*AgBioForum, 24(1): 1-12. ©2022**AgBioForum***

Economic Impact of Climate Change on Agriculture: A Case of Vietnam

Nguyen Van Huong
Faculty of Economics, Hung Yen University of Technology and Education (UTEHY), Hung Yen, Viet Nam
Email: vanhuong75hy@gmail.com

Bui Thi Minh Nguyet *
Vietnam National University of Forestry, Xuan Mai,
Ha Noi, Vietnam
Email: minhnguyetfuv@gmail.com

Hoang Van Hung
Faculty of Economics, Hung Yen University of Technology and Education (UTEHY), Hung Yen, Viet Nam
Email: davidhoang8585@gmail.com

Hoang Minh Duc
Faculty of Economics, Hung Yen University of Technology and Education (UTEHY), Hung Yen, Viet Nam
Email: duchoasunghau@gmail.com

Nguyen Van Chuong
University of Financial – Business Administration (UFBA),
Hung Yen, Viet Nam
Email: nguyenchuong.edu@gmail.com

Do Minh Tri
Nguyen Van Linh Political School, Hung Yen, Viet Nam
Email: minhtritct@gmail.com

Phung Van Hien
National Academy of Public Administration (NAPA),
Ha Noi, Viet Nam
Email: phunghiennapa@gmail.com

*** correspondence*:* Bui Thi Minh Nguyet**

Email: minhnguyetfuv@gmail.com

Food security, agricultural exports, and livelihoods have improved by rapid agricultural expansion in the previous 30 years. In the coming decades, warming trends and human pressures are expected to exacerbate the impact of climate change on agriculture. A time series of data from 1990 to 2020 examines the economic effects of climate change on Vietnamese farm production. After using the Augmented Dickey-Fuller and Philips-Perron unit root tests, the ARDL bounds testing technique estimates short and long-run cointegration. They found long-run cointegration between the variables. A positive influence of CO2 emissions is identified, although negative impacts of average temperature and rainfall are found. But only in the short term can energy consumption benefit agriculture. Non-climatic factors like crop production and fertiliser consumption have beneficial short- and long-term impacts on agriculture production and yield. Juselius Jhansen As well as proving long-term cointegration between variables. The report advises the Vietnamese government to create and implement many adaptation programmes to preserve the agriculture industry from climate change.

Key words: Climate change; Agriculture output; Vietnam; ARDL bound testing approach.

---

1. INTRODUCTION

Climate change is one of the most pressing issues of the modern era, as it has significantly impacted or is in the process of affecting ecosystems. On the planet, climate change has always been a continuous process. However, over the last century or so, the rate of change has accelerated dramatically. Since the nineteenth century, the mean temperature has increased by 0.9 degrees celcius, owing primarily to GHG emissions caused by human activity. This is projected to rise to 1.50C or possibly higher by 2050 due to the way deforestation is spreading, greenhouse gas emissions are increasing, and air, soil, and water resources are becoming contaminated. Droughts, food shortages, heat waves, erratic precipitation patterns, and other extreme events have worsened due to the world's historic temperature rise (Arora, 2019; Baloch et al., 2022; Nawaz et al., 2021).

While the consequences of climate change are widespread, their profound impact on the agricultural sector, which is the bedrock of food production and the global economy, is now abundantly clear. Agriculture is one of the sectors most vulnerable and sensitive to climate change. This sector creates jobs, supplies raw materials to manufacturing, ensures food security, and contributes foreign currency to an economy's foreign trade. According to surveys, the agriculture sector has grown slowly in recent years due to climate change. Variations in climatic variables such as precipitation, temperature, the intensity and frequency of extreme weather events, CO2 levels in the atmosphere, and sea-level rise all have a direct effect on agricultural products and livestock (Chien, Pantamee, et al., 2021; Dumrul, 2017; Nawaz et al., 2021). Significant climatic changes occurring faster have posed a threat to global food security. Crop yield per hectare is increasing at a much slower rate than population growth, according to the World Food Programme's (WFP) 2018 report. According to a recent study, if current greenhouse gas emissions and climate change trends continue, major cereal crop production will decline by 2100. (20 to 45 percent maize yields, 20 to 30 percent in rice, and 5 to 50 percent in wheat). As a result, if current trends continue, crop losses will accelerate shortly, resulting in decreased production, increased food costs, and difficulty meeting the needs of a growing population (Arora, 2019; Chien, Sadiq, et al., 2021; Shair et al., 2021).

While climate change is a global phenomenon, its effects vary according to location, country, sector, and community. The poor and rural communities in developing countries are disproportionately affected by climate change, as they lack adaptive capacity and access to alternative production resources (Chien, Pantamee, et al., 2021; Huong, Bo, & Fahad, 2019; Huong, Yao, & Fahad, 2019; Sun et al., 2021). The same is true for Vietnam. Due to its high population density, long coastlines, and economic activities such as agriculture, natural resource extraction, and forestry, it is associated with the world's most vulnerable countries to climate change (Huong, Bo, et al., 2019; Li et al., 2021; Xiang et al., 2021). Agriculture is a critical sector in Vietnam because it accounts for approximately one-fifth of GDP, employs around half of the workforce, and provides income to about three-quarters of the population (Chien, Sadiq, et al., 2021; T. Q. Trinh, Rañola, Camacho, & Simelton, 2018). Agriculture provides the majority of households with their primary source of income, and production is highly dependent on natural resource exploitation (Huong, Bo, et al., 2019; Zhuang et al., 2021). Climate change's effects on agriculture in Vietnam would result in a 0.7%–2.4% reduction in total GDP by 2050, as it affects crop production both directly and indirectly via variability in water availability, potential evapotranspiration, and irrigation (Liu, Lan, Chien, Sadiq, & Nawaz, 2022; T.-A. Trinh, Feeny, & Posso, 2021). Additionally, low literacy, traditional farming methods, insufficient infrastructure development, and transportation problems contribute to the county's climatic sensitivity. As a result, a climate change impact assessment on agriculture will assist in clarifying perceptions of the issues, quantifying the impact, and helping in the development of plans for timely response (Chien, Sadiq, et al., 2021; Huong, Yao, et al., 2019).

Numerous studies have been conducted in the existing literature to examine the effects of climate change on developing and developed economies. On the one hand, considerable research has been conducted on the relationship between climatic change as measured by precipitation and temperature and agriculture in various economies using a variety of econometric methodologies (Dumrul, 2017), (Chandio, Jiang, & Rehman, 2020), and (Huong, Yao, et al., 2019). (Bozzola, Massetti, Mendelsohn, & Capitanio, 2017; Nawaz et al., 2021). On the other hand, an increasing number of scholars have examined the relationship between natural disasters and agriculture. These studies acknowledged that the economic consequences of natural disasters might be greater than previously recognised due to their magnitude and intensity (Coulibaly, Islam, & Managi, 2020). (Klomp & Hoogezand, 2018) and (Blanc & Strobl, 2016; Keerthiratne & Tol, 2018). This article contributes to the body of knowledge by demonstrating the effect of climate change on agriculture in Vietnam, which has remained relatively understudied in terms of the climate change-agriculture relationship in the literature. This paper seeks to quantify the economic impacts of climate change on agriculture in Vietnam from 1990 to 2020. Vietnam is an important case study due to its heavy reliance on agriculture and vulnerability to climate change and natural disasters. Agriculture has established itself as a significant sector, accounting for over 21% of GDP and employing more than 40% of the workforce. In 2020, agriculture, forestry, fishing, and agriculture contributed 14.85 percent to GDP. With approximately 17.72 million workers, agriculture accounted for 33.06 percent of total employment in Vietnam (Le Toan et al., 2021; Mohsin, Kamran, Atif Nawaz, Sajjad Hussain, & Dahri, 2021). It's worth noting that most agricultural activities take place in rural areas, making rural households particularly vulnerable to climate change and climate shocks. As a result, a study of the economic effects of climate change on agriculture in Vietnam is unquestionably necessary (T.-A. Trinh et al., 2021).

