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Economics Impact of Climate Change on Agriculture GDP in Bhutan: Empirical Evidence from ARDL Approach

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ABSTRACTS

This paper examines the economic impacts of climate change on agriculture in Bhutan. It focuses on the significance of the agriculture sector in Bhutan and analyzes the economic effects of climate change using the Autoregressive Distributed Lag (ARDL) model. The dependent variable used in the ARDL model is agriculture GDP, while the independent variables are temperature and rainfall. The ARDL model is employed to assess the short-run and long-run economic impacts of climate change on agriculture. The results of the study indicate that the agriculture sector has consistently contributed the highest GDP from 2009 to 2020 in Bhutan. Additionally, it has provided the most significant employment opportunities compared to other sectors between 2009 and 2019. The ARDL model results demonstrate that in the short run, the coefficient for temperature is positive at 0.16, and the coefficient for rainfall is 0.5, indicating that climate change has a positive impact on agriculture GDP. However, in the long run, the ARDL model reveals a negative impact of climate change on agriculture GDP. The coefficient for temperature is -11.2, and for rainfall, it is -1.13. These findings underscore the urgent need for measures to address the challenges posed by climate change. The paper recommends raising awareness about climate-smart initiatives and programs among stakeholders. Additionally, training and the adoption of climate-resilient seeds and techniques are necessary to mitigate the adverse effects of climate change on the agriculture sector.

Keywords: ARDL Model, Agriculture GDP, Temperature and Rainfall, climate change, and agriculture

INTRODUCTION

Bhutan, a small nation nestled within the youthful Himalayan Mountain range, is home to around 700,000 people. The majority of Bhutan's population, approximately 80%, relies on crop cultivation and livestock practices to sustain their way of life. With an impressive 70% forest cover, Bhutan has earned the distinction of being the world's first carbon-negative country. However, despite its environmental achievements, Bhutan faces significant challenges stemming from global issues that threaten its pristine heritage and the livelihoods of its farmers. Of particular concern is the adverse impact of climate change on agriculture and livestock, which poses a grave threat to the country, given its heavy dependence on agriculture for economic stability. Urgent and effective mitigation measures are needed to address these pressing issues. Consequently, research and development focusing on understanding and mitigating the impacts of climate change on agriculture in Bhutan have become vital. Numerous studies have explored the effects of climate change on agricultural systems in various regions worldwide. For instance, Nasrullah et al. (2021) conducted a study in South Korea utilizing the Autoregressive Distributed Lag (ARDL) model to examine the influence of climate change, technology, and agricultural policy on rice output. Their

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findings revealed that increased carbon dioxide (CO_2) emissions had a positive effect on rice output, enhancing it by 0.15%. Moreover, they observed that higher average temperatures had a substantially positive impact, increasing rice output by 1.16%. However, the study also found that rainfall had a negative influence on rice production, suggesting that inefficient irrigation systems and inadequate weather forecasting reports might be contributing factors to this phenomenon.

In a similar vein, Chandio et al. (2022) employed the ARDL model to investigate the impact of climate change on cereal production in Bangladesh. Their research demonstrated a positive correlation between rainfall and cereal production, both in the short and long term. This suggests that adequate precipitation plays a crucial role in enhancing cereal crop yields. Building on this, Ahmed et al. (2023) explored the effects of climate change on food production in India using the ARDL model. Their study revealed that rising temperatures and increased emissions had a significant negative impact on food production. Conversely, they found that rainfall and the presence of methane had positive effects, indicating that these factors can contribute to improved crop productivity in India. Additionally, Dumrul (2017) conducted a study in Turkey utilizing the ARDL model to analyze the economic consequences of climate change on agriculture. The findings of this research indicated that increased precipitation had a positive influence on agricultural GDP, suggesting that adequate rainfall can contribute to economic growth in the agricultural sector. Conversely, rising temperatures were found to have a detrimental impact on agricultural GDP.

Numerous researchers have conducted studies on the impacts of climate change on agriculture in Bhutan. Chhogyel et al. (2020) conducted a study in six districts of Bhutan to understand the factors influencing farm work and the effects of climate change on individual farmers. Through a semi-structured questionnaire, they found that the availability of irrigation water was the most significant factor influencing farmers' crop production decisions. The study emphasized the importance of identifying solutions and allocating resources to ensure the sustainability of agriculture in Bhutan. Tenzin et al. (2019) analyzed climate change, climate-smart agriculture, and adaptation and mitigation strategies in Bhutan. They observed variations in rainfall and temperature across different regions, which had mixed effects on agriculture. The study highlighted changes in crop production, including shifts in the cultivation of certain crops due to climate change. It emphasized the need for appropriate institutional structures and human resources to address food security and self-sufficiency in the face of climate change. Chhogyel and Kumar (2018) emphasized the impact of climate change on Bhutan's agriculture, including extreme weather events, irregular rainfall, and the introduction of new diseases and pests. The study stressed the importance of strengthening farming resilience through cross-sectoral strategies and increased support from the government, investment, research and development, and technology. Katwal et al. (2015) investigated community opinions on on-farm variety and climate change in Bhutan. The study found that farmers perceived climate change as the most immediate threat to agriculture. A majority of farmers recognized changing local climates and were aware of the potential impacts on their livelihoods. Parker et al. (2017) used climate models to assess the consequences of climate change on crop suitability in Bhutan. They discovered that changes in rainfall and temperature had a significant impact on crop yields, particularly for potatoes. Due to increased temperatures, lower altitude areas became unsuitable for potato cultivation, while mid-

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latitude areas experienced an expansion of suitable areas. Suberi et al. (2018) examined people's perceptions of climate change impacts and adaptation methods in Khotokha Valley, Bhutan. The study revealed that climate change and unpredictability had affected the lives of local people, particularly in terms of potato crops and winter feed production. Increased insect infestations also hindered production. The majority of the community showed awareness of climate change and its potential consequences. Similar research was also conducted by (Lobell et al., 2007; Malla, 2008; Cline, W.R. 1996; Reddy et al., 2022 and Mendelsohn, 2014).

