and Groundnut practice upward situations between 2000 to 2020 and the lowest yield among them was from the Sesame crop with 131.6 kg per year in 2020. The harvested area of selected crop yields in Sesame experiences the highest between 2000 to 2020 and the lowest harvested area was the Paddy, before the Sunflower changes in 2020. The amount of Annual Rainfall was appeared the highest in 2003 with 1735 mm and the lowest was received in 2020 with 584 mm. Switching to Annual Mean Temperature, there is a highest in 2020 with 35.9 ℃ and the lowest is happened in 2002 with 17.7 ℃.

Furthermore, the panel data regression models (fixed effects model and random effects model) are operated to analyze the panel data. According to the outcomes of the fixed effects model and the random effects model, the coefficients of rainfall, maximum temperature, and minimum temperature have significant and negatively correlated on crops yields. Hausman test is used to choose the appropriate among the two models – fixed effects model and random effects model. According to the result of Hausman test, the random effects model is more effective than the fixed effects model. Besides the Hausman test, the Breusch and Pagan Lagrangian multiplier test is used to determine the appropriate model between ordinary least squares model and random effects model. The result showed that random effects model is appropriate than ordinary least squares model. Hence, the random effects model is the most appropriate for this study.

In addition, diagnostic tests (Lagrange Multiplier LM test and Wooldridge test) are undertaken to examine equal variance of residual and serial correlation in the random effects model. The results show that the random effects model has equal variance of residual and serial correlation. Therefore, feasible generalized least squares model is used to remedy equal variance of residual and serial correlation in the model. The feasible generalized least squares model indicates that the rainfall is significant and negatively related on crops yields. In addition, the harvested is significant and positively associated on crop yields. However, the maximum temperature and minimum temperature have not significant level, it's not effect on crop yields.

The findings showed that an increase in rainfall, can lead to crop yields decline and an increase in harvested area, can lead to crop yields progress. The results of study is consistent the study of Nang Ei Mon The (2012) which expressed the impact of climate change on rural likelihoods in Pakokku Township, Magway Region, Myanmar. In this study, the multiple regression models was analyzed the relationship between (average maximum temperature, average minimum temperature, and average rainfall) were used as the independent variables and yield of some major crops (paddy, groundnut, and sesame) are recorded as the dependent variable. According to multiple regression analysis result, rainfall has significant and negative relationship with yield of groundnut.

The results of study also is inline the study of Poudel and Shaw (2016) which examined the relationship between climate variability and crop yield in Lamjung Distict, Nepal. The multiple regression models was analyzed the relationship between the independent variables (summer and winter; precipitation, maximum temperature, and minimum temperature) and the dependent variable (rice, maize, millet, wheat, and barley). According to the result, summer precipitation has significant and negative relationship on the production of maize crop.

The results of study is consistent the study of Htoo (2021) which indicated the macro analysis of climate change and agricultural production in Myanmar. The multiple regression model was performed to observe the relationship between the independent variables (average annual maximum, minimum temperatures, average annual precipitation, application of fertilizer consumption, and phosphate and potash) and dependent variable (cereal crop production in kg per hectare). According to multiple regression analysis result, rainfall has significant and negative relationship on the production of cereal crops.

The results of study is in line the study of Byishimo (2017) which mentioned the assessment of climate change impacts on crop yields and farmer's adaptation measures: a case of Rwanda. In this study expressed finding of the regression model was analyzed to examine the association between the explanatory variables (area harvested, annual rainfall, maximum and minimum temperatures, floods, and droughts) and the explained variable (crop yields). Based on the result, an increase in area harvested has a positive and significant effect on maize, cassava and Irish potato yields.

5.2 Recommendations

The climate change effects on agriculture of rural people in Magway Township need a multiple approach to tackle the issues. According to the results, agriculture sector was influenced by the climate change effects. Hence, more improved technology; suitable varieties, trainings for farmers are recommended to combat with the risk associated as a consequent of climate shift. Moreover, local cropping calendars should be updated to suit the changing weather pattern and disseminate to the community. Agricultural workers must be followed by government adaptation policies about the so that they can adjust to climate change without unnecessary losses to agricultural production. There is also needed to reduce landless poor and unemployment by enhancing the microfinance efficiency and creating employment opportunities in order to administer the climate change effects.