The remainder of the paper is arranged in the following manner. Section 2 summarises the pertinent existing literature. Section 3 contains the data and the empirical methodology used. The fourth section discusses the empirical findings. The concluding section 5 includes the paper's conclusion and some worthwhile recommendations.

2. REVIEW OF EXISTING LITERATURE

As more agronomists and economists began rigorously examining the effect of various climate elements on agricultural production, research on the impact of climatic variations on agricultural output gained prominence. For example, (Zhao et al., 2017) investigated the effect of water availability and temperature on crops using a variety of methodologies, including experiments. According to the findings, crop yields are being threatened by rising temperatures and water variability. Even though their research took various approaches, their results demonstrated that increasing temperatures harmed site-scale, country-level, and global crop productivity. Wielogorska et al. (2019) assessed 140 wheat, sorghum, and maize samples in Somalia using the UPLC-MS and MS multi-mycotoxin approaches. During the whole-crop research, they discovered mycotoxins, which were poisonous substances produced by certain types of fungus. These toxins were produced by fungi that grew on crops and were aided by severe environmental conditions such as high temperatures, which reduced crop yields before and after harvesting.

Furthermore, (Karimi, Karami, & Keshavarz, 2018) examined the impact of climate change on Iran's agriculture sector and the government's and farmers' existing adaptation efforts. The authors concluded that water endowments and changes in rainfall had a significant impact on crop yield and water requirements, and farm family welfare and income. In terms of adaptability, the government was found to have made significant progress in increasing agricultural production and irrigation expansion by using cutting-edge technology, developing new technologies, and reforming policies. (Chavas, Di Falco, Adinolfi, & Capitanio, 2018) examined the effect of weather on agricultural output distribution (corn and wheat yields) in seven Italian provinces from 1900 to 2014. The quantile-autoregression model revealed that weather impacts were asymmetric, with a greater impact on the lower tail of the distribution than on the upper tail. It was discovered that adverse weather has a persistent and significant effect on agricultural productivity. (Migliore, 2019) attempted to quantify the impact of climate variations on permanent crop cultivation in Southern Italy. The authors demonstrated a significant effect of climate change in the region by assembling climate projections from 2021 to 2050.

Numerous researchers have recently used various econometric techniques to estimate the impact of climate change on agriculture or crop yields. Among these, the ARDL bound testing technique has been extensively used in studies to evaluate the short and long run impacts of climate variability on agriculture. For example, (Dumrul, 2017)) used the ARDL bounds testing technique to examine the effects of climate variations on agricultural output in Turkey from 1961 to 2013. Precipitation was found to have a significant positive effect on agriculture in Turkey, whereas temperature had a negative impact. (Chandio, Jiang, & Rehman, 2020) used an ARDL bound testing approach to examine how climate change affected agriculture output in China from 1982 to 2014. They discovered that rainfall and temperature had a negative long-run effect on agriculture production.

In contrast, fertilizers, energy consumption, and land area under cereal crops had a significantly positive long-run effect on agriculture production in both the short and long run estimations. According to the study's findings, rainfall has been shown to improve crop production over time. However, it was discovered that it had a detrimental effect in the short run. The temperature harmed crop production in both the short and long term, but CO2 emissions has a negligible impact on crop production. (Attiaoui & Boufateh, 2019) estimated the short- and long-term effects of climate change on Tunisia's cereal cropping. The results of ARDL bound testing indicated that climate issues harmed cereal output and that the negative impact of climate were felt most acutely during periods of low rainfall, while temperature levels were favourable for cereal crop production. (Ahsan, Chandio, & Fang, 2020) examined the effect of climate variation on cereal crop production in Pakistan using ARDL and Johansen cointegration tests. The researchers observed a positive long-run cointegration between cereal crop production and CO2 emissions and bidirectional causality between the variables in their analysis. Additionally, (Asumadu-Sarkodie & Owusu, 2017; Sarkodie, 2017) established a bidirectional causal relationship between CO2 emissions and cereal crop production in Ghana.

Additionally, the Ricardian approach has been extensively used to estimate the agriculture-climate change nexus. (Huong, Yao, et al., 2019) estimated the impacts of climate change on agriculture in the northwestern region of Vietnam using the Ricardian equivalence approach. The authors examined the effects of rainfall and temperature change on Northwest farming using primary data collected through Vietnam Household Living Standards Surveys and discovered a significant nonlinear and inverted U-shaped relationship between weather variables and household revenues. Net revenue decreased during the dry season as rainfall and temperature increased. For Pakistan, (Sadiq, Saboor, Mohsin, Khalid, & Tanveer, 2019) determined the impact of climate change on agriculture production using a Ricardian evaluation approach. They demonstrated that total precipitation and diurnal temperature decreased the farm's net revenue per hectare, particularly in rain-fed fields. The findings indicated that rain-fed farms appeared more susceptible to climate change than irrigated farms. In a similar vein, (Bozzola et al., 2017) assessed the impact of temperature warming on agriculture in Italy using the Ricardian Equivalence approach and discovered that a minor increase in temperature over a year had no significant effect on land values in Italy. Summer warming has a detrimental impact, whereas spring and autumn warming is having a beneficial impact. A normal marginal increase in precipitation over the year was not significant at the national level but was significant at the regional level. In the case of Vietnam (T. Q. Trinh et al., 2018), different factors influencing farmers' adaptations to climate change in agricultural output were analysed using multivariate probit and binary logit models. The authors concluded that while farm size and climate change training significantly impacted farmers' climate change adaptation decisions, membership in local organisations and labour availability had no significant effect on these decisions. The impact of climate change on European agriculture was estimated using Continental Scale Ricardian Analysis (Van Passel, Massetti, & Mendelsohn, 2017).

According to the findings, European farms were slightly more vulnerable to warming than those in the United States. (Sultan, 2021) quantified the impact of climate change on Mauritius' agriculture. Based on cross-sectional farm data from 392 farmers and a Ricardian approach, the findings indicated that agriculture was negatively affected by mean precipitation and summer temperature. (Chandio, Jiang, & Rehman, 2020) examined the impact of climate change on rice production in Pakistan. Surprisingly, their study found that CO2 emissions positively affected rice production in both the short and long run. Another study (Chandio, Jiang, & Rehman, 2020) found that CO2 emissions and mean temperature had an inverse relationship with cereal production in Turkey. In contrast, mean rainfall had a positive relationship with cereal production in the short and long run.

2.1 Literature Gap

The literature contains a sufficient number of evidence for the impact of climate change on agriculture in various economies and estimation methods. However, in terms of this investigation, the Vietnamese economy remained under-researched in the literature (Huong, Yao, et al., 2019; T.-A. Trinh et al., 2021). (T.-A. Trinh et al., 2021). Furthermore, to our knowledge, no empirical research has been conducted in Vietnam to examine the effect of climate change on agricultural output using the ARDL Bound Testing Approach. As a result, this paper seeks to address this shortcoming by examining the short and long-run effects of climate change variables on agriculture in Vietnam.