These studies provide valuable insights into the specific challenges faced by farmers in Bhutan and highlight the need for adaptation strategies and support systems to mitigate the adverse effects of climate change on agriculture. By understanding the local context and perceptions of farmers, policymakers and stakeholders can develop targeted measures to enhance the resilience of Bhutan's agricultural sector. Against this backdrop, the present paper aims to achieve two main objectives. Firstly, it seeks to investigate the significance of the agriculture sector in Bhutan, given its central role in the country's economy and the livelihoods of its population. Secondly, the paper aims to examine the specific impacts of climate change on agriculture in Bhutan using the ARDL model. The study will consider agriculture GDP as the dependent variable, while temperature and rainfall will serve as the independent variables. To accomplish these objectives, the paper will follow a structured format. The subsequent section will provide a detailed explanation of the research methodology employed in this study. It will outline the data collection process, the statistical techniques utilized, and any assumptions made during the analysis. Following that, the third section will present the results and facilitate a comprehensive discussion of the findings. This section will delve into the observed relationships between agriculture GDP, temperature, and rainfall, offering insights into the effects of climate change on Bhutan's agricultural sector. Finally, the last section will offer recommendations based on the study's outcomes and conclusion.

Research Method

1. Study Area

To analyze the results, secondary data was utilized, specifically focusing on the significance of agriculture in Bhutan. This data was sourced from the Ministry of Agriculture and Livestock, providing insights into the importance of agriculture in the country. Similarly, secondary data on agriculture GDP was obtained from the World Development Indicator, offering information on the economic contributions of the agricultural sector. To understand the climate-related aspects, data regarding temperature and rainfall was collected from the Climate Change Knowledge Portal, enabling an examination of the changing climate patterns in Bhutan.

Bhutan was chosen as the study area due to its relevance and significance in understanding the effects of climate change on the agricultural sector. The research focused on investigating the economic impacts of climate change on agriculture in Bhutan. To conduct the study, secondary data was utilized as the primary source of information. The study employed the ARDL (Autoregressive Distributed Lag) model as a statistical tool to analyze the relationship between climate change and the economic aspects of agriculture in Bhutan. By utilizing this model, the

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study aimed to provide insights into the economic implications of climate change on agricultural practices in Bhutan.

2. Sample Techniques used

ARDL MODEL

We will take Agricultural GDP as a dependent variable and temperature and rainfall as the main independent variables. Data is transformed in logarithmic form as it provides consistent, better, and efficient results. Annual time series data is utilized between 1961 and 2013. The World Bank's World Development Indicator database is used for all time series. Below is the empirical model.

Agricultural GDP= *f* (rainfall and temperature)

Econometric Model

$$AGDP = \beta_0 + \beta_1 rainfall_t + \beta_2 temp_t + \varepsilon_t$$

Here Rain is the amount of rainfall in millimeters, Temp denotes the temperature in degrees Celsius, and AGDP denotes the agricultural GDP as measured in agriculture, value added (% of GDP). The temporal trend is denoted by t, and the white noise error term by ε. The agricultural GDP's long-term elasticity for temperature and rainfall are represented by parameters 1 and 2, respectively.

We have employed the Autoregressive Distributed Lag (ARDL) bounds testing approach developed by Pesaran and Shin (1999) and Pesaran, Shin, and Smith (2001) to ascertain the long-run relationship between Agricultural GDP, Rainfall, and Temperature. The ARDL approach has several advantages. First, The ARDL approach is that it can be used even in cases when different variables have different orders of integration. Second, the ARDL test offers more accurate estimations in the event of small samples as compared to the Johansen and Juselius cointegration test. Third, the ARDL test can deal with the inevitable phenomena of endogeneity among variables since it is devoid of residual correlation (Marques et al., 2016). Fourth, by deriving the error correction mechanism (ECM) using a straightforward linear transformation without lagging the knowledge about the long-run, short-run corrections may be merged with the long-run equilibrium in ARDL (Ali et al., 2017).

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RESULTS AND DISCUSSION

1. Significance of agriculture in Bhutan

1.1 Agriculture Growth in Bhutan

Figure 1 shows the annual percentage growth of agriculture in Bhutan from 2000 to 2021, based on data from the World Development Indicator. The graph displays a general trend of fluctuation in agriculture growth, with periods of growth and decline throughout time. In 2000, the agriculture growth rate in Bhutan was 6.14%, which was followed by a period of decline until 2002. From 2003 to 2006, the growth rate fluctuated between 3% and 4%, with a peak of 4.72% in 2005. The period between 2007 and 2011 saw a continuous increase in agriculture growth, with a peak of 8.11% in 2011. However, from 2012 to 2015, the agriculture growth rate declined again, with a low of 2.29% in 2015. After a slight increase in 2016, the growth rate fluctuated between 2% and 3% until 2019. In 2020, the agriculture growth rate declined to 1.06% due to the impacts of the COVID-19 pandemic on the economy. In 2021, the agriculture growth rate in Bhutan was reported at 2.0526%, showing a slight increase compared to the previous year. Overall, the graph highlights the variability in agriculture growth in Bhutan over the past two decades, with various factors contributing to the fluctuations.