Policies that are aimed at promoting farm-level awareness need to emphasize the critical role of provision of improved extension together with information about climate change. Educational and outreach plan on climate shift should also be encouraged. In addition, appropriate policies and mechanisms need to be developed for this purpose. The policies and mechanisms have to balance among economic, society and environment aspects. Modern techniques also play a crucial role in assisting farmers in adjusting to climate alteration. Therefore, the government should support the change from manual farming to mechanized farming. For example, providing knowledge about machinery, facilitating easy purchase of necessary equipment and disseminating greenhouse cultivation techniques. A system of agricultural disaster insurance or weather index insurance should be introduced in Myanmar to compensate for losses by farmers through drought and flood. A drought and flood management system could include relief activities for the welfare of those who are impoverished and who cannot afford to take disaster insurance.

Agricultural planning must be able in a position to respond to short and long-term changes in climate. Based on the research, as major source of climate change information was radio and television, therefore, dissemination of climate information by radio should be promoted with more attractive and effective programs. Moreover, the information should be disseminated by timely and regularly. It was seen that climate change would negative impacts on yield of crops in Magway Township for which it is needed to give more important by introducing suitable variety and appropriate technologies so that farmers are able to modify to the situations. Magway Township is a tropical region, as it is an area with rain fed. Therefore, the government should be built dams and creation of canals to use irrigation systems in agriculture.

5.3 Needs for Further Research

This study was conducted in only a Magway Township within Magway Region. As the remaining of the researchers, it is necessary to study the states and regions in the Central Dry Zone and the Delta Zone, which are the harsh climate regions of Myanmar. It is probable to study and compare the relationship between rainfall and temperatures according to crops, in addition to study the same crop from different regions by year. Instead of the studied panel regression analysis, it is also possible to analyze with multi-level analysis. In addition, climate change adaptation and mitigation policies should be developed at a national level. For farmers who mainly work in rural agriculture, it is to protect against climate change and to improve and optimize agriculture in the future.

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APPENDICES

APPENDIX – A

Table (A – 1): Crop Yields per Acre and Harvested Area in Acre of Paddy (2000-2020)

Year	Crop Yields per Acre (kg)	Harvested Area in Acre
2000	1295.406	4135
2001	1308.965	4270
2002	1312.094	5055
2003	1324.61	5120
2004	1339.6292	4594
2005	1407.8414	6443
2006	1506.3006	7633
2007	1544.0572	7709
2008	1712.3974	7964
2009	1740.1412	8882
2010	1767.2592	9048
2011	1830.465	8950
2012	1848.8218	8995
2013	1851.9508	9008
2014	1819.2006	7997
2015	1821.9124	5991
2016	1732.2144	2793
2017	1562.8312	2450
2018	1336.5002	2075
2019	1496.0792	2026
2020	1463.5376	2578

Source: Department of Agriculture (2000-2020)

Table (A – 2): Crop Yields per Acre and Harvested Area in Acre of Groundnut (2000-2020)

Year	Crop Yields per Acre (kg)	Harvested Area in Acre
2000	1327.055	40050
2001	1308.0474	40425
2002	1291.8214	41850
2003	1300.398	42050
2004	1307.352	42732
2005	1343.0492	42767
2006	1332.85	42734
2007	1346.5262	42886
2008	1390.5682	45849
2009	1553.5236	46064
2010	1554.6826	46470
2011	1592.0024	54087
2012	1597.7974	54301
2013	1626.077	54689
2014	1637.667	53231
2015	1623.5272	54181
2016	1349.076	71864
2017	1373.1832	107052
2018	1085.7512	58892
2019	1022.4698	71776
2020	1041.4774	115473

Source: Department of Agriculture (2000-2020)

Table (A – 3): Crop Yields per Acre and Harvested Area in Acre of Sesame (2000-2020)

Year	Crop Yields per Acre (kg)	Harvested Area in Acre
2000	231.035	180453
2001	312.375	180745
2002	219.275	181250
2003	191.835	182020
2004	264.6	184314
2005	169.295	186638
2006	300.37	186922
2007	302.82	187693
2008	318.255	188291
2009	318.745	188391
2010	319.48	188155
2011	362.11	181081
2012	363.09	186471
2013	363.825	180504
2014	365.785	182326
2015	341.285	182409
2016	330.75	182600
2017	218.54	181326
2018	158.025	168215
2019	171.255	183562
2020	131.565	128226