3. DATA AND EMPLOYED METHODOLOGY

This article discusses critical variables that significantly impact agricultural production in Vietnam. Previous research by (Nasrullah et al., 2021), (Chandio, Jiang, & Rehman, 2020), and (Warsame, Sheik-Ali, Ali, & Sarkodie, 2021) indicated that various natural and technological factors have a significant impact on agricultural production. As a result, the study uses rainfall, average temperature, CO2 emissions, and energy consumption (all of which are climate-changing variables), land area under cereal cropping, and fertiliser consumption (all of which are non-climatic variables) as explanatory variables, and agriculture production as the dependent variable. Annual data for the variables mentioned above have been gathered from the World Bank from 1990 to 2020. (2021). To conduct empirical analysis, all variables are transformed into logarithmic forms. Table 1 contains the data description for the variable series, whereas Figures 1–7 depict the time trends for the study variables.

Table 1: Detailed Description of the Variables

Variables	Measurement	Data source
Agriculture production	Agriculture value added (% of GDP)	World development indicators
CO2 emission	CO2 emissions per capita (metric tons)	World development indicators
Rain fall	Mean rainfall annual (mm)	World development indicators
Temperature	Average annual temperature (°C)	World development indicators
Area under crop production	Land under cereal crops (hectares)	World development indicators
Energy consumption	Energy consumption (kg of oil equivalent per capita)	World development indicators
Fertilizer consumption	Fertilizer's consumption (kilograms per hectare of arable land)	World development indicators