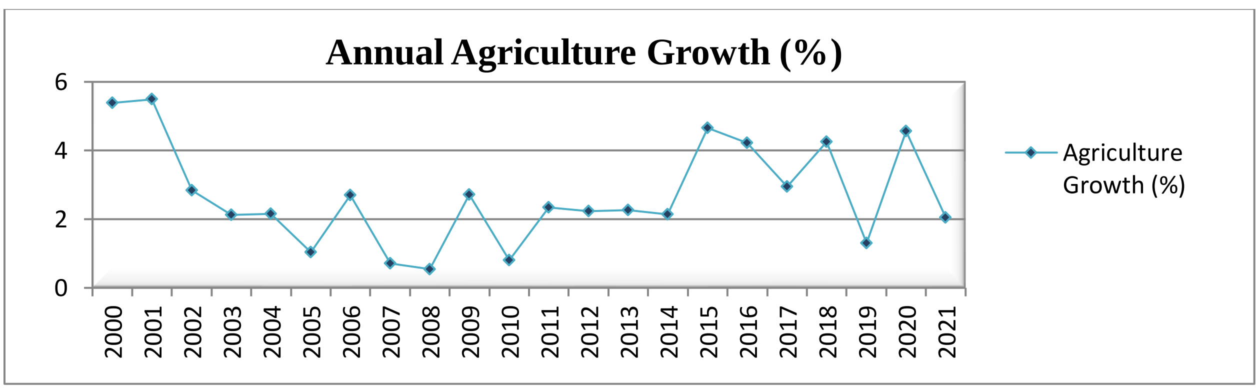

Figure 1: Annual agriculture growth

From the above figure, it shows that there is an increase in the annual agriculture growth percentage in recent years. From the year 2000 to 2008, the annual agriculture growth percentage decreases from 5.3 percent to 0.3 percent as shown in Figure 1. From 2010 to 2020, the annual agriculture growth increased from 0.8 percent to 4.5 percent. This indicates that agriculture has taken an important milestone for the sustainability of the Bhutanese people. Therefore, the overall annual agriculture growth percentage has seen increasing over the last decade in Bhutan. Thus, agriculture is most important for the livelihood of farmers in Bhutan.

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1.2 Contribution of Agriculture to Gross Domestic Products (GDP)

The trend in the contribution of agriculture to GDP can also be visualized in Figures 2 and 3, which show the absolute value of the GDP from agriculture over the years. The graph shows that the GDP from agriculture has been steadily increasing from 2000 to 2020. Although there is some fluctuation, the general trend is upward, indicating a growing contribution of agriculture to the overall GDP of Bhutan. The increase in the contribution of agriculture to GDP in recent years is a positive sign for the economy of Bhutan. Despite the decline in the share of agriculture in GDP over the years, it remains a crucial sector for the livelihood of a significant proportion of the population. The growth in the contribution of agriculture to GDP indicates the potential for further development and expansion of the sector in Bhutan.

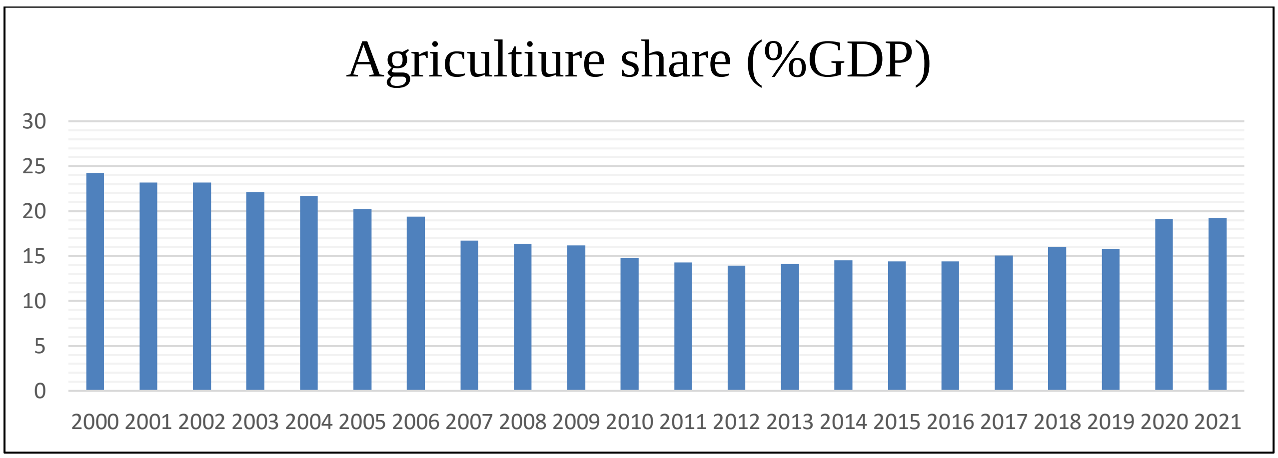

Figure 2: Graphical representation of agriculture contribution to GDP

Note: World Development Indicator. https://databank.worldbank.org/source/world-development-indicators