Source: Department of Agriculture (2000-2020)

Table (A – 4): Crop Yields per Acre and Harvested Area in Acre of Sunflower (2000-2020)

Year	Crop Yields per Acre (kg)	Harvested Area in Acre
2000	183.75	10384
2001	156.6	10355
2002	186.45	10395
2003	147.45	10410
2004	146.1	10414
2005	298.05	10832
2006	184.2	9231
2007	274.2	16347
2008	281.25	16352
2009	299.85	16501
2010	323.7	15835
2011	366.45	15831
2012	331.95	9647
2013	330.45	10216
2014	364.35	8375
2015	352.05	7395
2016	369.45	1551
2017	355.95	195
2018	357.9	273
2019	352.5	151
2020	190.5	20

Source: Department of Agriculture (2000-2020)

Table (A – 5): Crop Yields per Acre and Harvested Area in Acre of Green gram (2000-2020)

Year	Crop Yields per Acre (kg)	Harvested Area in Acre
2000	301.76	63492
2001	323.84	59873
2002	285.76	60782
2003	280.64	63454
2004	277.12	63733
2005	328.64	59750
2006	343.68	62345
2007	376	62591
2008	379.2	60271
2009	456	63553
2010	515.52	63905
2011	514.88	64930
2012	516.8	64856
2013	537.6	64893
2014	520.32	68457
2015	518.72	63915
2016	464.64	53559
2017	399.36	31979
2018	265.28	25241
2019	289.92	20776
2020	284.8	26377

Source: Department of Agriculture (2000-2020)

Table (A – 6): Crop Yields per Acre and Harvested Area in Acre of Pigeon pea (2000-2020)

Year	Crop Yields per Acre (kg)	Harvested Area in Acre
2000	407.769	29638
2001	351.525	30705
2002	293.973	30045
2003	282.201	30455
2004	269.775	30455
2005	527.124	31152
2006	335.175	31667
2007	547.725	33088
2008	572.25	33112
2009	573.885	33675
2010	580.425	33684
2011	550.995	33750
2012	550.995	33752
2013	550.995	33697
2014	550.995	32069
2015	552.63	31081
2016	570.942	28616
2017	418.233	21391
2018	259.638	2069
2019	275.334	1489
2020	298.878	1708

Source: Department of Agriculture (2000-2020)

Table (A – 7): Rainfall, Maximum Temperature and Minimum Temperature of Magway Township (2000-2020)

Year	Rainfall (mm)	Maximum Temperature (℃)	Minimum Temperature (℃)
2000	810	35.5	22.4
2001	1191	34.3	20.6
2002	1283	34.4	17.7
2003	1735	34.7	18.4
2004	1171	34.8	20.7
2005	605	35.3	21.9
2006	1006	34.4	22.3
2007	746	34.7	22.6
2008	1051	33.3	21.7
2009	1141	35	20.1
2010	802	35.1	18.9
2011	903	34.1	17.9
2012	962	33.8	18.6
2013	1175	34.3	19.2
2014	963	34.3	20.3
2015	712	33.9	20.1
2016	898	34.5	20.6
2017	1065	34.2	20.9
2018	914	33.9	21.1
2019	695	33.1	21.6
2020	584	35.9	21.9

Source: Statistical Year Book (2000-2020)

APPENDIX – B

Table (B-1): The Scatter Plot Matrix for Paddy (Kg) (2000-2020)