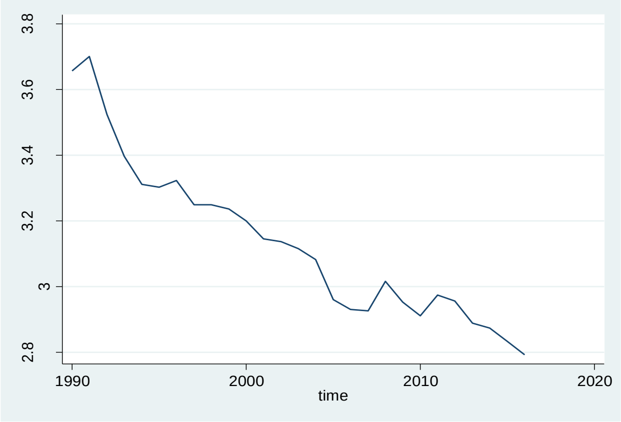

Figure 1: Time plot of agriculture production (lnAGRI) over 1990-2020

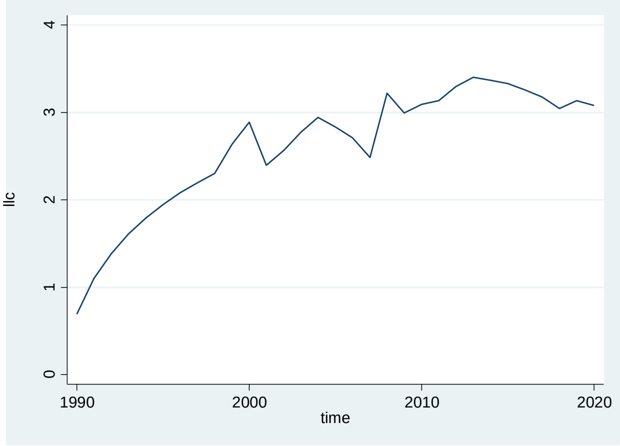

Figure 2: Time plot of land area under cereal crop (lnCL) over 1990-2020

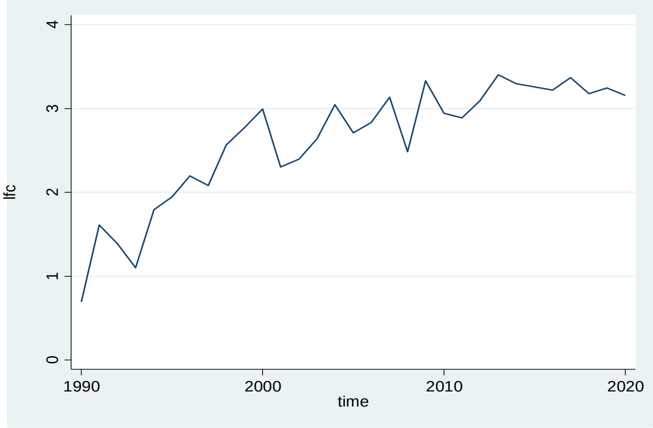

Figure 3: Time plot of fertilizer consumption (lnFC) over 1990-2020

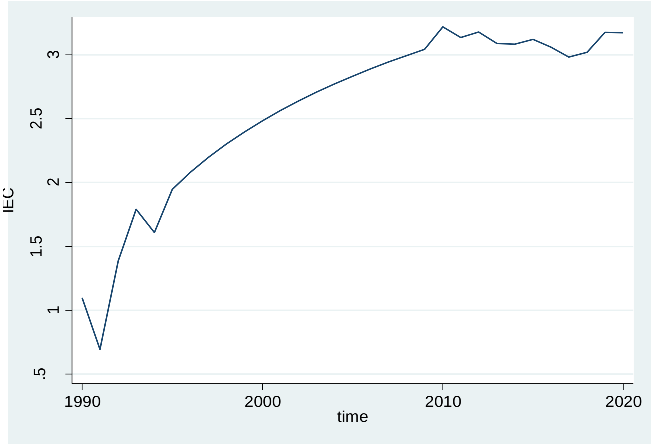

Figure 4: Time plot of energy consumption (lnEC) over 1990-2020

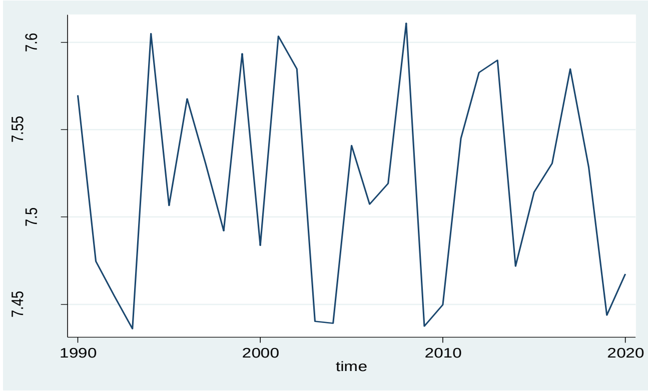

Figure 5: Time plot of rainfall (lnRain) over 1990-2020

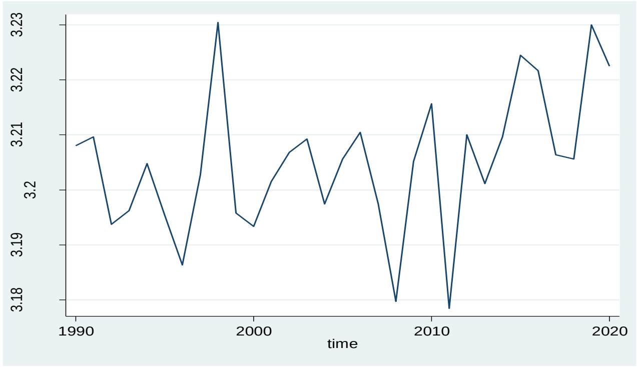

Figure 6: Time plot of average temperature (lnTemp) over 1990-2020

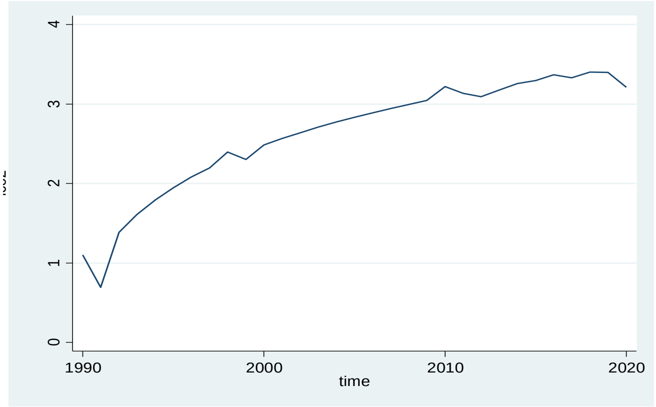

Figure 7: Time plot of CO2 emission (lnCO2) over 1990-2020

4. METHODOLOGY

(Charemza, 1992) pioneered the ARDL technique, which was later improved by (M. H. Pesaran, Shin, & Smith, 2001) and (M. H. Pesaran, & Shin, Y, 1995).The ARDL technique outperforms several conventional cointegration techniques, including the Chandio, Jiang, Rehman, and Rauf (2020) and Engle-Granger cointegration approaches. It presupposes a small sample size and simultaneity biases in the variable associations. Traditional cointegration techniques have a significant drawback. They require that all variables in this study are non-stationary or unit root at the level, i.e., I(0), but stationary in any similar order. This problem is solved by utilising novel cointegration techniques such as the ARDL, which is insensitive to the order in which variables are integrated, whether at the level, first difference, or mixed integration order. This current approach is advantageous because it enables the empirical model to select the optimal number of lags. These estimable properties support the ARDL technique's use in achieving reliable estimations.

The economic impact of climate change on agriculture in Vietnam from 1990 to 2020 is studied using the following empirical model:

$$AGRI_t = f\,(Rain_t, Temp_t, CO2_t, CL_t, EC_t, FC_t) \qquad (1)$$

Where AGRI= Agriculture production, Rain= rain fall, Temp= average temperature, CL= cereal crops land area, EC= energy consumption, FC= fertilizer consumption and CO2= carbon dioxide emission.

The model, after transforming the variables into logarithmic form, is specified in the econometric form as:

$$lnAGRI_t = \alpha_0 + \alpha_1 CO_{2t} + \alpha_2 lnRain_t + \alpha_3 lnTemp_t + \alpha_4 lnEC_t + \alpha_5 lnFC_t + \alpha_6 lnCL_t + \varepsilon_t \qquad (2)$$

The ARDL model has two primary steps for evaluating the long-term relationship. The initial step is to analyze if the study variables have a long-term relationship. Equation (3) specifies the ARDL model as follows:

$$\Delta lnAGRI_t = \alpha_0 + \sum_{i=1}^{r} \alpha_{1k}\Delta lnAGRI_{t-j} + \sum_{i=0}^{r} \alpha_{2k}\Delta lnCO2_{t-j} + \sum_{i=0}^{r} \alpha_{3k}\Delta lnRain_{t-j} + \sum_{i=0}^{r} \alpha_{4k}\Delta lnTemp_{t-j} + \sum_{i=0}^{r} \alpha_{5k}\Delta lnEC_{t-j} + \sum_{i=0}^{r} \alpha_{6k}\Delta lnFC_{t-j} + \sum_{i=0}^{r} \alpha_{7k}\Delta lnCL_{t-j} + \beta_1 lnAGRI_{t-1} + \beta_2 lnRain_{t-1} + \beta_3 lnTemp_{t-1} + \beta_4 lnEC_{t-1} + \beta_5 lnFC_{t-1} + \beta_6 lnCL_{t-1} + \beta_7 CO2_{t-1} + \varepsilon_t \tag{3}$$

Where α_0 stands for the intercept, r for the lag order, Δ represents the first difference operator, ε_t for the error term. Moreover, F-test has been applied in the study to the long-run equilibrium relation between lnAGRI, lnCO2, lnCL, lnFC, lnEC, lnTemp, lnRain. The null hypothesis (H0) is that the variables do not have any cointegration.

H0: $\rho_1 = \rho_2 = \rho_3 = \rho_4 = \rho_5 = \rho_6 = \rho_7$

and the alternative hypothesis (H1) states the reverse

H1: $\rho_1 \neq \rho_2 \neq \rho_3 \neq \rho_4 \neq \rho_5 \neq \rho_6 \neq \rho_7$

The estimated F test is compared with lower and upper bound values (M. H. Pesaran et al., 2001). The H0 of the absence of cointegration among lnAGRI, lnCO2, lnFC, lnCL, lnEC, lnTemp, lnRain is rejected if the computed F-test exceeds the upper bound. The H0 of the absence of cointegration between lnAGRI, lnCO2, lnCL, lnFC, lnEC, lnTemp, lnRain cannot be rejected if the estimated F-test is lower than the upper bound. The H0 of the absence of cointegration becomes inconclusive if the estimated F-test lies between the lower and upper levels of the ranges, which can be verified using either the Johansen cointegration technique or the CUSUM (cumulative sum recursive residuals) and CUSUMSQ (cumulative of square recursive residuals) to confirm cointegration consistency.

The second step of ARDL estimation involves assessing the short-run relationship between agriculture production, temperature, CO2 emissions, rainfall, fertilizers consumption, cereal cropland area, and energy consumption in Vietnam. In the ARDL formulation, the ECM can be stated as

$$\Delta lnAGRI_t = \alpha_0 + \sum_{i=1}^{r} \alpha_{1k}\Delta lnAGRI_{t-j} + \sum_{i=0}^{r} \alpha_{2k}\Delta lnCO2_{t-j} + \sum_{i=0}^{r} \alpha_{3k}\Delta lnRain_{t-j} + \sum_{i=0}^{r} \alpha_{4k}\Delta lnTemp_{t-j} + \sum_{i=0}^{r} \alpha_{5k}\Delta lnEC_{t-j} + \sum_{i=0}^{r} \alpha_{6k}\Delta lnFC_{t-j} + \sum_{i=0}^{r} \alpha_{7k}\Delta lnCL_{t-j} + \alpha ECM_{t-1} + \varepsilon_t \tag{4}$$

5. EMPIRICAL ESTIMATION AND DISCUSSION

Time series data are used in this empirical analysis to quantify the impact of climate change on agriculture in Vietnam. Table 2 contains the descriptive statistics for the variables included in the analysis. According to Jarque-Bera statistics, all variables have a normal distribution with zero covariance and a constant variance.

Table 2. Descriptive Statistics

Variables	lnAGRI	lnCO2	lnEC	lnFC	lnCL	lnRain	lnTemp
Mean	3.17281	-0.31140	6.01360	5.639958	15.89584	7.523563	3.201465
Median	3.141347	-0.28724	5.977751	5.791568	15.93597	7.524909	3.202136
Max	3.701034	0.529926	6.50683	6.181791	16.02093	7.610878	3.230409
Min	2.888347	-1.33297	5.563719	4.653397	15.6834	7.436034	3.17847
Standard Deviation.	0.233103	0.63908	0.334679	0.400249	0.094652	0.061445	0.011266
Skewness	0.74198	-0.17200	0.164992	-1.09593	-0.81123	-0.08497	0.077957
Kurtosis	2.751208	1.714527	1.611901	3.243245	2.4943	1.572907	3.753149
Jarque-Bera	2.264034	1.770789	2.035708	4.86343	2.888159	2.065476	0.591543
Probability	0.322382	0.412551	0.36137	0.087886	0.235963	0.356031	0.743957
Sum	76.14743	-7.47374	144.3266	135.359	381.5002	180.5655	76.83517
Sum Sq. Dev.	1.249752	9.393743	2.57623	3.684583	0.206057	0.086836	0.002919
Observations	31	31	31	31	31	31	31

Table 3 shows the correlation matrix in the same way. According to correlation analysis, fertilizer consumption, land under cereal production, energy consumption, CO2 emission, rainfall, and temperatu are all negatively correlated with agriculture production. The correlation analysis also shows a negative correlation between average temperature and rainfall.