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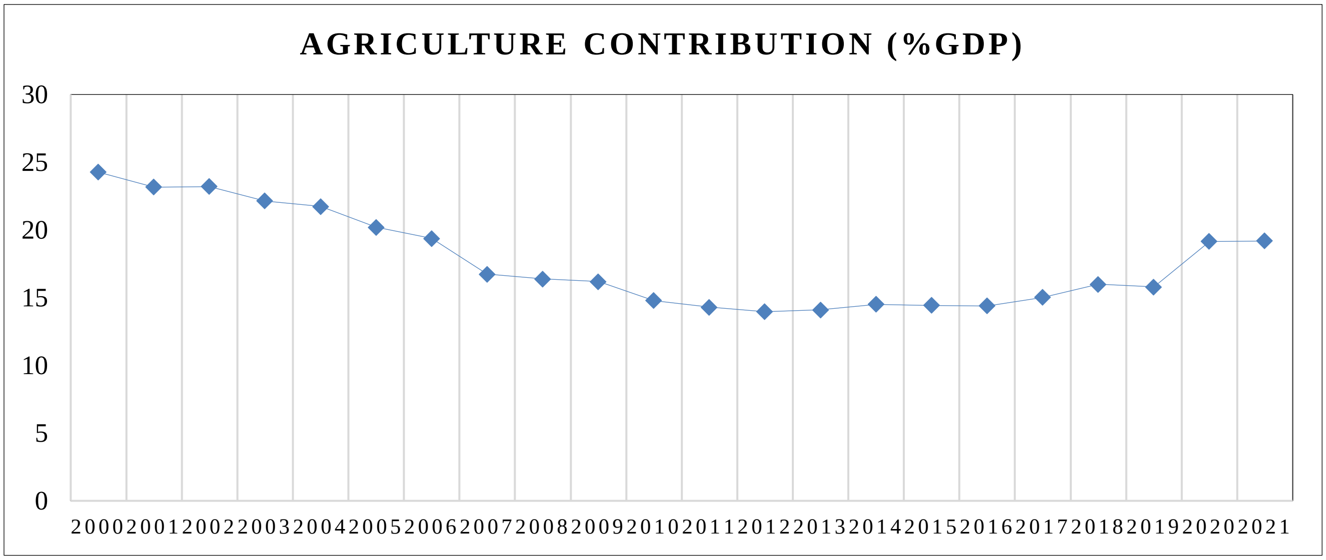

Figure 3: Agriculture Contribution to GDP

Note: World Development Indicator. https://databank.worldbank.org/source/world-development-indicators

1.3 Employment in Agriculture Sectors

Figure 4 shows the total percentage of employment in the agriculture sector in Bhutan from 2000 to 2020. The data reveals that the share of employment in agriculture has been declining over the years, from 66.77 percent in 2000 to 54.62 percent in 2020. This trend is not unique to Bhutan and is a common occurrence in developing countries experiencing economic growth and structural change. As countries develop, they tend to shift away from traditional agriculture-based economies towards industrial and service-based economies.

There are several reasons why the share of employment in agriculture is decreasing in Bhutan. First, the country has been experiencing rapid economic growth in recent years, driven primarily by the hydropower sector. This growth has led to the emergence of new industries and services, creating employment opportunities in non-agricultural sectors. Second, the government has been investing heavily in infrastructure development, such as roads and airports, to facilitate economic growth. This investment has improved connectivity and transportation, making it easier for businesses to operate and access markets, further contributing to the shift away from agriculture. Finally, the younger generation is increasingly educated and seeking employment in non-agricultural sectors, further driving the shift towards a service-based economy. Despite the declining trend, agriculture remains the primary source of livelihood for a significant portion of the Bhutanese population. The sector contributes around 16 percent of the country's GDP and employs over half of the labor force. Agriculture also plays a vital role in ensuring food security and reducing poverty in the country. The government recognizes the importance of the sector and has implemented several policies and programs to support its development. One of the key policies is the National Organic Policy, which promotes the production and marketing of organic

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agricultural products. The policy aims to enhance the livelihoods of farmers and promote sustainable agricultural practices while preserving the country's biodiversity. The government also provides various forms of support to farmers, such as subsidies on inputs, extension services, and market linkages.

Furthermore, the government has initiated programs to improve agricultural productivity and diversify the sector. The Agriculture Research and Development Centre conducts research and develops new crop varieties and farming practices. The government also provides support for irrigation, mechanization, and post-harvest management to increase productivity and reduce post-harvest losses. These efforts are crucial in sustaining and improving the livelihoods of those dependent on agriculture. Despite the government's efforts to support the sector, the agriculture sector faces several challenges. One of the significant challenges is the small landholding size, which limits the adoption of modern technologies and hinders economies of scale. This results in low productivity and income levels for smallholder farmers. Another challenge is the lack of access to markets, which limits the ability of farmers to sell their produce at a fair price. Poor infrastructure, limited storage and processing facilities, and inadequate market information systems further exacerbate the issue. Climate change is also a significant challenge for the agriculture sector in Bhutan. The country is vulnerable to the adverse impacts of climate change, such as erratic rainfall patterns, increasing temperatures, and the emergence of new pests and diseases. These factors have a significant impact on agricultural productivity and the livelihoods of those dependent on the sector. The government has implemented several adaptation measures, such as the construction of water storage tanks and the promotion of climate-resilient crops. However, these measures are not sufficient to address the scale of the challenge.

