# Analysis of Climate Change Effects on Agriculture in Bhutan

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## Abstract

Although some researchers conducted research on climate change vulnerability on agriculture in Bhutan based on their research area and problem definition, climate change effects on paddy, maize, chilli, and cardamom in five districts (Dagana, Monger, Pemagatshel, Zhemgang, and Trongsa) have been least explored and limited. Therefore, this paper, conducted in five districts of Bhutan, analyses the trends of paddy, maize, chilli, and cardamom and the vulnerability of this variable under extreme weather. Apart from this, the effects of climate change were analyzed by comparing trends of temperature and precipitation (1901–2021). The results showed that there is a negative relationship as well as a positive relationship between climate change and agriculture production in the study area. Further, the study area is under threat of extreme weather, especially drought, flash flooding, windstorms, and hailstones. Additionally, results revealed that, in next decade, there is a threat of climate change, which results in a more rapid decline in paddy and maize production in all five districts. Climate adaptation policies such as climate smart agriculture (CSA) and climate smart villages (CSV) and on remote sensing (RS) and global information systems (GIS) must be promoted in villages to reduce the long-term vulnerability of agriculture to climate change.


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**Keywords:**agriculture, climate change, climate smart agriculture,extreme weather, RS and GIS

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## 1. Introduction

Climate change is defined as an unusual shift in weather patterns and temperatures caused by both natural and human action (UN, 2022).At the local, national, and global levels, climate change is one of the most significant challenges and threats to achieving sustainable development and food security. Globally, climate change is impacting food security and the sustainability of development. In the global scenario, Africa is experiencing the worst drought and massive floods in Nigeria and Sudan. This shows that the impact of climate change on the globe is felt more now, and adaptation to climate resilience is important (UNF, 2022). The climate changes felt around the globe are having a devastating impact on the well-being and livelihood of rural people in backward nations. Furthermore, countries in the Himalayan zone are more vulnerable to the effects of climate change. Farming and hydropower are the main sources of revenue in Bhutan, which is a Himalayan country with a lack of adaptation to modern technology and resources. Aside from this, climate change and extreme weather is biggest challenges for farming practice and more area is under threat of GLOF. The impact of climate change is most prominent and serious challenges for agrarian country like Bhutan whose 57% of

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population depends on agriculture(Royal Government of Bhutan, 2020). Thus, Bhutan is facing more of global threat in achieving sustainable development goal and maintaining the sustainability of carbon neutral policy.In places like Dagana, Monger, Pemagatshel, Trongsa, and Zhemgang, farmers rely heavily on agriculture, particularly maize, rice, chilli, and cardamom, as their primary source of income. Geographically, each district is located at a distinct height, with varying temperatures and precipitation. As a result of catastrophic weather events and changes in temperature and precipitation, the sustainability of farmers' livelihoods through agriculture becomes difficult.Earlier studies made on the village of Goa, west of India, observed that farmers are convinced that climate change has affected their farming in terms of declining crop and livestock yields, rising input costs, enormous pressure on agricultural land, groundwater depletion, and a wild animal menace on crops, and their study suggests a strong institutional environment is needed to support adaptation, focusing on farmer-led participation and the security of farmers' livelihoods (Reddy et al., 2022). In Pakistan, agriculture is exposed to temperature and precipitation. Furthermore, the agricultural sector is heavily reliant on each of these factors and has a strong relationship with each of them. As a result, rapid adaptation measures to address these difficulties are necessary in Pakistan (Ali et al., 2021).(Derbile et al., 2022) observed that, in the upper region of Ghana, smallholder farmers are vulnerable to a variety of climatic extremes, including drought, flood, sunlight, and bushfires; drought is the most severe occurrence that impacts the majority of farmers each year, and hot, bright circumstances and temperatures are the second most severe occurrence affecting food crops and agriculture in Ghana.According to Mokhtar et al. (2022), scientific advancements such as agriculture biotechnology, remote sensing (RS), and geographic information systems (GIS) could be more efficient and help us make better decisions in land management, environmental protection, and restoration solutions, thereby mitigating the negative effects of climate change on Asian agriculture. (Agbo, 2022) mentions that Egypt has not reached a critical or hazardous point. Barrio et al. (2020) view a favourable relationship between fruit tree dormancy and climate change in Argentina's North Patagonia, and rising temperatures may provide chances for growers to introduce new species and cultivars to the region. In northern China, there is a rise in water irrigation demand for maize in Jiangsu Province and a modest decrease in central Shandong Province (Lin & Li, 2022). (Chhogyel et al., 2020; Tenzin et al., 2019) mention that lack of availability of irrigation water is one of the most common influencing factors in Bhutan, and climate change has both positive and negative effects on agriculture in Bhutan. Climate change increased the production of crops such as mandarin oranges while decreasing the production of citrus and apples in Bhutan from 2012 to 2015 (CIAT & World Bank, 2017).