Table 3: Correlation Matrix

	lnAGRI	lnFC	lnCL	lnEC	lnRain	lnTemp	lnCO2
lnAGRI	1.000						
lnFC	-0.892	1.00					
lnCL	-0.934	0.929	1.00				
lnEC	-0.967	0.887	0.955	1.00			
lnRain	-0.048	-0.033	0.054	0.050	1.00		
lnTemp	-0.180	0.178	0.075	0.080	-0.220	1.00	
LnCO2	-0.982	0.902	0.959	0.991	0.062	0.141	1.00

After descriptive and correlation analysis, The ADF test is used to evaluate the stationarity of the series. The PP unit root test has also been applied to verify the results of the ADF test. Table 4 below shows us the results of both unit root tests. Agriculture production (lnAGRI), CO2 emission (lnCO2), fertilizer consumption (lnFC), and energy consumption (lnEC) are found to contain unit root at level I (1), both with intercept and intercept and trend, but land area under cereal production (lnCL), average temperature (lnTemp) and rainfall (lnRain) are found to stationary I(0) at the level both with intercept and intercept and trend. As a result, the ARDL technique of cointegration should be used to examine the effect of climate change on agriculture in Vietnam from 1990 to 2020.

Table 4. Unit Root Testing

Variables	ADF Test (Level)		PP Test (Level)	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
lnAGRI	-1.8499	-2.470	-2.931	-2.367
lnCO2	-0.6470	-1.905	-1.378	-1.831
lnFC	-6.638	-3.112	-4.7409	3.1277
lnEC	-0.1076	-2.116	0.0709	-2.568
lnCL	-3.503***	-1.433***	-3.9014***	-1.295**
lnRain	-4.845***	-4.715***	-7.4001***	-7.151***
lnTemp	-4.384***	-5.030***	-4.316***	-5.020***
	First Difference		First Difference	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
lnAGRI	-4.769***	-5.237***	-4.769***	-5.207***
lnCO2	-5.1223***	-5.233***	-5.354***	-6.6388***
lnFC	-7.382***	-8.3139***	-7.916***	-10.255***
lnEC	-3.997***	-3.7214**	-3.968***	-3.609***
lnCL	----------	-----------	----------	------------
lnRain	----------	-----------	----------	------------
lnTemp	-----------	-----------	----------	------------

Where, **,*** shows 5 and 1 percent significance level. ADF= Augumented Dickey Fuller and PP=Philips-Perron

The study examines the long-term association between climate change and other variables using the ARDL technique. As a result, the initial step is to determine the appropriate lag length. The results of numerous selection criteria are summarised in Table 5, and the optimal lag length is determined using the SIC.

Table 6 summarises the results of the ARDL bounds testing approach. The results indicate that when agriculture production, CO2 emissions, fertiliser consumption, energy consumption, land area under cereal production, rainfall, and average temperature are used as dependent variables, the computed F-stat exceeds the upper critical bound. As a result, the ARDL bounds test for cointegration reveals that all variables examined have a long-run relationship.

Table 5: Results of Optimal Lag Order Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	60.67805		3.65e-08	− 3.392501	− 3.846271	− 1.156981
1	162.0746*	178.3118*	9.33e-11*	− 5.243706	− 3.954683*	− 5.720845*
2	178.4786	23.42559	1.35e-08	− 5.102569	− 5.697989	− 4.839718
3	218.4225	25.48107	2.21e-08	− 6.790689	− 1.074171	− 5.647345
4	225.3254	24.68841	2.66e-08	− 5.767629	− 1.324641	− 4.838596

*Represents optimal lag order. LR, sequential modified LR test statistic, FPE= final prediction error, AIC=Akaike information criterion, SIC Schwarz information criterion, HQ = Hannan–Quinan information criterion.

Table 6: Findings of ARDL-Bound Testing Approach

Variables	lnAGRI	lnCO2	lnFC	lnEC	lnCL	lnRain	lnTemp
F-stat	6.896***	5.906***	4.7699***	3.986***	4.361***	5.091***	4.591***
Structure of optimal lag	(1,1,1,0,0,1,1,)	(1,1,0,0,0,1,1)	(1,1,0,0,0,0,0)	(1,0,0,0,1,1,1)	(1,1,0,0,0,1,1)	(1,1,0,0,0,1,1,1)	(1,0,0,0,0,0,0,)

Lower bounds I(0)	2.27 (5%)						
Upper bounds I(I)	3.28 (5%)						
Diagnostic test							
R^2	0.578	0.734	0.999	0.481	0.98	0.557	0.635
Adjusted.R^2	0.841	0.749	0.998	0.487	0.97	0.559	0.671
F^2-stat	6.592**	8.905**	17.07***	8.264***	9.29**	1.63***	7.983

In ARDL analysis, Table 7 shows the long-run effects of climate and non-climate variables on agricultural output. Among climatic variables, CO2 emissions are associated with increased agricultural production in Vietnam. Agriculture output increases by 0.1 percent for every percent increase in CO2 emissions in the long run. (Chandio, Jiang, & Rehman, 2020), (Xiang et al., 2021) found similar results for CO2 emission on various crop productions and argued that increased CO2 emission aids in crop photosynthesis enhancement. According to the long-run coefficients, rainfall and average temperature negatively affect agriculture. Agriculture production is reduced by 0.5 and 1.2 percent due to a one percent increase in rainfall and moderate temperature. These findings corroborate (Korres, Norsworthy, Burgos, & Oosterhuis, 2017) and (Chandio, Jiang, & Rehman, 2020) findings regarding the adverse effect of temperature on rice and agricultural production. According to Ali et al. (2017), the highest temperature is having a detrimental impact on wheat productivity. (Rotich & Mulungu, 2017), (Mosammam, Mosammam, Sarrafi, Nia, & Esmaeilzadeh, 2015), (Chandio, Jiang, & Rehman, 2020), and (Kakumanu, Kotapati, Nagothu, Kuppanan, & Kallam, 2018) all reported that excessive rainfall was detrimental to crop production and strongly support our findings.

Additionally, among non-climatic variables, there is a significant and positive relationship between cereal cropland area and agricultural productivity. Thus, increasing the size planted to cereal crops will be critical for long-term agricultural production growth. The findings indicate that a 1% increase in cereal cropland area results in a 1.16 percent increase in agricultural production. This paper's conclusion is comparable to those of (Chandio, Jiang, & Rehman, 2020), (Warsame et al., 2021) and (Nasrullah et al., 2021). Similarly, it has been discovered that fertilisers are critical in mitigating any long-term negative impact on agricultural production. In the long run, each per cent increase in fertiliser consumption increases agriculture production by 0.3 percent. Thus, proper fertiliser application can help improve the health and fertility of the soil. Additionally, (Rehman, Chandio, Hussain, & Jingdong, 2019),Chandio, Magsi, and Ozturk (2020)), and (Nasrullah et al., 2021) discovered that fertiliser consumption benefits agricultural production. Finally, energy consumption has a long-term beneficial effect on agricultural production, as demonstrated by (Chandio, Magsi, et al., 2020) and (Chandio, Jiang, & Rehman, 2020).More precisely, agriculture production in Vietnam increases by 0.2% for every unit increase in energy consumption.