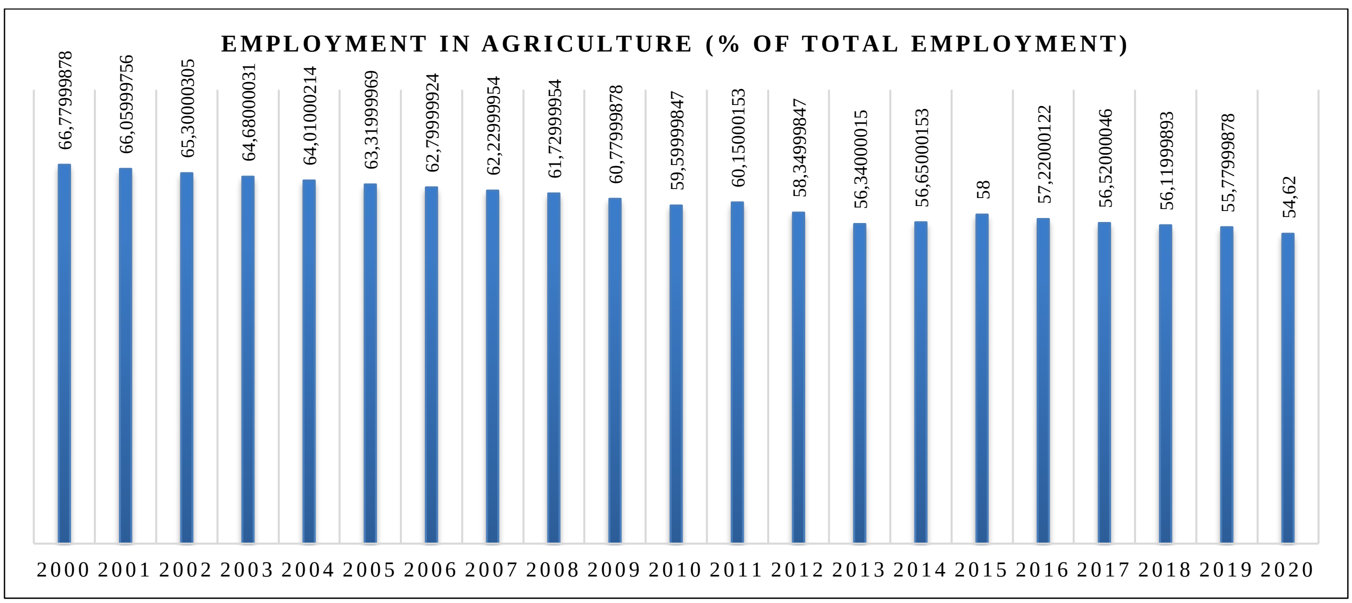

Figure 4: Total Percentage of Employment in Agriculture

Note: World Development Indicator. https://databank.worldbank.org/source/world-development-indicators

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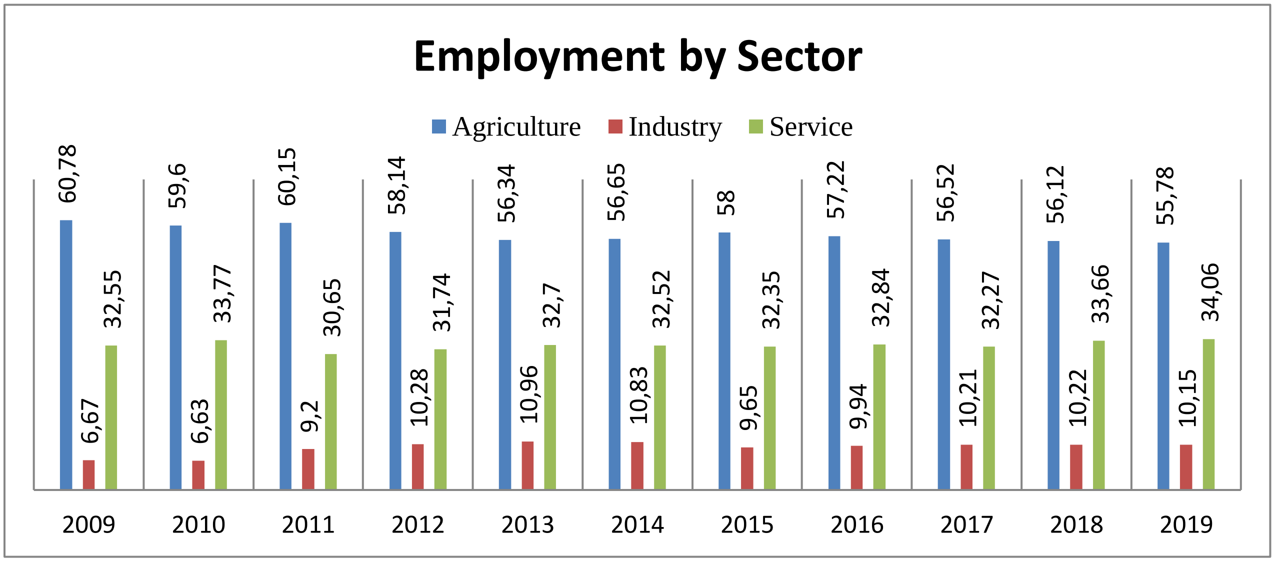

Figure 5: Graphical representation of employment by sectors

Figure 5 represents the percentage of employment in the agriculture, service, and industry sectors in Bhutan from 2016 to 2019. The data indicates that agriculture remains the largest employer in the country, accounting for 55.7% of total employment in 2019. This is followed by the service sector, which employs 39.7% of the workforce, and the industry sector, which employs 4.6% of the workforce. The high percentage of employment in the agriculture sector is not surprising given the country's geographical and climatic conditions. Bhutan's rugged terrain and mountainous landscape make it challenging to develop industries and infrastructure, leading to a heavy reliance on agriculture. Furthermore, the majority of the population lives in rural areas, where agriculture is the main source of livelihood. Despite the high percentage of employment in agriculture, there has been a gradual decrease in recent years, as shown in Figure 4. This decrease can be attributed to the government's efforts to diversify the economy and promote the growth of other sectors. The service sector has seen significant growth in recent years, driven by the development of the tourism industry, which has created job opportunities in hospitality, transportation, and other related services.