Bhutan has witnessed numerous temperature variations, rainfall patterns, flash floods, windstorms, hailstorms, and droughts, resulting in massive losses and damage to agriculture farmers (Shrestha et al., 2012; UNDP, 2013). Bhutan's farming resistance to climate change must be strengthened by government aid, greater investment, R&D, and technology creation (Chhogyel & Kumar, 2018).Therefore, the purpose of this paper is to analyze the trends and forecast the cereal (paddy and maize), vegetable (chilli), and species (cardamom) in five districts of Bhutan from 2004 to 2021. It also aims to analyze the impact of extreme weather events on paddy, maize, chilli, and cardamom production in five districts of Bhutan, as well as the other control factors that influence agricultural productivity in the research region. It also gives a possible option for dealing with the detrimental impact of climate change on Bhutan's agricultural productivity. The remainder of the paper is structured as follows: The next sections

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are on methodology and materials. The third section is the results and discussion. The fourth section is a recommendation, and the final section is the paper conclusion.

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## 2. Methods and Materials

### *2.1 Study area*

The research was carried out in five districts of Bhutan: Dagana, Trongsa, Monger, Pemagatshel and Zhemgangas shown in figure 1.The regions were chosen based on their low poverty levels and increased sensitivity to climate change. People in these areas rely on agriculture for a living. These five districts are located at different altitudes and experience variations in temperature and precipitation.Thus, study for climate change effects on agriculture in this area will be significant for farmer.

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**Dagana:**Dagana is 1722.83 square kilometres in size and has a population of 24,965 (PHCB, 2017). Agriculture is the primary source of income for the majority of farmers. Dagana has more orchard land than wet land and dry land combined, with dry land measuring 5432.334 hectors, wet land measuring 18167.165 hectors, and orchard land measuring 1922.564 hectors (RGoB, 2018). The city is located at an elevation of 1580.23 metres (5184.48 feet) above sea level and has a temperate highland tropical climate with dry winters. The average annual temperature is 9.61 °C, with 142.46 wet days and 71.39 millimetres (2.81 inches) of precipitation. The hottest month is August, while the coldest month is January with -2.68 °C (Weather & Climate, 2022).Aside from rice and maize, framers in Dagana mostly grow cardamom and mandarin. Their subsistence is dependent on grain and cash crops.

**Trongsa:**Trongsa has a population of 19,960 (PHCB, 2017) and a temperate highland tropical climate with dry winters. It is located at a height of 2169.73 metres above sea level. The city has a yearly temperature of 9.61 °C, 71.39 millimetres of precipitation, and 142.46 wet days (Weather & Climate, 2022). Trongsa practises mixed agriculture like paddy, maize, chilli, and cardamom cultivation.

**Monger:** Mongar Dzongkhag has a population of 37,150 (PHCB, 2017), and it is located between latitude 27.25 and longitude 91.2. Its size is around 1,940.26 square kilometers, and its height ranges from 400 to 4000 metres above sea level. While the northern and upper regions have temperate climates, the lower and southern regions are subtropical. Winters can be frigid, while summers can be hot and muggy. The people of Monger harvested more maize than paddy, and their economy depends on these two types of production as well as chilli production.

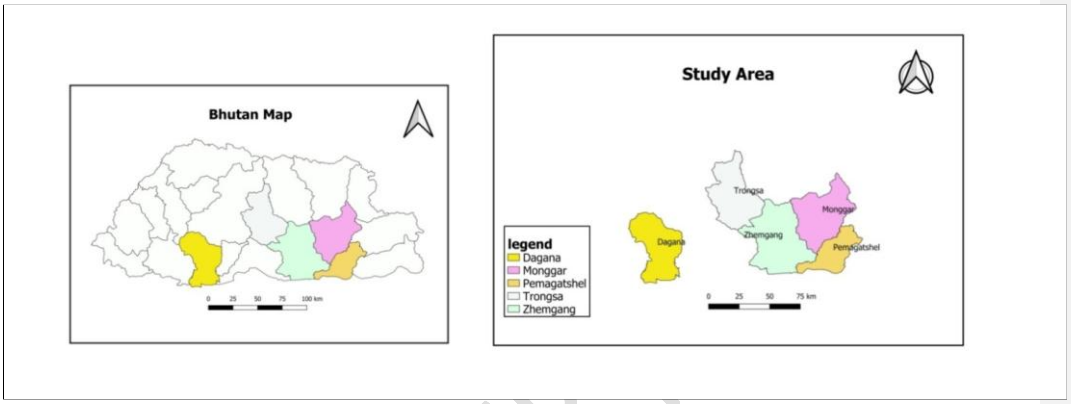
**Pemagatshel**:Pemagatshel mostly cultivates maize and rice, as well as cardamom and chilli, to supplement their income.Pemagatshel has a population of 23,726 (PHCB, 2017), a humid subtropical, dry winter climate, and is located at a height of 1467.34 metres (4814.11 feet) above sea level. The city's annual temperature is 26.75 °C, which is 11.15% higher than the national average. Pemagatshel gets roughly 180.8 millimetres (7.12 inches) of rain per year and has 147.56 wet days. The coldest month is January, and the warmest month is May (Weather & Climate, 2022).