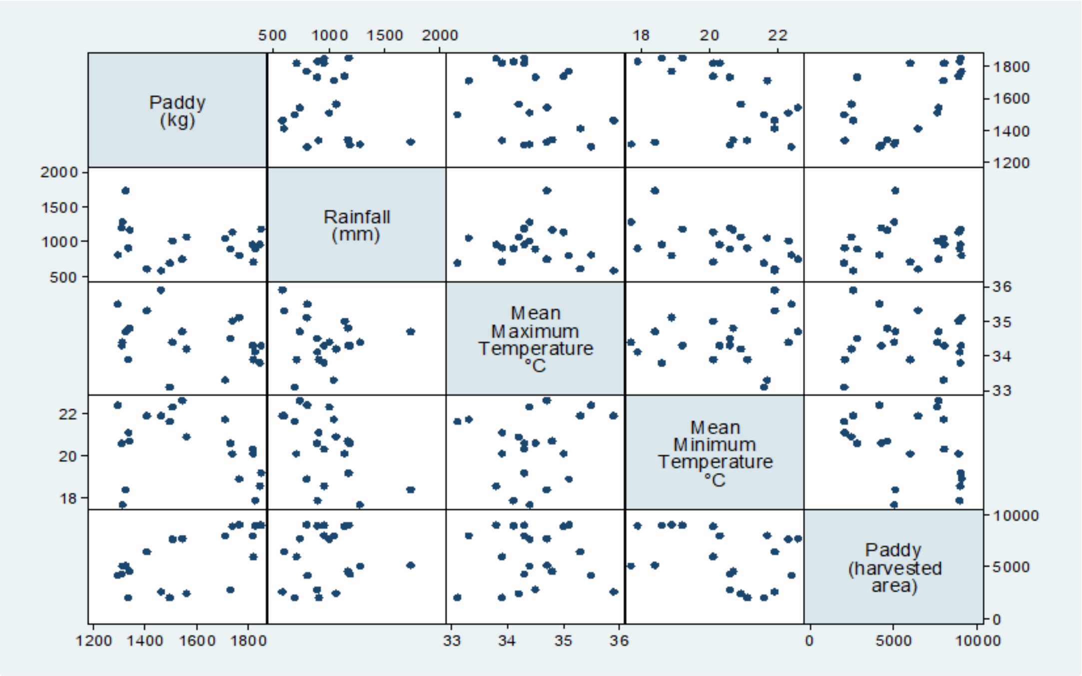


Table (B-2): The Scatter Plot Matrix for Groundnut (Kg) (2000-2020)