The industry sector, on the other hand, has been slower to develop due to the challenges posed by Bhutan's geography and lack of resources. However, the government has been investing in infrastructure development and promoting foreign investment to attract industries such as manufacturing and mining. These efforts aim to reduce the country's reliance on agriculture and create more employment opportunities in other sectors. Despite the government's efforts to diversify the economy, agriculture remains an essential sector in Bhutan's economy. The sector contributes around 16% of the country's GDP and provides livelihoods for a significant portion of the population. The government recognizes the importance of the sector and has implemented several policies and programs to support its development. One of the significant challenges facing the agriculture sector is the small landholding size. Most farmers in Bhutan own small plots of land, which limits their ability to adopt modern technologies and hinders economies of scale. This

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results in low productivity and income levels for smallholder farmers. The government has implemented several programs to address this issue, such as the National Land Use Policy, which aims to consolidate and redistribute land to increase productivity and income levels for farmers. Another challenge facing the agriculture sector is the lack of access to markets. Poor infrastructure, limited storage and processing facilities, and inadequate market information systems limit the ability of farmers to sell their produce at a fair price. The government has implemented several programs to address this issue, such as the Market Access and Growth Intensification Project, which aims to improve access to markets and increase agricultural productivity.

Therefore, agriculture remains the largest employer in Bhutan, providing livelihoods for a significant portion of the population. While there has been a gradual decrease in the percentage of employment in agriculture, the sector continues to be an important contributor to the country's economy. The government's efforts to diversify the economy and promote the growth of other sectors aim to reduce the country's reliance on agriculture and create more employment opportunities in other sectors. However, the government must continue to support the agriculture sector by implementing policies and programs that address the sector's challenges and promote its sustainable development.

Economic Impact of Climate Change on Agriculture

The impact of climate change on agriculture is analyzed by using the ARDL model and multiple regression analysis. The ADRL model is used to see the overall long-run and short-run impact of temperature and rainfall on the agriculture GDP of Bhutan. Furthermore, multiple regression analysis will illustrate the impact of temperature and rainfall on the paddy, maize, wheat, and barley of Dagana dzongkhag. We looked into the sequence in which each series was integrated before analyzing if the Agricultural GDP, rainfall, and temperature are cointegrated. Two different unit root tests were used to assess the integration order of the series: (i) the Augmented Dickey-Fuller (ADF) test; (ii) the Phillips Perron (PP) test.

Unit Root Test

Table 1: ARDL unit root test

	ADF Unit Root Test		Phillips-PerronUnit Root Test	
Variables	Level	First Difference	Level	First Difference
AgriGDP				-19.5459
rainfall	-6.3314	-9.2037	-6.3284	-14.8995
Temp	-4.7481	-8.0212	-4.7773	-6.8465

Note: Intercept and trend model with 5% significance level.

As stated in Table 1 above, the study used the unit root test on the natural logarithms of the variables in level and first difference forms. According to the results of the Phillips-Perron Unit Root Test (PP), agricultural GDP is stationary at the first difference whereas rainfall, temperature,

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and other variables are stationary at the level. The variable is therefore stationary at the initial difference. In other words, it signifies that although the Phillips-Perron (PP) test indicates that there is no stationary level, it is stationary after being converted into the first difference. It is hence ideal for the ARDL model.

Co-integration Test Results/Bound test

Table 2: ARDL cointegration test

Test Statistic	Value	K	Test Statistic	Value	k
F-statistic	4.581484	2	F-statistic	4.581485	3
Critical Value Bounds			Critical Value Bounds		
Significance	I0 Bound	I1 Bound	Significance	I0 Bound	I1 Bound
10%	3.17	4.14	651%	8.53	10.55
5%	3.79	4.85	770%	10.09666667	12.4967
2.50%	4.41	5.52	881.33%	11.56083333	14.3083
1%	5.15	6.36	1019%	13.365	16.54

Note: k shows the number of explanatory variables.

Before finding the long- and short-run relations that exist between variables, it is important to use the ARDL bound test for the confirmation of cointegration. In Table 2, (I0) indicates the lower bound value, and (I1) indicates the upper bound value. The f-statistic is 4.581484 and K shows the number of explanatory variables. Results show that the F-statistics value is more than the critical value at a 10 percent significance level in the lower bound (3.17) and upper bound (4.14). It means 4.58 > 3.17 at the lower bound (l0) and 4.58 > 4.14 at the upper bound (l1). This implies that there is a long-run relationship between the mentioned variable in the period given at a 10 percent significance level.

ARDL Overall Results

Following table 3 shows the overall results of the ARDL model. The model is selected at ARDL (1, 2, 2), indicating agriculture GDP as lag 1, rainfall as lag 2, and temperature in lag 2. Thus, a model is selected based on the Akaike info criterion (AIC) method. The Durbin-Watson value is 2.2 which indicates that there is no problem with correlation in the model. If the Durbin-Warson value is less than 1.73 i.e., (2.2 <1.73), then it indicates there is a problem of correlation. Therefore, the model below shows there is no problem with correlation. The probability value for rainfall is 0.3 and 0.06 at lag 1 and lag 2. Thus, rainfall is impacting agriculture at lag 1 and lag 2 at a 10 percent significant level. The probability value for the temperature is 0.5 and 0.07 at lag 1 and lag 2. Thus, the temperature is impacting agriculture at lag 1 and lag 2 at a 10 percent significant level. The impact of temperature on agriculture is negative as shown by the coefficient value.