**Zhemgang:** Zhemgang has a population of 17,763 (PHCB, 2017). Zhemgang, which is 572.11 metres above sea level, has a moderate highland tropical climate with dry winters. Around 180.8

millimetres of rain fall on Zhemgang annually, and there are 147.56 rainy days. May is the hottest month, while January is the coldest (Weather & Climate, 2022).Farmers in Zhemgang cultivate more maize than paddy, and their economy depends on these two types of production.

**Figure 1**

*Selected Study Area*




*Note:* Adapted from QGIS 3.4.4

### 2.2 The Sampling Methods and Design

The study employed a non-probability sampling technique to conduct research. According to Fowler (2002), non-probability sampling employs subjective judgement and a convenient selection of units from the population. The study is based on convenience sampling since five districts (Dagana, Trongsa, Monger, Pemagatshel, and Zhemgang) were chosen for examination from a total of twenty districts in Bhutan. The five districts were chosen because they had the lowest poverty rates in Bhutan and a heavy reliance on agricultural production for a living.

Therefore, it is convenient for collecting secondary data and analyzing the effects of climate change on their products. Since the consequences of climate change on agriculture are the most visible problems that people face and temperature variations occur every year, the study adopts an applied research approach to address the topic of the influence of climate change on farmers' livelihoods. Kothari (2008) defines applied research as seeking to solve a current or everyday problem that individuals and society face.

### 2.3 The study source and analysis tools

**Comment [u12]:** Better if you say methods of data collection and analysis

The data was collected from secondary sources for all the regions. Secondary data includes data collected by someone other than the primary user (Management Study Guide, 2022). To analyze the trends in agriculture production (paddy, maize, chilli, and cardamom), data was collected from the Ministry of Agriculture websites and the National Statistics Bureau (NSB).

Furthermore, data on the effects of extreme weather on agricultural production in these regions was collected from news reports, i.e., Kuensel and Bhutanese news.

To study the effects of climate change on these regions, the daily temperature and precipitation records were collected from the Climate Change Knowledge Portal (CCKP). Based on the main objective of this paper, i.e., to analyze the trends of agricultural production, this objective was fulfilled by analyzing the trend using an econometric model, i.e., time series analysis. Other temperature and precipitation trends are analyzed using the Climate Change Knowledge Portal System, and the forecast of agricultural production is done using the ARIMA model from the time series model in SPSS.

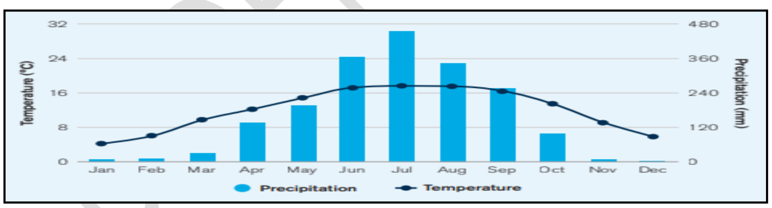
## 3. Results and Discussion

### 3.1Overall Trends of annual temperature and rainfall of Bhutan

Since the beginning of the 1960s, the increase in temperature and its impact have been felt by the people of Bhutan. Figure 2 shows that the rate of temperature rise has accelerated in the last decade. Temperature and precipitation increase more in the southern part of Bhutan, while they decrease in the northern part of the country. The graph below shows that in the summer temperatures will be high in Bhutan and that in the winter they will be low. Similarly, the months of May to September will have the highest rainfall and temperatures (Asian Development Bank, 2021). Results also show that there is a decline in the amount of rainfall in the country's wettest regions. The northern and southern parts of Bhutan will receive the highest rainfall in summer (Awange et al., 2017). As a result of monsoon rain, primary paddy farming begins in Bhutan from May to August. Most farmers in Bhutan grow vegetables during the dry season, which lasts from October to March, and rice during the monsoon. Thus, farmers encounter difficulties in planting paddy on time every year as the country experiences a rise in temperature and a fall in precipitation.

**Figure 2**

*Average monthly temperature and rainfall in Bhutan, 1991–2020*




*Note*. This graph shows the average monthly temperature and rainfalls trends in Bhutan from the year 1991 to 2022. Copyright by 2021 Asian Development Bank.