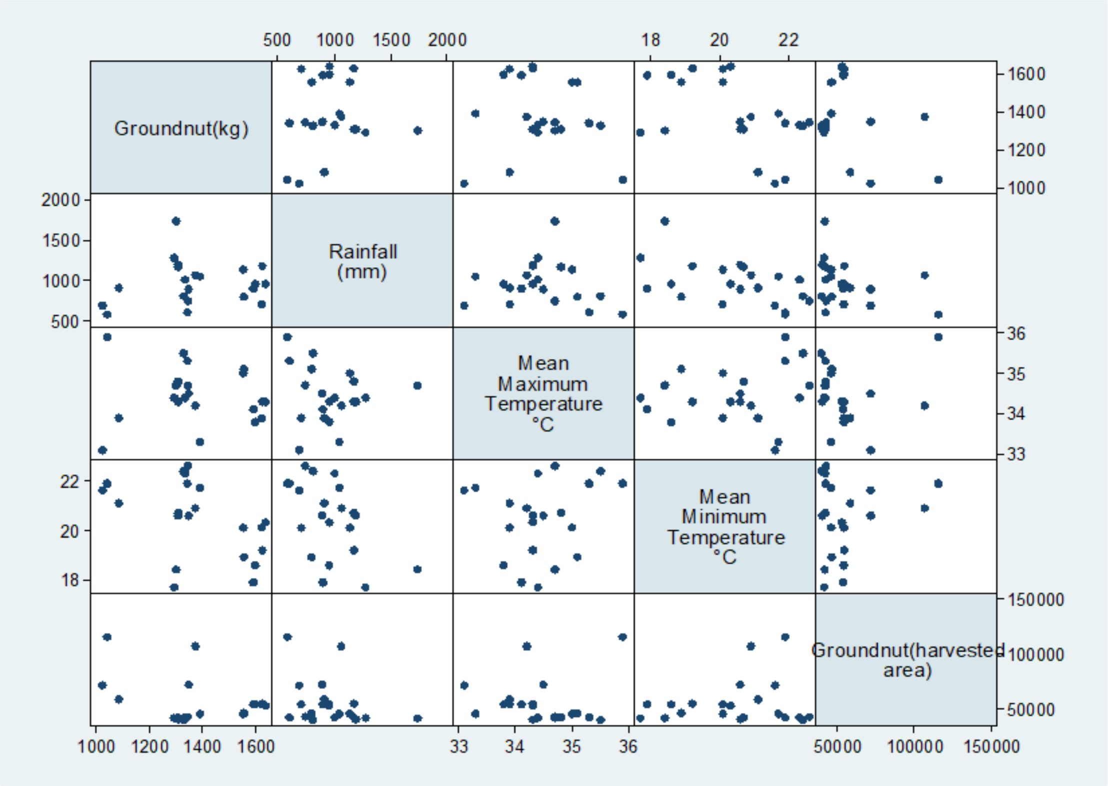


Table (B-3): The Scatter Plot Matrix for Sesame (Kg) (2000-2020)

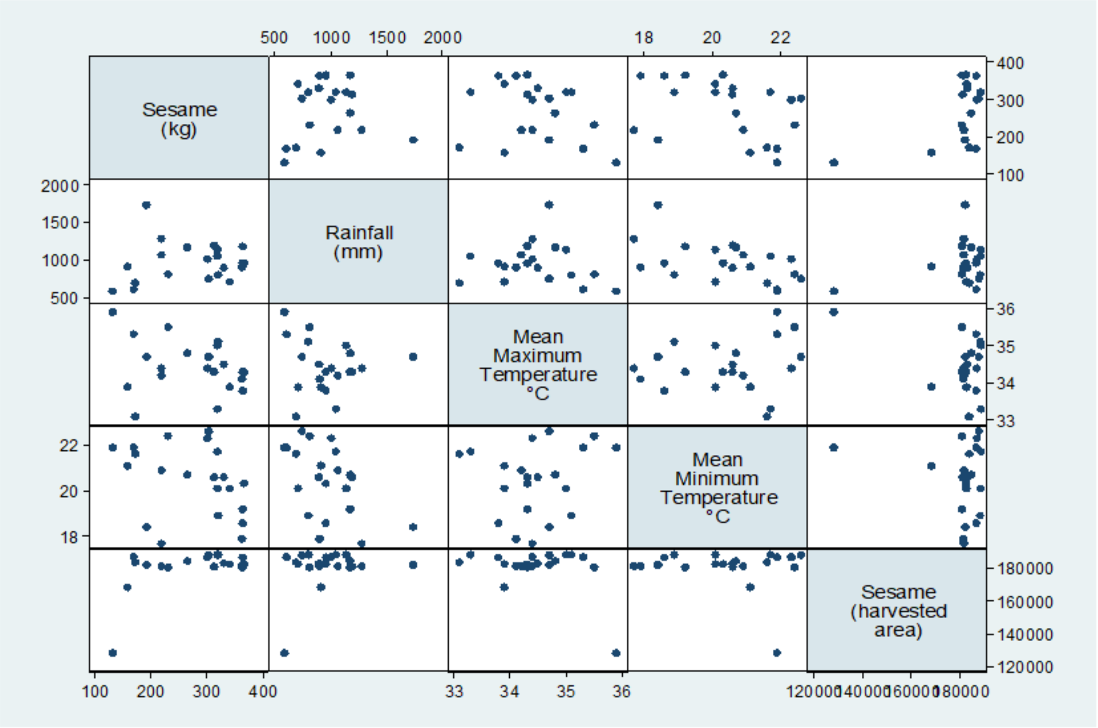


Table (B-4): The Scatter Plot Matrix for Sunflower (Kg) (2000-2020)