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Table 3: overall results of the ARDL model

ARDL (1, 2, 2)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNAGRIGDP(-1)	0.882862	0.039598	22.29535	0
LNRAINFALL(-1)	0.080907	0.084339	0.95931	0.3446
LNRAINFALL(-2)	-0.16346	0.086003	-1.900634	0.0664
LNTEMP(-1)	-0.182387	0.278418	-0.655083	0.5171
LNTEMP(-2)	-0.511709	0.278108	-1.839967	0.0751
C	4.427393	1.439718	3.07518	0.0043
Durbin-Watson stat	2.241742			

ARDL Short run Estimation

Table 4 presents the short-run coefficients of the ARDL model used to analyze the impact of climate change on agriculture GDP in Bhutan. The results show that both rainfall and temperature have a significant influence on agriculture GDP at the 10% significant level in the short run. The probability value for rainfall is less than 0.10, indicating a positive and significant impact on agriculture GDP in the short run. This means that an increase in rainfall can lead to a rise in agricultural output and hence, an increase in agriculture GDP. Similarly, the probability value for temperature is 0.0751, which is also less than 0.10, indicating a positive and significant influence on agriculture GDP. This means that an increase in temperature can also lead to a rise in agricultural output and hence, an increase in agriculture GDP in the short run.

The positive coefficient value for both rainfall and temperature suggests that climate change has a positive impact on agriculture in the short run. This is because rainfall and temperature are two critical factors that affect agricultural production in Bhutan. Higher rainfall and temperature can increase soil moisture and nutrient availability, leading to improved crop yields. However, it is important to note that the impact of climate change on agriculture GDP is not limited to the short run. The long-term impact of climate change on agriculture is likely to be negative, as it can lead to soil erosion, drought, and reduced crop yields.

Therefore, it is crucial to develop policies and strategies to mitigate the long-term impact of climate change on agriculture in developing countries. This includes investing in climate-resilient agriculture practices, promoting sustainable agriculture practices, and providing farmers with access to new technologies and information. Therefore, the short-run coefficients of the ARDL model show that rainfall and temperature have a positive and significant impact on agriculture GDP in Bhutan. However, the long-term impact of climate change on agriculture is likely to be negative, which underscores the importance of developing policies and strategies to mitigate its impact on agriculture.

Table 4: Short-run ARDL Coefficient

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Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNRAINFALL(-1))	0.16346	0.086003	1.900634	0.0664
D(LNTEMP(-1))	0.511709	0.278108	1.839967	0.0751
CointEq(-1)	-0.117138	0.039598	-2.958147	0.0058

ARDL Long run Estimation

Table 5 presents the long-run impacts of climate change on agriculture GDP in Bhutan, as estimated by the ARDL model. The results show that both rainfall and temperature have a significant influence on agriculture GDP at the 10% significant level in the long run. The probability value for rainfall is 0.444, which is less than the 10% significant level, indicating a significant influence of rainfall on agriculture GDP in the long run. Similarly, the probability value for temperature is 0.0001, which is also less than the 10% significant level, indicating a significant influence of temperature on agriculture GDP in the long run. However, the coefficient values for both rainfall and temperature are negative in the long run. The coefficient value for rainfall is -1.13, while that for temperature is -11.21. This indicates that an increase in rainfall and temperature can impact agriculture GDP in the long run.

The negative coefficient values suggest that climate change impact on agriculture in the long run. This is because an increase in rainfall and temperature can lead to soil erosion, reduced soil fertility, and changes in weather patterns that can negatively impact crop yields over time. Therefore, it is important to develop policies and strategies that mitigate the long-term impact of climate change on agriculture. This includes investing in sustainable agriculture practices, such as conservation agriculture, agro-forestry, and integrated soil fertility management. It also involves promoting the use of drought-resistant crop varieties, improving water management, and providing farmers with access to information and new technologies.

Thus, the long-run impacts of climate change on agriculture GDP in Bhutan, as estimated by the ARDL model, indicate that both rainfall and temperature have a significant influence on agriculture GDP. However, the negative coefficient values for both rainfall and temperature suggest that climate change is impacting agriculture negatively in the long run. This underscores the importance of developing policies and strategies that mitigate the long-term impact of climate change on agriculture in Bhutan. The long-run equation is as follows:

Cointeq = LNAGRIGDP - (-1.1387*LNRAINFALL -11.2124*LNTEMP + 37.7963)

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Table 5: ARDL Long-run impacts results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNRAINFALL	-1.138741	1.471865	-0.773672	0.4448
LNTEMP	-11.212388	2.502191	-4.481028	0.0001
C	37.796347	14.508863	2.605052	0.0138

Recommendation for Mitigation of Climate Change Impacts on Agriculture

The familiarity of researchers and governments with the concept of climate-smart agriculture is well established. However, it is crucial to develop appropriate policies that promote sustainable agriculture and effectively implement climate-smart practices to help farmers adapt to the impacts of climate change. To achieve this, providing more training sessions and workshops on climate-smart agriculture for farmers is essential. These educational initiatives can enhance farmers' understanding of climate-smart techniques and enable them to apply these practices in their agricultural activities. Furthermore, promoting agroforestry practices, such as the cultivation of fruit and timber trees, can have multiple benefits. Apart from providing additional income streams, agro-forestry can improve soil fertility and enhance water retention capacity, thus mitigating the adverse effects of climate change on crop yields. In addition to agro-forestry, advocating for sustainable land management practices like conservation agriculture can yield positive results in climate change adaptation. These practices contribute to the reduction of greenhouse gas emissions and enhance soil health, leading to improved agricultural resilience in the face of a changing climate. Another low-cost adaptation measure highlighted in the study is the adjustment of sowing time. This practice is commonly adopted among knowledgeable and experienced farmers. Disseminating proper knowledge about such adaptation strategies to both marginalized and small-scale farmers can play a vital role in minimizing the negative impact of climate change on crops. In conclusion, while the concept of climate-smart agriculture is well-known, the implementation of sustainable policies and the dissemination of knowledge to farmers is key to successful adaptation to climate change impacts. Encouraging agro-forestry, promoting sustainable land management practices, and educating farmers about low-cost adaptation strategies like adjusting sowing time can collectively contribute to reducing the adverse effects of climate change on agriculture.