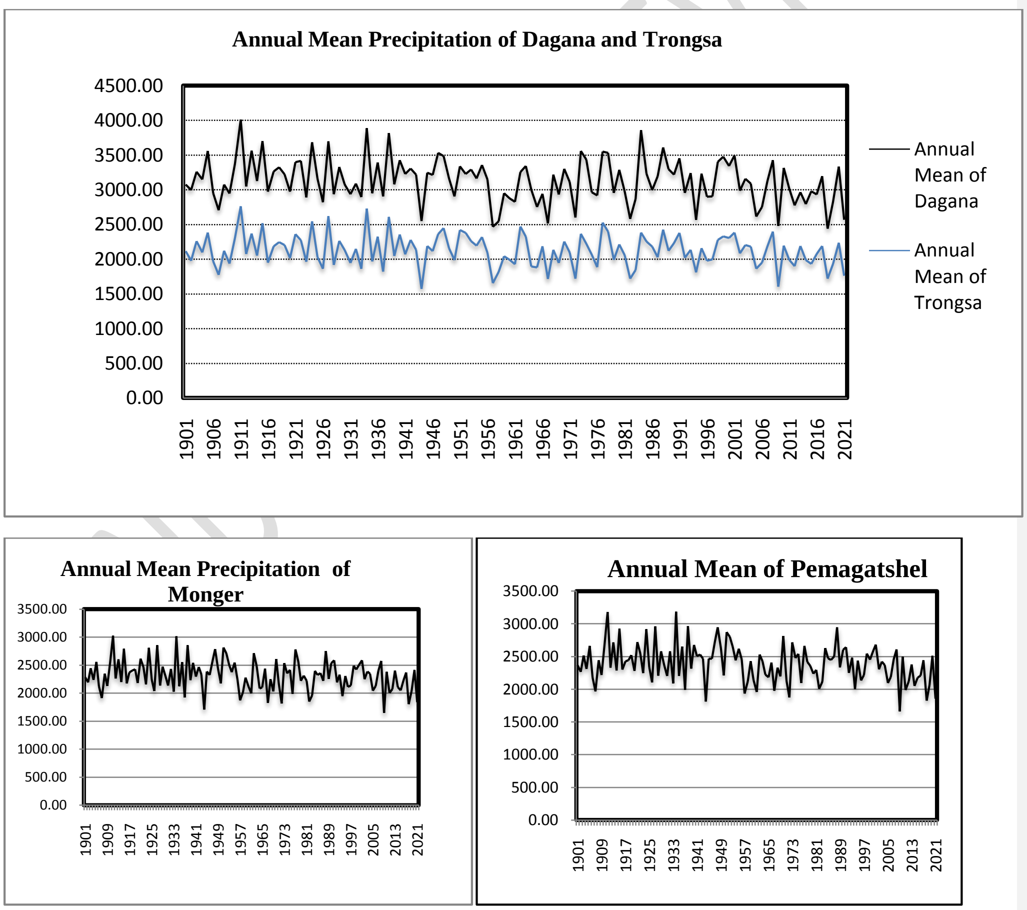
### 3.2 Trends of precipitation of study area, 1901-2021

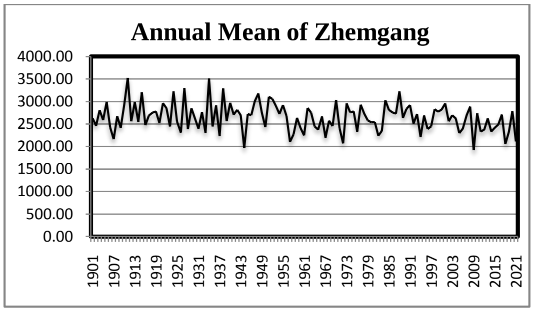
This section will examine the average annual precipitation trends in five research areas from 1901 to 2021, as shown in Figure 3. The purpose of assessing average precipitation trends for this research region is to determine the vulnerability of precipitation in study areas and examine the relation between precipitation and agriculture products in the study area. Observations show a year-to-year decrease in precipitation in all five study areas. Observations show that Pemagatshel experiences a more drastic decline in precipitation than other study areas. Compared to the other three districts, Dagana and Trongsa experience a constant decline in precipitation.

Thus, results show that all five study areas face climate change impacts every year. This means that those agriculture products that depend on rainwater for cultivation, like paddy, face challenges in cultivating on time due to the late monsoon and shortage of irrigation. According to the observations, there is a decrease in precipitation in all areas, indicating that drought is a problem in all five districts. Therefore, climate change is impacting the livelihood of these five districts.

**Figure 3**

*Annual mean precipitation of study area (1901-2021)*





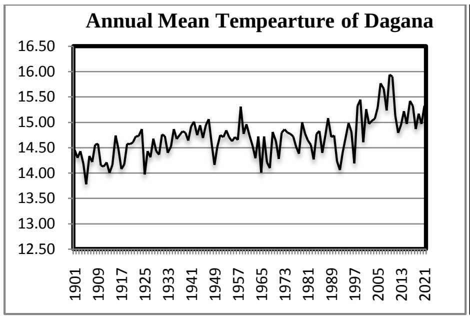

*Note.* The graph show the overall decline in annual mean precipitation trends from 1901 to 2021 of Dagana, Trongsa, Monger, Pemagatshel and Zhemgang. Copyright by 2021 The World Bank Group.