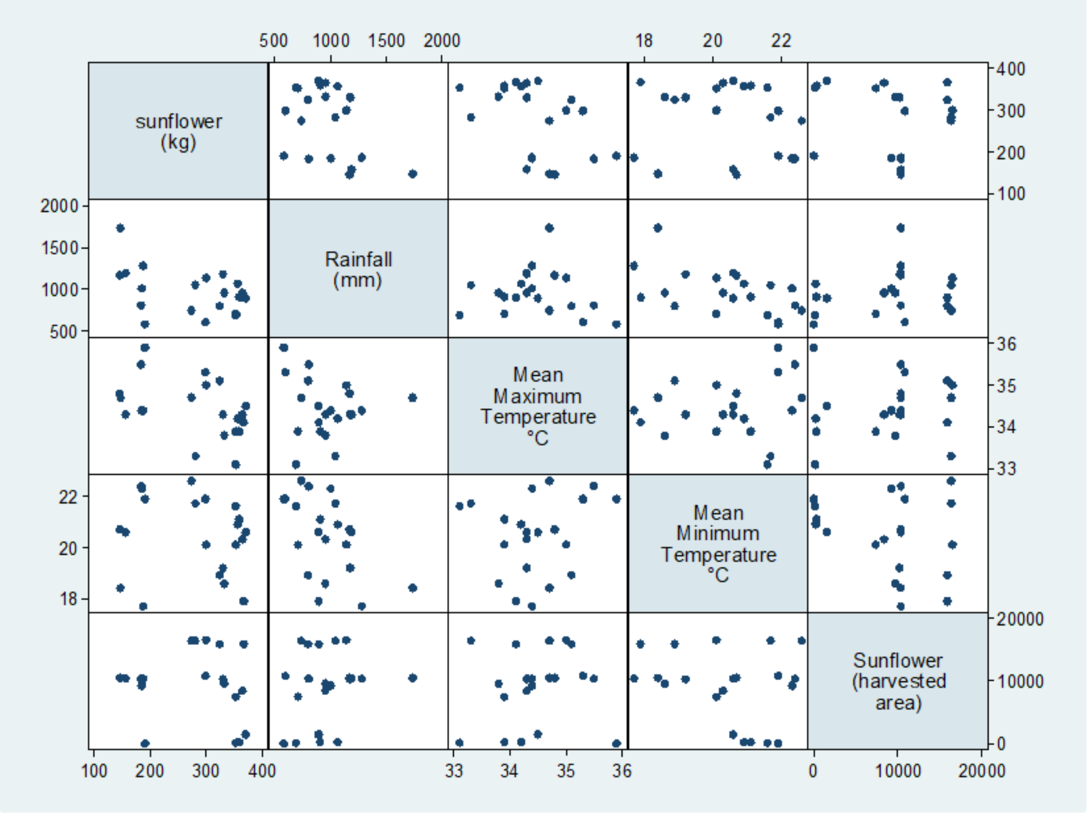


Table (B-5): The Scatter Plot Matrix for Green gram (Kg) (2000-2020)