CONCLUSION

In conclusion, Bhutan is experiencing the detrimental effects of climate change, which are directly impacting the livelihoods of its people. The agriculture sector plays a crucial role in the country's GDP contribution and employment generation, making it of utmost importance in Bhutan. The findings from the ARDL model analysis highlight the economic impacts of climate change on agriculture, with both positive and negative implications. The short-run analysis reveals that temperature and rainfall have a positive impact on agriculture GDP, suggesting that certain aspects

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of climate change may initially benefit agricultural production in Bhutan. However, the long-run analysis reveals a negative impact of temperature and rainfall on agriculture GDP, indicating that the adverse effects of climate change become more pronounced over time. These results emphasize the urgent need for appropriate measures to address the challenges posed by climate change on agriculture and the livelihoods of farmers in Bhutan. One key recommendation is to provide more training sessions and workshops on climate-smart agriculture for farmers. This would enhance their knowledge and skills in adopting sustainable agricultural practices that are resilient to climate change. By equipping farmers with the necessary tools and techniques, they can better adapt to changing climatic conditions and mitigate the negative impacts on their agricultural production. Additionally, promoting agroforestry practices, such as the cultivation of fruit and timber trees, can have multiple benefits. Agro-forestry not only diversifies income sources for farmers but also helps in carbon sequestration and soil conservation. This approach enhances the overall resilience of the agriculture sector and reduces its vulnerability to climate change. Furthermore, policy interventions should prioritize the development and dissemination of climate-resilient seeds and technologies. This would enable farmers to cultivate crops that are better adapted to changing climatic conditions, ensuring greater productivity and food security in the face of climate change impacts.

REFERENCE

Ahmed, M., Shuai, J., & Ali, H. (2023). The effects of climate change on food production in India: evidence from the ARDL model. *Environment, Development, and Sustainability*. https://doi.org/10.1007/s10668-023-03209-w

Cline, W.R. (1996). The Impact of Global Warming on Agriculture: Comment. *American Economic Review,* 86, 1309–1313

Chandio, A. A., Jiang, Y., Fatima, T., Ahmad, F., Ahmad, M., & Li, J. (2022). Assessing the impacts of climate change on cereal production in Bangladesh: evidence from ARDL modeling approach. *International Journal of Climate Change Strategies and Management*, ***14***(2), 125–147. https://doi.org/10.1108/ijccsm-10-2020-0111

Chhogyel, N., Kumar, L., & Bajgai, Y. 2020 Consequences of climate change Impacts and incidences of extreme weather with crop production in Bhutan. *Sustainability*, **12**(4319), 1-18. https://doi.org/10.3390/su12104319

Dumrul, Y., & Kilicaslan, Z. (2017). Economic Impacts of Climate Change on Agriculture: Empirical Evidence From The ARDL Approach for Turkey. *Journal of Business, Economics, and Finance*, ***6***(4), 336347. https://doi.org/10.17261/pressacademia.2017.766

Katwal, T.B., Dorji, S., Dorji, R., Tshering, L., Ghimiray, M., Chhetri, Dorji, T.Y. and Tamang, A.M. (2015). Community Perspective on the On-Farm Diversity of Six Major Cereals and Climate Change in Bhutan. *Agriculture, 5*, 2-16. doi:10.3390/agriculture5010002

Kumar, L., & Chhogyel, N. (2018). Climate change and potential impacts on Agriculture in Bhutan: a discussion of pertinent issues. *Agriculture & Food Security*, **7:79**(2018), 1-13. https://doi.org/10.1186/s40066-018-0229-6

Lobell, D. B., Ortiz-Monasterio, J.I., Falcon, W.P. (2007). Yield uncertainty at the field scale evaluated with multi-year satellite data. *Agricultural Systems*, 92, 76–90

e-ISSN: 2961-712X
Vol. 2 No. 2, July-December 2023
DOI: 10.55299/ijec.v2i2.604

Malla, R. K. and Singh, K. K. (2000). Climate variability and wheat yield progress in Punjab using the theCERES-wheat and WTGROWS models. *Yayu Mandal , 30* (3-4), 35-41.

Mendelsohn, R. (2014). The Impact of Climate Change on Agriculture in Asia. *Journal of Integrative Agriculture,* **13** (4), 660-665.

Nasrullah, M., Rizwanullah, M., Yu, X., Jo, H., Sohail, M., & Liang, L. (2021). Autoregressive distributed lag (ARDL) approach to study the impact of climate change and other factors on rice production in South Korea. *Journal of Water and Climate Change*, ***12***(6), 2256 2270. https://doi.org/10.2166/wcc.2021.030

Reddy, K.V., Paeamesh, V., Arunachalam, V., Das, B., Ramasundaram, P., Pramanik, M., Sridhara, S., Reddy, D. D., Alataway, A., Dewidar, A. Z., & Mattar, M. A. (2022). Farmers' Perception and Efficacy of Adaptation Decisions to Climate Change. *Agronomy,* **12** (1023), 1-18. https://doi.org/10.3390/ agronomy12051023

Suberi, B., Tiwari, K. R., Gurung, DB., Bajracharya, R. M *and* Sitaula, B. K. *(2018).* People's perception of climate change impacts and their adaptation practices in Khotokha Valley, Wangdue, Bhutan. Indian Journal of Traditional Knowledge. NISCAIR-CSIR, India, ***17(****1), 97-105* http://nopr.niscpr.res.in/handle/123456789/43144

Tenzin, J., Phuntsho, L., & Lakey, L. (2019, August). *Climate-smart agriculture: adaptation and mitigation strategies to climate change in Bhutan.* SAARC Agriculture Centre (SAC), 37-61. ttps://www.researchgate.net/publication/335137542