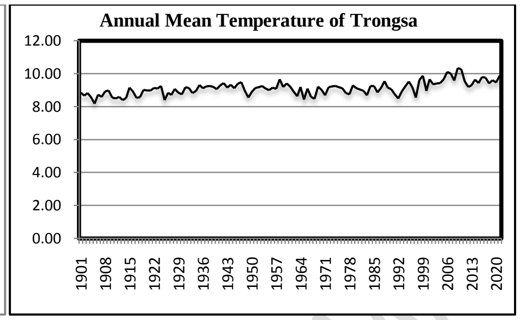
**3.3 Trends of Temperature of study area, 1901-2021**

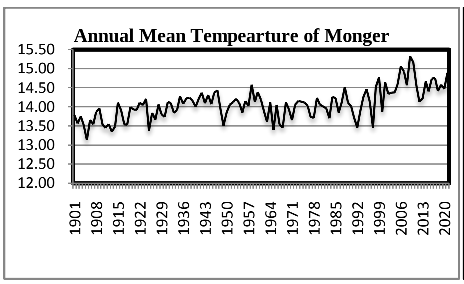
This section examines the study area's maximum temperature changes from 1901 to 2021. Due to the recent increase in temperature and the difficulty farmers have had in cultivating in past years, five research locations have been selected to evaluate temperature patterns. The goal of this study was to determine the temperature change and the sensitivity of the studied region to climate change. The following trends show that the annual mean temperature has continued to rise from 1901 to 2021 in all five research areas. According to the data, Pemagatshal is the hottest site among the others, with a temperature of 25°C in 2021, indicating that this region is more sensitive to climate change than other areas. In 2009, almost five area experience maximum temperature, Dagana with 21.4℃, Zhemgang with 22.94℃, Trongsa with 16.11℃, Monger 21.16℃ and Pemagatshal with 26.1℃. Based on the analysis, the growing trends in maximum temperature as shown in the trends analysis show their sensitivity to climate change, particularly temperature.

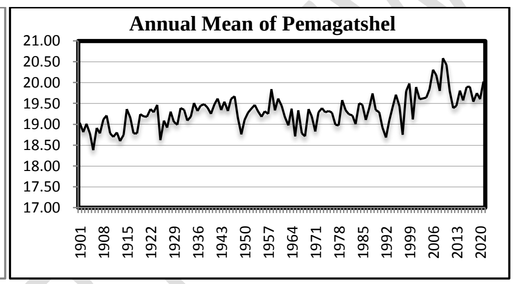
**Figure 4**

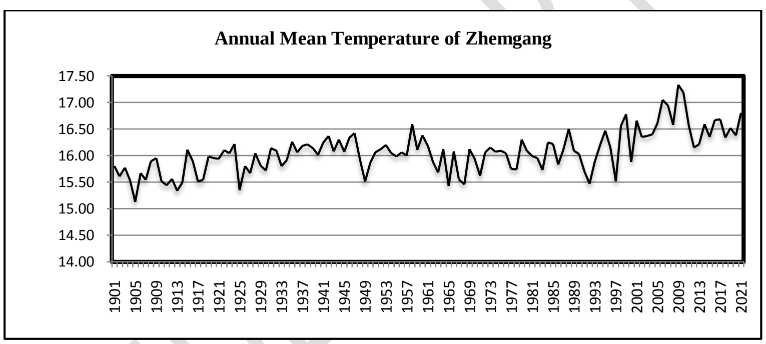
*Annual mean temperature of study area (1901-2021)*




*Note*. The graph show the overall increase in annual mean temperature trends from 1901 to 2021 of Dagana, Trongsa, Monger, Pemagatshel and Zhemgang. Copy right by 2021 The World Bank Group.

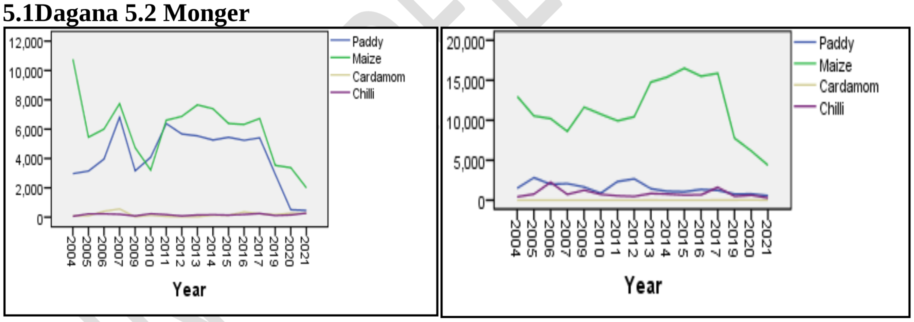
### 3.4 Trends analysis of different crops under different regions

These sections will analysis the trends of paddy, maize, fruits and vegetable production of five districts i.e., Dagana, Pemagatshel, Monger, Trongsa and Zhemgang under the climate change. The 18 years data (2004-2021) was use to analysis the trends of agriculture variable paddy, maize, cardamom and chilli of five study area. The purpose of analyzing the trends was to determine the vulnerability of these variables to climate change in particular study area and to see the pattern of agriculture production. From the igure 5, observation shows that over the last two decade, agriculture production in this area has seen to be non-stationary over the time. Dagana has been seen drastically decrease in the maize and paddy production over the time and almost constant in chilli production. As a results Dagana are more vulnerability to climate change in term of maize and paddy. Dagana grows maximum of cardamom from decade but climate change has been significantly impacting the traditional management practices of cardamom farming. The harvested production of cardamom has become uncertain due to persistent pests and diseases. Climate change and all these challenges have impacted the productivity and production of cardamom growers in Dagana. Thus, cardamom production in Dagana is slightly decreasing over the year.