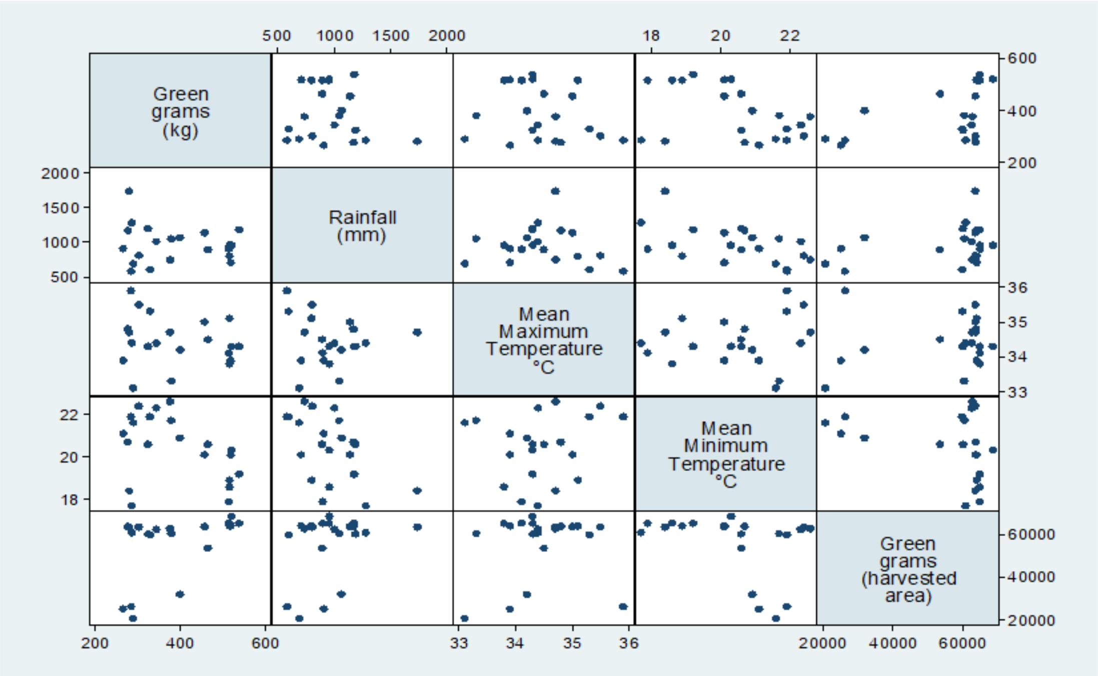
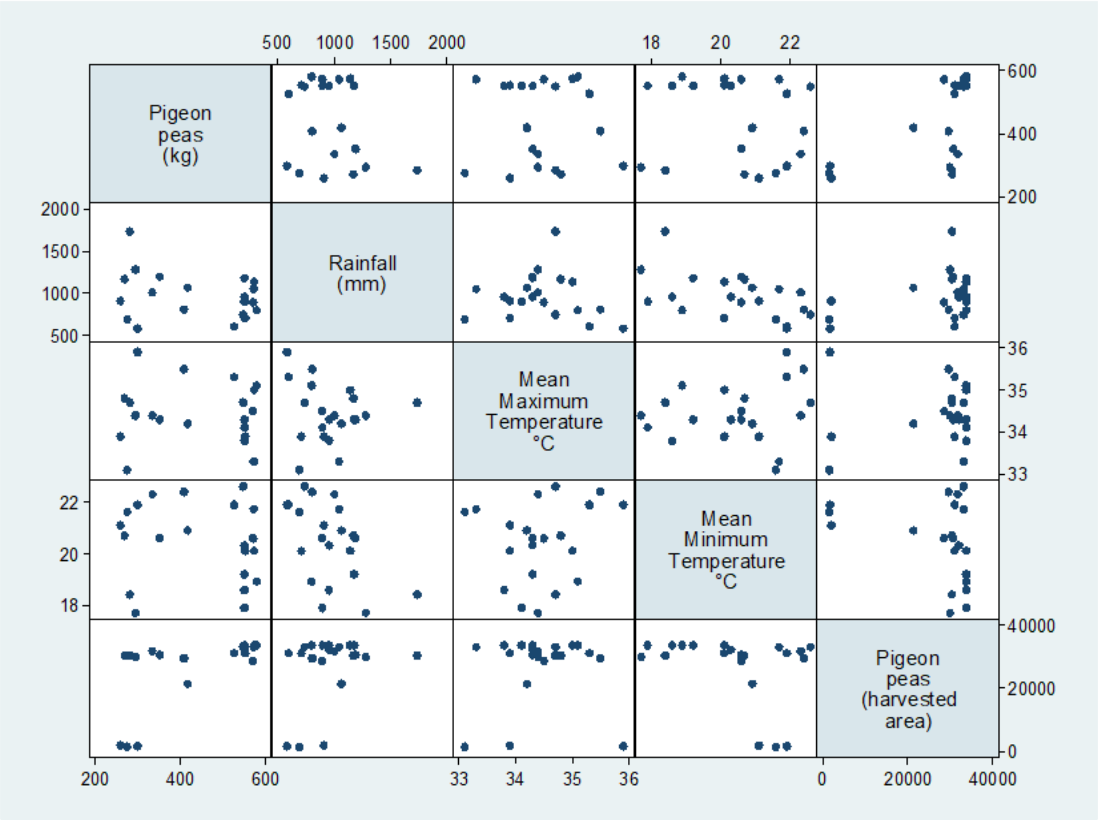


Table (B-6): The Scatter Plot Matrix for Pigeon pea (Kg) (2000-2020)



APPENDIX – C

Table (C – 1): The Stata Output of Fixed Effects Model

Fixed-effects (within) regression Number of obs = 126

Group variable: Crops1 Number of groups = 6

R-sq: Obs per group:

within = 0.1604 min = 21

between = 0.0539 avg = 21.0

overall = 0.0007 max = 21

F (4,116) = 5.54

corr(u_i, Xb) = -0.1259 Prob > F = 0.0004

lnYieldskg	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
lnrainfall	-.3178411	.1017924	-3.12	0.002	-.5194538	-.1162284
lnmaxtem	-2.982658	1.164002	-2.56	0.012	-5.288112	-.6772046
lnmintem	-1.156546	.3529433	-3.28	0.001	-1.855595	-.4574977
lnarea	.0368882	.0248807	1.48	0.141	-.0123912	.0861676
_cons	9.611479	1.913217	5.02	0.000	5.822112	13.40085
sigma_u	.35377492					
sigma_e	.10706455					
rho	.91609678	(fraction of variance due to u_i)				