Table 7. Short Run and Long run ARDL estimations

Dependent Variable: lnAGRI, ARDL Model (1,1,1,0,0,1,1)		
Explanatory Variables	Long Run	Short Run
lnCO2	0.107*** (0.047)	0.799*** (0.045)
lnEC	0.292*** (0.010)	1.322 (0.139)
lnRain	-0.055*** (0.058)	-0.034** (0.084)
lnTemp	-1.298** (0.064)	-0.812** (0.036)
lnFC	0.398** (0.086)	0.023** (0.079)
lnCL	1.163** (0.063)	1.949*** (0.019)
cons	-6.84 (0.741)	
ECM (-1)		-0.369***

Diagnostic tests
DW-stat = 2.55
F-stat = 5.326***
R^2 = 0.874
χ^2 serial 1.2579 (0.283)
$\chi^2 Normal$ 1.548
$\chi^2 ARCH$ 0.4169
$\chi^2 White$ 1.0521
$\chi^2 RESET$ 1.352 (0.055)
CUSUM stable

CUSUM square stable

Where, *** and ** show 1 and 5 percent level of significance respectively and p-values are given in parantheses

Additionally, Table 6 contains the short-run results of the ARDL estimation. The findings indicate that climatic explanatory variables have the same effect on agricultural output in the short run as in the long run. Similarly, to the long run, it is discovered that rainfall and average temperature have a detrimental effect on agricultural production. However, the magnitude of these factors' coefficients is smaller than in the long run. Agriculture production is reduced by 0.034 and 0.8 percent in the short run when rainfall and temperature both increase by one percent. CO2 emissions positively affect agricultural production, similar to what has been discovered in the long run. A 1% increase in CO2 emissions results in a 0.79 % increase in agricultural output.

Similarly, among non-climatic factors, the short-run findings indicated that cereal crop area has a sizable impact and can boost agricultural production in Vietnam. A 1% increase in land area under cereal crop production results in a 0.07 percent increase in agriculture production. Similar to long-run estimates, fertiliser use has a significant positive effect on agricultural output, as it results in a 0.02 percent increase in agricultural production for every percent increase in fertiliser consumption in the short run. In contrast to the long run, energy consumption has no discernible (though beneficial) effect on agricultural production, similar to the finding of (Chandio, Jiang, & Rehman, 2020). The ECM coefficient is significantly negative, indicating that the variables are cointegrated. ECM illustrates the rate at which long-run equilibrium adjusts following short-run shocks. The coefficient of ECM is 0.36, with a 1% level of significance, indicating that divergence from the short-run balance between agriculture production and variables is adjusted and can be regained in the long run at a rate of 0.36 per cent per year, as indicated in Table 7. The ARDL model passes several diagnostic tests.

including $\chi^2\ Normal\ ,\ \chi^2$ serial, $\chi^2 ARCH, \chi^2 White\ and\ \chi^2 RESET.$

Furthermore, the study also uses Johansen and Juselius cointegration approach to check the robustness of the present long-run relationship between variables. Table 8 below provides evidence for the robustness of the long-run cointegration among the variables in the Johansen Juselius test.

Table 8. Johansen Juselius Cointegration Results

Hypothesis	Test statistics	C V 5%	Prob -value
Trace Stat			
r≤0	305.721***	125.615	0.000
r≤1	187.719***	95.753	0.000
r≤2	105.740***	69.8189	0.000
r≤3	66.464***	47.856	0.004
r≤4	38.941***	29.797	0.0034
r≤5	15.760***	15.494	0.0456
r≤6	3.2113**	3.8414	0.0731
Maximum Eigenvalue			
r≤0	118.302***	46.231	0.000
r≤1	81.678***	40.077	0.000
r≤2	39.276***	33.876	0.0103
r≤3	27.523**	27.584	0.0509
r≤4	23.180***	21.131	0.0254
r≤5	12.549**	14.264	0.0917
r≤6	3.2113**	3.8414	0.0731

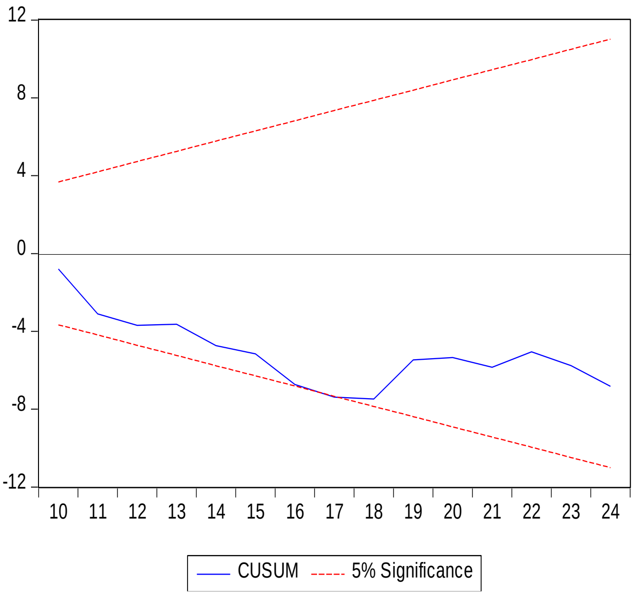

Figure 2. CUSUM plot for the stability of coefficients of ARDL model (1990–2020).

Last, the study used (CUSUM) and (CUSUMSQ) tests developed by (Brown, Durbin, & Evans, 1975) to check stability in the short-run and long-run coefficients as the structural changes in variables may exist due to multiple or single structure break. The CUSUM and CUSUMSQ agricultural production lines shown in Figure 2 and Figure 3 fall under critical boundaries at 5 %, supporting the ARDL model's stability and fitness.

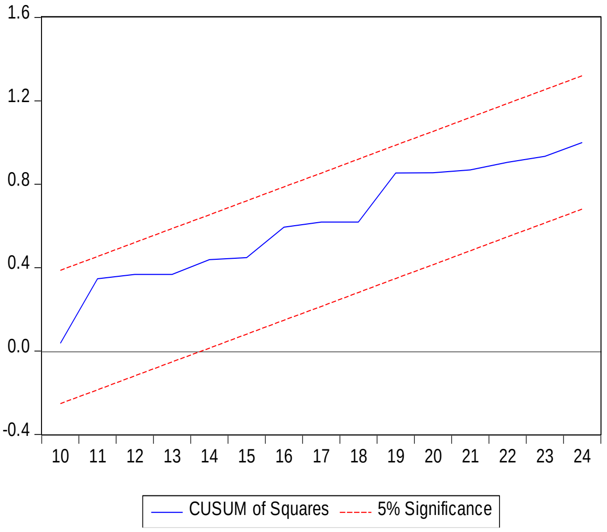

Figure 3. CUSUMSQ plot for stability of coefficients of ARDL model (1990–2020).

6. CONCLUSION AND POLICY RECOMMENDATIONS

Climate change is expected to have a detrimental effect on agricultural output and rural incomes in an economy. As a result, comprehensive empirical research on the impacts of climate change on agriculture is required to develop policies to prevent and mitigate harmful climatic shocks. Thus, the current study examines the effect of climate change on agriculture productivity in Vietnam using annual time series data from 1990 to 2020. To determine the presence of a long-term relationship between climate change components such as CO2 emissions, average temperature, precipitation, energy consumption, and non-climatic factors such as land area under cereal crop production and fertilizer consumption with agriculture production, the ARDL bounds technique for cointegration was used. The findings indicate a long-term relationship between climate change and agriculture production in Pakistan. CO2 emissions and energy consumption positively affect agriculture production, whereas average temperature and precipitation harm agriculture production in the short and long run. Similarly, in both runs, non-climatic variables such as the area under crop production and fertilizer consumption positively affect agriculture production. Additionally, the Johansen and Juselius cointegration method and the CUSUM and CUSUMSQ tests were used to estimate the validity of the variables' long-run cointegration and coefficients' stability.