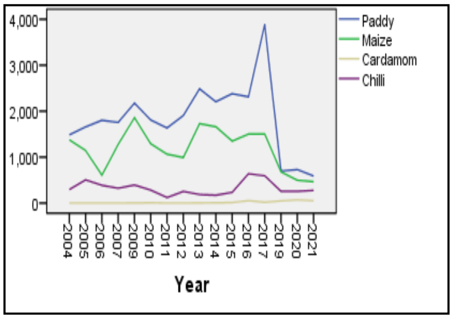
Most of the livelihood of people in Monger depends on maize production and considered maize as the highest production comparing other products. At the same time Monger has been seen decrease in the maize production over the time due to climate change and other factors. Recently, slight increase in cardamom production is also seen in Monger, Pemagatshel, Zhemgang and Trongsa due to change in temperature and precipitation pattern. This shows that there is positive relation between climate change and cardamom production in Monger. The people of Pemagatshel and Zhemgang practice more of paddy cultivation and second as maize. Both the area is seen to be decline in the paddy and maize production over the year. Trongsa seem to be highest grower of maize comparing to paddy, chilli, cardamom respectively. If we look into the trend of temperature and precipitation of Trongsa in figure 4 and 5, we can observe that contributing factors for decline in paddy production in Trongsa is due to increase in temperature and decline in precipitation which leads to drought.

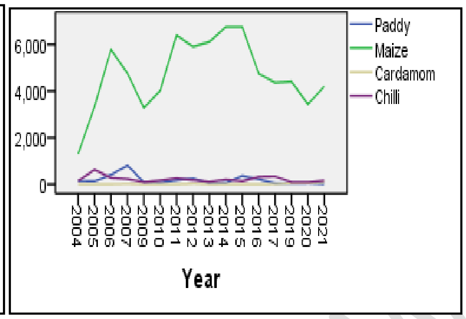
**Figure 5**
Trends of Agriculture Production in Study Area

**5.1Dagana 5.2 Monger**

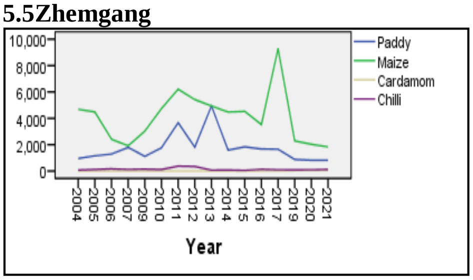



**5.3 Trongsa** **5.4 Pemagatshel**




**5.5Zhemgang**




*Note.* The graph show overall decline trends of agriculture production in five districts of Bhutan.

### 3.5 Effect of climate change on agriculture production in study area

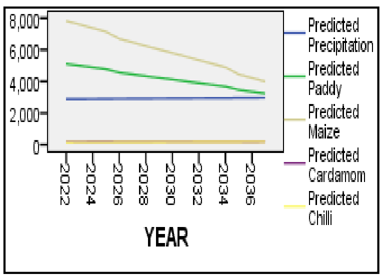
This section will examine the long run effects of climate change on agriculture production in study area by analyzing future trends base on the previous year data. The forecast, of data is done through time series model using ARIMA model. The ARIMA model is econometric model which is used in forecasting the future production. The following figure 6 will forecast the trends of precipitation, paddy, chilli, maize and cardamom. The purpose of this study is to examine long run effects of climate change on agriculture production in study area and to forecast specific crops under precipitation. The forecast was done base on the previous year data from 2004 and 2021 using ARIMA model.  Figure 6 shows the forecast of Dagana and observation depicts that, in long run Dagana will experience decline in paddy and maize production due to decline in the precipitation. Other product like cardamom and chilli will experience slight decline or almost stay stationary.

In figure 6 we observed that, due to slight increase in precipitation in future, monger will practice shift in crops from maize to cardamom because cardamom seem favourable in long run in monger. There will be declining trends in maize even after decade in monger. In figure 6, results show Trongsa will experience decline in precipitation over long run and cause decline in paddy and maize production. Cardamom and chilliseems steady increase at constant rate in Trongsa and Zhemgang. Figure 6 depicts that in long run maize production will increase and other product will increase at constant rate. Therefore, base on the previous year data, results show that there is overall decline in precipitation in next decade and paddy and maize too in all study area. Results show study area is vulnerable to climate change in long run which further affects the livelihood of people and food security. From the following results, we conclude that, effects of climate change will be more in next coming decade and damaged on agriculture crops like paddy, maize, cardamom and chilli by extreme weather events will hamper the food security.