F test that all u_i=0: F(5, 116) = 215.54 Prob > F = 0.0000

Table (C – 2): The Stata Output of Random Effects Model

Random-effects GLS regression   Number of obs = 126

Group variable: Crops1   Number of groups = 6

R-sq: Obs per group:

within = 0.1604   min = 21

between = 0.0539   avg = 21.0

overall = 0.0009   max = 21

Wald chi2(4) = 22.13

corr(u_i, X) = 0 (assumed)   Prob > chi2 = 0.0002

lnYieldskg	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
lnrainfall	-.3169192	.1015182	-3.12	0.002	-.5158911	-.1179472
lnmaxtem	-2.976946	1.160956	-2.56	0.010	-5.252378	-.7015137
lnmintem	-1.158976	.3520087	-3.29	0.001	-1.848901	-.4690519
lnarea	.0354765	.0247097	1.44	0.151	-.0129536	.0839066
_cons	9.609343	1.914443	5.02	0.000	5.857104	13.36158
sigma_u	.3773297					
sigma_e	.10706455					
rho	.92548896	(fraction of variance due to u_i)				

Table (C – 3): The Stata Output of Hausman Test

	---- Coefficients ----			
	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	fe	re	Difference	S.E.
lnrainfall	-.3178411	-.3169192	-.0009219	.0074671
lnmaxtem	-2.982658	-2.976946	-.0057124	.0841589
lnmintem	-1.156546	-1.158976	.0024298	.0256687
lnarea	.0368882	.0354765	.0014117	.0029121

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2 (4) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 0.23

Prob>chi2 = 0.9936

Table (C – 4): The Stata Output of Breusch and Pagan Lagrangian Multiplier Test for Random Effects

Breusch and Pagan Lagrangian multiplier test for random effects

lnYieldskg[Crops1,t] = Xb + u[Crops1] + e[Crops1,t]

Estimated results:

	Var	sd = sqrt(Var)
lnYield~g	.1141833	.3379102
e	.0114628	.1070645
u	.1423777	.3773297

Test: Var(u) = 0

chibar2(01) = 974.52

Prob > chibar2 = 0.0000

Table (C – 5): The Stata Output of Lagrange Multiplier Test for Heteroskedasticity

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* Panel Groupwise Heteroscedasticity Tests

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Ho: Panel Homoscedasticity - Ha: Panel Groupwise Heteroscedasticity

- Lagrange Multiplier LM Test	=2198.6558	P-Value > Chi2 (5)	0.0000
- Likelihood Ratio LR Test	= 32.2340	P-Value > Chi2 (5)	0.0000
- Wald Test	= 1.45e+04	P-Value > Chi2 (6)	0.0000

Table (C – 5): The Stata Output of Wooldridge Test for Auto-correlation

Wooldridge test for autocorrelation in panel data

H0: no first-order autocorrelation

F (1, 5) = 7.138

Prob > F = 0.0443

Table (C – 6): The Stata Output of Feasible Generalized Least Squares Model

Cross-sectional time-series FGLS regression

Coefficients: generalized least squares

Panels: heteroskedastic

Correlation: common AR (1) coefficient for all panels (0.9489)

Estimated covariances =	6	Number of obs =	126
Estimated autocorrelations =	1	Number of groups =	6
Estimated coefficients =	5	Time periods =	21
		Wald chi2(4) =	14.36
		Prob > chi2 =	0.0062

lnYieldskg	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
lnrainfall	-.0876846	.0500546	-1.75	0.080	-.1857898	.0104206
lnmaxtem	-.2741125	.5235612	-0.52	0.601	-1.300274	.7520486
lnmintem	-.0992828	.2456708	-0.40	0.686	-.5807888	.3822231
lnarea	.1324039	.0393722	3.36	0.001	.0552358	.2095721
_cons	3.061055	.9379236	3.26	0.001	1.222759	4.899352