Based on empirical findings, the study recommends that the Vietnamese government consider establishing and implementing adaptation programmes to mitigate the negative effects of climate change. The government should adopt a consistent agriculture policy that allows development partners, farmers, non-governmental organisations (NGOs), experts, and the civil, private, and public sectors to participate fully in the planning and implementation of strategies to address agriculture's already-devastated state as a result of climate change. Intervention and adaptation policies must be designed to increase water availability and management, as the most significant aspect of climate change affecting agriculture is erratic rain patterns. Additionally, the government should invest in weather forecasting technologies and drought monitoring systems to enable policymakers to develop and implement mitigation strategies that will mitigate the severity of extreme weather events, particularly droughts and floods. Additionally, to create sustainable and resilient agriculture in Vietnam, new crop varieties withstanding extreme temperatures and shortage must be developed, new farming techniques introduced, and institutional research supported.

REFERENCES

Ahsan, F., Chandio, A. A., & Fang, W. (2020). Climate change impacts on cereal crops production in Pakistan. *International Journal of Climate Change Strategies and Management*, *12*(2), 257-269. doi:https://doi.org/10.1108/IJCCSM-04-2019-0020

Ali, S., Liu, Y., Ishaq, M., Shah, T., Abdullah, Ilyas, A., & Din, I. U. (2017). Climate Change and Its Impact on the Yield of Major Food Crops: Evidence from Pakistan. *Foods*, *6*(6), 39. doi:https://doi.org/10.3390/foods6060039

Arora, N. K. (2019). Impact of climate change on agriculture production and its sustainable solutions. *Environmental Sustainability*, *2*(2), 95-

96. doi:https://doi.org/10.1007/s42398-019-00078-w

Asumadu-Sarkodie, S., & Owusu, P. A. (2017). The causal nexus between carbon dioxide emissions and agricultural ecosystem—an econometric approach. *Environmental Science and Pollution Research*, *24*(2), 1608-1618. doi:https://doi.org/10.1007/s11356-016-7908-2

Attiaoui, I., & Boufateh, T. (2019). Impacts of climate change on cereal farming in Tunisia: a panel ARDL–PMG approach. *Environmental Science and Pollution Research*, *26*(13), 13334-13345. doi:https://doi.org/10.1007/s11356-019-04867-y

Baloch, Z. A., Tan, Q., Kamran, H. W., Nawaz, M. A., Albashar, G., & Hameed, J. (2022). A multi-perspective assessment approach of renewable energy production: policy perspective analysis. *Environment, Development and Sustainability*, *24*(2), 2164-2192. doi:https://doi.org/10.1007/s10668-021-01524-8

Blanc, E., & Strobl, E. (2016). Assessing the impact of typhoons on rice production in the Philippines. *Journal of Applied Meteorology and Climatology*, *55*(4), 993-1007. doi:https://doi.org/10.1175/JAMC-D-15-0214.1

Bozzola, M., Massetti, E., Mendelsohn, R., & Capitanio, F. (2017). A Ricardian analysis of the impact of climate change on Italian agriculture. *European Review of Agricultural Economics*, *45*(1), 57-79. doi:https://doi.org/10.1093/erae/jbx023

Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society: Series B (Methodological), 37*(2), 149-163.

Chandio, A. A., Jiang, Y., & Rehman, A. (2020). Energy consumption and agricultural economic growth in Pakistan: is there a nexus? *International Journal of Energy Sector Management*, *13*(3), 597-609. doi:https://doi.org/10.1108/IJESM-08-2018-0009

Chandio, A. A., Jiang, Y., Rehman, A., & Rauf, A. (2020). Short and long-run impacts of climate change on agriculture: an empirical evidence from China. *International Journal of Climate Change Strategies and Management*, *12*(2), 201-221. doi:https://doi.org/10.1108/IJCCSM-05-2019-0026

Chandio, A. A., Magsi, H., & Ozturk, I. (2020). Examining the effects of climate change on rice production: case study of Pakistan. *Environmental Science and Pollution Research*, *27*(8), 7812-7822. doi:https://doi.org/10.1007/s11356-019-07486-9

Charemza, W. W., & Deadman, D. F. (1992). New Directions in Econometric Practice: General to Specific Modelling. *Cointegration and Vector Autoregressions, England: Edward Elgar Pub.* . Retrieved from https://ideas.repec.org/b/elg/eebook/1139.html

Chavas, J.-P., Di Falco, S., Adinolfi, F., & Capitanio, F. (2018). Weather effects and their long-term impact on the distribution of agricultural yields: evidence from Italy. *European Review of Agricultural Economics*, *46*(1), 29-51. doi:https://doi.org/10.1093/erae/jby019

Chien, F., Pantamee, A. A., Hussain, M. S., Chupradit, S., Nawaz, M. A., & Mohsin, M. (2021). Nexus Between Financial Innovation And Bankruptcy: Evidence From Information, Communication And Technology (Ict) Sector. *The Singapore Economic Review*, *0*(0), 1-22. doi:https://doi.org/10.1142/s0217590821500181

Chien, F., Sadiq, M., Kamran, H. W., Nawaz, M. A., Hussain, M. S., & Raza, M. (2021). Co-movement of energy prices and stock market return: environmental wavelet nexus of COVID-19 pandemic from the USA, Europe, and China. *Environmental Science and Pollution Research*, *28*(25), 32359-32373. doi:https://doi.org/10.1007/s11356-021-12938-2

Coulibaly, T., Islam, M., & Managi, S. (2020). The Impacts of Climate Change and Natural Disasters on Agriculture in African Countries. *Economics of Disasters and Climate Change*, *4*(2), 347-364. doi:https://doi.org/10.1007/s41885-019-00057-9

Dumrul, Y., & Kilicaslan, Z. (2017). Economic impacts of climate change on agriculture: Empirical evidence from ARDL approach for Turkey. *Journal of Business Economics and Finance*, *6*(4), 336-347. doi:https://doi.org/10.17261/Pressacademia.2017.766

Huong, N. T. L., Bo, Y. S., & Fahad, S. (2019). Economic impact of climate change on agriculture using Ricardian approach: A case of northwest Vietnam. *Journal of the Saudi Society of Agricultural Sciences*, *18*(4), 449-457. doi:https://doi.org/10.1016/j.jssas.2018.02.006

Huong, N. T. L., Yao, S., & Fahad, S. (2019). Assessing household livelihood vulnerability to climate change: The case of Northwest Vietnam. *Human and Ecological Risk Assessment: An International Journal*, *25*(5), 1157-1175. doi:https://doi.org/10.1080/10807039.2018.1460801

Kakumanu, K. R., Kotapati, G. R., Nagothu, U. S., Kuppanan, P., & Kallam, S. R. (2018). Adaptation to climate change and variability: a case of direct seeded rice in Andhra Pradesh, India. *Journal of Water and Climate Change*, *10*(2), 419-430. doi:https://doi.org/10.2166/wcc.2018.141

Karimi, V., Karami, E., & Keshavarz, M. (2018). Climate change and agriculture: Impacts and adaptive responses in Iran. *Journal of Integrative Agriculture*, *17*(1), 1-15. doi:https://doi.org/10.1016/S2095-3119(17)61794-5

Keerthiratne, S., & Tol, R. S. J. (2018). Impact of natural disasters on income inequality in Sri Lanka.