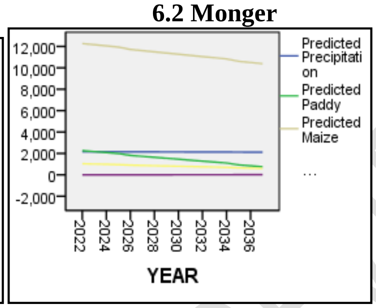
**Figure 6**

Forecast of precipitation, paddy, maize, chilli and cardamom in study area

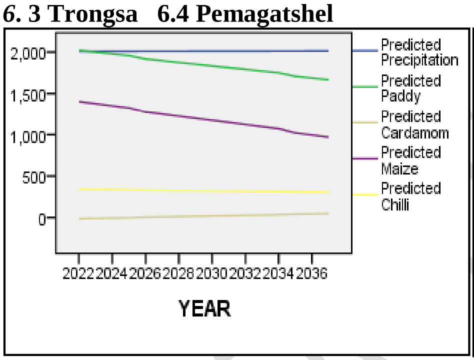
**6.1 Dagana**

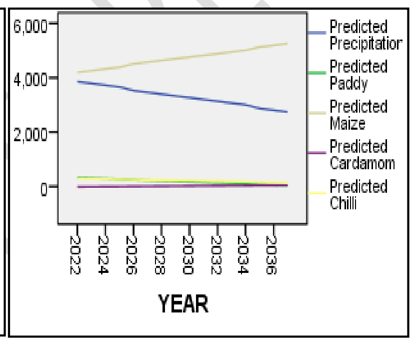



**6.2 Monger**

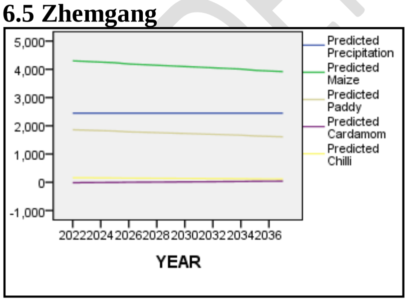



***6.* 3 Trongsa** **6.4 Pemagatshel**




**6.5 Zhemgang**




*Note*. The graph shows the overall decline in cardamom, chilli, paddy, maize and precipitaion in next decade.

### 3.6 Effects of Extreme Weather on Agriculture in study area

Based on historical data, this section will investigate the impact of extreme weather on agricultural productivity in the study region. The primary goal is to determine which climatic factors have the greatest impact on agricultural output in the research region and to analyze the sensitivity of these factors to the study area in the present and future. Data was obtained from previous news articles and ministry of agriculture reports to determine the impacts of extreme weather (drought, rainfall, temperature, wind, snowfall, flash floods, landslides, and other variables) on agriculture in each research location.According to the Agriculture Survey Report (2021), acres of paddy crops were damaged in Dagana and Zhemgang owing to frequent rain, resulting in a drop in maize and rice output in this region in 2021. Heavy rains and windstorms recently devastated 167 acres of corn crop in Dagana (Wangmo, 2022). Similarly, Dungmaed village in Pemagatshel would lose 15 acres of grain in 2020 due to a week of constant severe rain. They claim that this is the first time they have experienced a continual downpour in Pemagatshel (Wangchuck& Rai, 2020). This also explains the influence of climate change on agriculture.Furthermore, a flood caused by heavy rain destroyed crops in Mongar, destroying 120,785 kg of corn distributed across 81.23 acres. Similar damage was caused by a hailstorm in Trongsa Dzongkhag, which affected 95.22 acres of cultivated land (Delma, 2016). Thus, a gradual and continuous increase in harsh weather has resulted in significant crop and grain losses in this region.

In Monger, maize is a vital source of revenue; however, owing to climate change, several new pests and diseases have devastated the crop and the livelihoods of farmers.According to Namgyal (2021), armyworm infestation has devastated over 15 acres of corn crop in numerous villages in Monger, and drought has also impacted the growth of maize in another village in Monger (Thangrong gewog) in the same year, causing damage to 54 households. Thus, all of these factors are consequences of extreme weather and climate change on agriculture, implying that climate change is also harming agriculture productivity in Bhutan. As a result, in the research region, wind, rainfall, drought, flash flooding, pests, and diseases are the most prevalent factors affecting agricultural productivity and farmer livelihood. This also suggests that the research region is under threat from climate change, including wind, drought; flash flooding, rainfall, pests, and diseases.

### 3.7 Other Factors effecting climate change in study area

The other factors that affect agriculture production in the research region will be examined in this part based on a news source from the previous year. Bhutan is a Himalayan country with a forest cover that exceeds 60%, making farming difficult for farmers due to land near to forest. In Bhutan, human-wildlife conflict is another factor that affects agricultural production and farmers' means of subsistence. These additional factors make it difficult for farmers to conduct sustainable agriculture. Aside from climate change, the major reasons in farmer crop losses each year are wild animals and human-wildlife conflict. According to statistics, 117.79 acres of paddy fields were damaged by wild animals the most in Trongsa between 2002 and 2011 (Zangpo, 2013).Farmers are thus extremely exposed to wild animals during the peak season of agriculture crops such as potatoes, maize, and rice. As a result of the increased production of maize and paddy, which attacks more wild animals, the research region is also threatened by wild animals.

**Comment [u13]:** Is it proposal? Please try to edit this minor issues

## 4. Climate Change adaptation planning

This section will discuss the somerecommendation for climate change adaptation panning and policy with respect to agriculture in Bhutan. As mention in study, major crops and cereal are more vulnerable to extreme weather and this has negative effects on food security and livelihood of farmer in study area. Therefore, to achieve the major sustainable development goal (SDGs) specially ending poverty, zero hunger and climate action, appropriate national planning and policy is needed to mitigation the climate change impact on food security. To support the national planning and policy, paper recommend three policiesas follow:

### 4.1 Climate Smart Agriculture (CSA) and Climate Smart Village Model (CSV)

**Comment [u14]:** From where and how you take this data, be clear

Climate smart agriculture (CSA) is an integrated method for managing landscapes, including cropland, cattle, forests, and fisheries, that addresses the interconnected challenges of food security and climate change (World Bank, 2021). Climate smart agriculture is a strategy for boosting agricultural productivity and revenue in a sustainable way, adapting to and creating resilience to climate change, and reducing greenhouse gas emissions. People in each village district require proper climatic knowledge, practice, and training in CSA. For example, a location with high temperature vulnerability can substitute crops that are tolerant of high temperatures, and when temperatures are normal, farmers can produce previous crops cultivated in that region. As a result, farmers may make money and enhance productivity in the long run. To lower costs, a shift in farming systems must use cutting-edge technologies. Climate-smart agriculture will be accomplished by introducing the climate-smart village (CSV) paradigm. Climate Smart Villages (CSV) enable every farmer in the village to employ climate-smart agricultural services, increasing the community's adaptive potential. Climate smart technology and climate information services may be integrated into village development plans with the help of local institutions and local expertise. This can be accomplished by promoting new and shorter maturation times for drought-tolerant crop types, enhanced and novel soil and water conservation technologies such as compost production and application, and the use of appropriate amounts of fertilizer. According to the study, adaptation planning and incorporating climate-smart agriculture will serve as a tool and a path for farmers to make crop farming more productive and resilient in the face of a changing climate system.

### 4.2 Remote Sensing (RS) and Geographical Information System (GIS)

**Comment [u15]:** Why this? I never seen in your objective and methods about this topic, so please be consistence and don't mix

Geographic information systems (GIS) and Remote Sensing (RS) are globally significant tools in modern agriculture. Agriculture will be less influenced by climate change due to the use of geographic information systems (GIS) and remote sensing on a local scale (RS). RS and GIS are critical tools for detecting crops and places where crop patterns are changing. They are also useful for agricultural surveys and mapping. Remote sensing and geographic information systems (GIS) are important in site-specific nutrient management because they can identify nutrient issues, reduce crop costs, and improve fertilizer usage efficiency. Water management requires a solid understanding of geographical space and related spatial information such as water sources, watersheds, terrain surfaces, land use, land cover, rainfall, temperature, humidity, soil condition and composition, geology, atmospheric conditions, human activities, environmental data, and so on. The issues, relevance, and long-term management of groundwater and freshwater are further described using geographic information system (GIS) and remote sensing (RS) technology (Kumar et al., 2006).

Furthermore, combining data acquired from distant sensors with that from sensors put directly on farm machinery can increase farmers' decision-making abilities for planning their agriculture to optimize yields. In agriculture, remote sensing is used to estimate biomass and yield, monitor vegetation and drought stress, analyze crop phenological development, estimate crop acreage and cropland mapping, map disturbances and land use land cover changes, and manage precision agriculture and irrigation (Atzberger, 2013). Thus, the research suggests that using current technologies like as GIS and RS in rural villages will aid in minimizing the effects of climate change on agriculture.

**Comment [u16]:** It looks like out of your topic

### 4.3 Action on Innovation

In the name of introducing the new technology for agriculture production, emission is producing through food system, where most of people forget about emission is producing from farm machinery and transport. To eliminate this, innovation of new electric farm machinery and use of eco-friendly transport will eliminate the emission. Innovation here can include even introducing of new high variety seeds that is grown in warm temperature. Innovation in research and development is upward development which takes time for farmers to implement the policy and know about situation but innovation on downward development will helpful by improving practice and new technology will help smallholder farmer.

**Comment [u17]:** ?????

## 5. Conclusion

This study was undertaken in five areas of Bhutan to analyze the impacts of climate change on agricultural products by analyzing trends in certain crops and extreme weather events, as well as the implications of climate change adaptation in the study area of Bhutan. The study relied on secondary data from five districts. We determined that farmers in five areas are more vulnerable to extreme weather occurrences such as drought, flash floods, and windstorms as a result of our findings. Aside from climate change, another regulating element that influences agriculture is human-wildlife conflict. Furthermore, we infer that maize and rice are more sensitive due to the rising temperature and decreasing precipitation trends in our five research locations. Climate change adaptation, such as the promotion of Climate Smart Agriculture (CSA) and the climate smart village concept for smallholder farmers, is critical to reducing all of these severe weather occurrences. Furthermore, employing environmentally friendly agricultural equipment, such as electric power tractors, may aid in the reduction of emissions and the sustainability of livelihoods.

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