World Development, *105*, 217-230. doi:https://doi.org/10.1016/j.worlddev.2018.01.001

Klomp, J., & Hoogezand, B. (2018). Natural disasters and agricultural protection: A panel data analysis. *World Development*, *104*, 404-417. doi:https://doi.org/10.1016/j.worlddev.2017.11.013

Korres, N. E., Norsworthy, J. K., Burgos, N. R., & Oosterhuis, D. M. (2017). Temperature and drought impacts on rice production: An agronomic perspective regarding short- and long-term adaptation measures. *Water Resources and Rural Development*, *9*, 12-27. doi:https://doi.org/10.1016/j.wrr.2016.10.001

Le Toan, T., Huu, N., Simioni, M., Phan, H., Arai, H., Mermoz, S., . . . Espagne, E. (2021). *Agriculture in Viet Nam under the impact of climate change*. AFD. Paris. Retrieved from https://hal.inrae.fr/hal-03456472

Li, W., Chien, F., Hsu, C.-C., Zhang, Y., Nawaz, M. A., Iqbal, S., & Mohsin, M. (2021). Nexus between energy poverty and energy efficiency: Estimating the long-run dynamics. *Resources Policy*, *72*, 102063. doi:https://doi.org/10.1016/j.resourpol.2021.102063

Liu, Z., Lan, J., Chien, F., Sadiq, M., & Nawaz, M. A. (2022). Role of tourism development in environmental degradation: A step towards emission reduction. *Journal of Environmental Management*, *303*, 114078. doi:https://doi.org/10.1016/j.jenvman.2021.114078

Migliore, G., Zinnanti, C., Schimmenti, E., Borsellino, V., Schifani, G., Di Franco, C. P., & Asciuto, A. (2019). A Ricardian analysis of the impact of climate change on permanent crops in a Mediterranean region. *New Medit*, *18*(1), 41-52. Retrieved from https://iris.unipa.it/retrieve/handle/10447/362250/719645/Migliore%20et%20al.,%202019_NM.pdf

Mohsin, M., Kamran, H. W., Atif Nawaz, M., Sajjad Hussain, M., & Dahri, A. S. (2021). Assessing the impact of transition from nonrenewable to renewable energy consumption on economic growth-environmental nexus from developing Asian economies. *Journal of Environmental Management*, *284*, 111999. doi:https://doi.org/10.1016/j.jenvman.2021.111999

Mosammam, H. M., Mosammam, A. M., Sarrafi, M., Nia, J. T., & Esmaeilzadeh, H. (2015). Analyzing the potential impacts of climate change on rainfed wheat production in Hamedan Province, Iran, via generalized additive models. *Journal of Water and Climate Change*, *7*(1), 212-223. doi:https://doi.org/10.2166/wcc.2015.153

Nasrullah, M., Rizwanullah, M., Yu, X., Jo, H., Sohail, M. T., & 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. doi:https://doi.org/10.2166/wcc.2021.030

Nawaz, M. A., Seshadri, U., Kumar, P., Aqdas, R., Patwary, A. K., & Riaz, M. (2021). Nexus between green finance and climate change mitigation in N-11 and BRICS countries: empirical estimation through difference in differences (DID) approach. *Environmental Science and Pollution Research, 28*(6), 6504-6519. doi:https://doi.org/10.1007/s11356-020-10920-y

Pesaran, M. H., & Shin, Y. (1995). An autoregressive distributed lag modelling approach to cointegration analysis. Retrieved from http://request-attachments.storage.googleapis.com

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics, 16*(3), 289-326.

Rehman, A., Chandio, A. A., Hussain, I., & Jingdong, L. (2019). Fertilizer consumption, water availability and credit distribution: Major factors affecting agricultural productivity in Pakistan. *Journal of the Saudi Society of Agricultural Sciences, 18*(3), 269-274. doi:https://doi.org/10.1016/j.jssas.2017.08.002

Rotich, S. C., & Mulungu, D. M. M. (2017). Adaptation to climate change impacts on crop water requirements in Kikafu catchment, Tanzania. *Journal of Water and Climate Change, 8*(2), 274-292. doi:https://doi.org/10.2166/wcc.2017.058

Sadiq, S., Saboor, A., Mohsin, A. Q., Khalid, A., & Tanveer, F. (2019). Ricardian analysis of climate change–agriculture linkages in Pakistan. *Climate and Development*, *11*(8), 679-686. doi:https://doi.org/10.1080/17565529.2018.1531746

Sarkodie, S. A., & Owusu, P. A. (2017). The relationship between carbon dioxide, crop and food production index in Ghana: By estimating the long-run elasticities and variance decomposition. *Environmental Engineering Research*, *22*(2), 193-202. doi:http://doi.org/10.4491/eer.2016.135

Shair, F., Shaorong, S., Kamran, H. W., Hussain, M. S., Nawaz, M. A., & Nguyen, V. C. (2021). Assessing the efficiency and total factor productivity growth of the banking industry: do environmental concerns matters? *Environmental Science and Pollution Research, 28*(16), 20822-20838. doi:https://doi.org/10.1007/s11356-020-11938-y

Sultan, R. (2021). Economic Impacts of Climate Change on Agriculture: Insights from the Small Island Economy of Mauritius. In S. Moncada, L. Briguglio, H. Bambrick, I. Kelman, C. Iorns, &

L. Nurse (Eds.), *Small Island Developing States: Vulnerability and Resilience Under Climate Change* (pp. 137-158). Cham: Springer International Publishing.

Sun, H., Awan, R. U., Nawaz, M. A., Mohsin, M., Rasheed, A. K., & Iqbal, N. (2021). Assessing the socio-economic viability of solar commercialization and electrification in south Asian countries. *Environment, Development and Sustainability, 23*(7), 9875-9897. doi:https://doi.org/10.1007/s10668-020-01038-9

Trinh, T.-A., Feeny, S., & Posso, A. (2021). Chapter 17 - The Impact of Natural Disasters and Climate Change on Agriculture: Findings From Vietnam. In T. Chaiechi (Ed.), *Economic Effects of Natural Disasters* (pp. 261-280): Academic Press.

Trinh, T. Q., Rañola, R. F., Camacho, L. D., & Simelton, E. (2018). Determinants of farmers' adaptation to climate change in agricultural production in the central region of Vietnam. *Land Use Policy, 70*, 224-231. doi:https://doi.org/10.1016/j.landusepol.2017.10.023

Van Passel, S., Massetti, E., & Mendelsohn, R. (2017). A Ricardian Analysis of the Impact of Climate Change on European Agriculture. *Environmental and Resource Economics, 67*(4), 725-760. doi:https://doi.org/10.1007/s10640-016-0001-y

Warsame, A. A., Sheik-Ali, I. A., Ali, A. O., & Sarkodie, S. A. (2021). Climate change and crop production nexus in Somalia: an empirical evidence from ARDL technique. *Environmental Science and Pollution Research, 28*(16), 19838-19850. doi:https://doi.org/10.1007/s11356-020-11739-3

Wielogorska, E., Mooney, M., Eskola, M., Ezekiel, C. N., Stranska, M., Krska, R., & Elliott, C. (2019). Occurrence and Human-Health Impacts of Mycotoxins in Somalia. *Journal of Agricultural and Food Chemistry, 67*(7), 2052-2060. doi:https://doi.org/10.1021/acs.jafc.8b05141

Xiang, H., Ch, P., Nawaz, M. A., Chupradit, S., Fatima, A., & Sadiq, M. (2021). Integration and economic viability of fueling the future with green hydrogen: An integration of its determinants from renewable economics. *International Journal of Hydrogen Energy, 46*(77), 38145-38162. doi:https://doi.org/10.1016/j.ijhydene.2021.09.067

Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D. B., Huang, Y., . . . Asseng, S. (2017). Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of Sciences, 114*(35), 9326-9331. doi:https://doi.org/10.1073/pnas.1701762114

Zhuang, Y., Yang, S., Chupradit, S., Nawaz, M. A., Xiong, R., & Koksal, C. (2021). A nexus between macroeconomic dynamics and trade openness: moderating role of institutional quality. *Business Process Management Journal, 27*(6), 1703-1719. doi:https://doi.org/10.1108/BPMJ-12-2020-0594