Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454
Vol. 22 No. 4 pp. 2173-2179 2023
Original Research Paper
https://doi.org/10.46488/NEPT.2023.v22i04.043
Open Access Journal

Economic Impact of Climate Change on Agriculture: A Study of India and its Neighbouring Countries Using ARDL Approach

Mashud Ahmed*† and Paramita Saha**
*Department of Economics, Tripura University & Khairun Nessa Begum Women's College, Badarpur, Assam, India
**Department of Economics, Tripura University. Tripura, India
†Corresponding author: Mashud Ahmed; hmashud786@gmail.com

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 30-03-2023
Revised: 18-05-2023
Accepted: 30-05-2023

Key Words:
Agriculture
ARDL model
Climate change
CO_2 emission
Temperature

ABSTRACT

This study aims to analyze the association between the share of agriculture in GDP and changes in climatic variables, notably per capita CO_2 emissions and temperature change, using time series data of India, Bangladesh, and Nepal for the period 1961-2018. The ARDL bounds testing method was applied to analyze the relationships among the research variables for both short-term and long-term. The results revealed that in the long run, per capita CO_2 emissions and temperature change have no statistically significant relationship with India and Nepal's share of agriculture in GDP. However, temperature change has demonstrated a positive and statistically significant relationship with the share of agriculture in Bangladesh's GDP. Temperature change has a significant and adverse impact on the share of agriculture in India's GDP in the short run, whereas CO_2 has no significant effect. In the short run, CO_2 shows a positive and significant connection with the share of agriculture in Bangladesh's GDP. Still, temperature change is negatively and significantly associated with the proportion of agriculture in the nation's GDP. Different lag values of both CO_2 and temperature change have significant relationships with the share of GDP in agriculture in the short run in Nepal. As agriculture is a key source of GDP for all three countries, it is vital to implement suitable policies and make plans and strategies to mitigate climate change's harmful consequences in agriculture.

INTRODUCTION

Climate change's impact on agriculture has received a lot of attention since it is linked to food security and poverty for a major portion of the population in the world (Dinar et al. 1998). By raising food prices and reducing food production, it will directly contribute to future food insecurity. Climate change decreases agricultural productivity directly by causing crop damage and indirectly by changing cropping choices (Trinh et al. 2021). The agriculture sector is highly susceptible to the change of climate in the world since it relies on adequate temperature ranges and rainfall patterns to produce crops and cattle (Nastis et al. 2012, Mendelsohn & Dinar 2009).

In agricultural production, climatic factors interact directly with input variables, including land, water, fertilizer, and pesticides. As a result, empirical research on climate change and agricultural production has shown that poor nations are negatively affected (Cline 2007, Xie et al. 2019). In India, a large number of people are engaged in farming activities. Climate change is having a detrimental impact on agriculture, hydropower, forest management, and biodiversity (Senapati et al. 2013). According to research, climate change would reduce agricultural productivity in India by 4.5 to 9 percent between 2010 and 2039 (Guiteras 2009). A gradual increase in global temperature over the past few years seems to have a visible effect on agriculture all across the world. Nepal's agricultural production has already been impacted by rising temperatures, which has an impact on food security and agrarian communities (Karki & Gurung 2012). Climate change's impact on agriculture poses a huge danger to Bangladesh's national food security, as agriculture is vital to people's lives and livelihoods (Sikder & Xiaoying 2014).

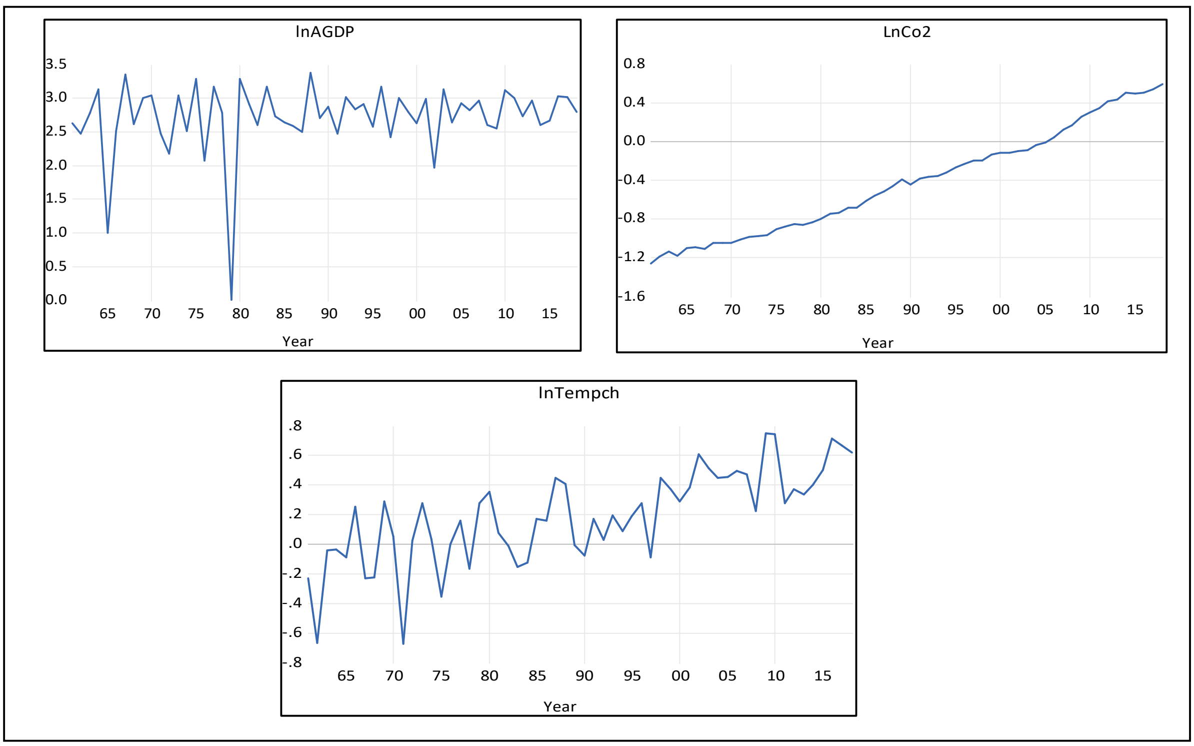
The Indian Prime Minister promised to decrease India's total predictable carbon emissions by 1 billion tonnes within 2030, decrease the carbon concentration of the country's economy by fewer than 45 percent by the end of the decade, and reach net-zero carbon emissions by 2070 at the 26th UN climate change conference (COP26) summit in Glasgow, held in November 2021. The Prime Minister of Bangladesh, on the other hand, has urged wealthy countries to follow through on their pledges to diminish greenhouse gas emissions and to provide the promised $100 billion in annual financial aid to less developed countries to help them to mitigate and adapt to climate change. Nepal committed to reaching net zero emissions by 2045, and 15 percent of total energy demand to be supplied from clean energy sources.

In the above context, the current study aims to look at the associations between changes in the share of agriculture in GDP and climatic variables in India, Bangladesh, and Nepal from 1961 to 2018. These countries are immediately neighboring each other and vulnerable to climate change in different manners because of their diverse geographical characteristics as well as low per capita GDPs as compared to developed countries. Temperature changes, changes in rainfall and weather patterns, an increase in the frequency of extreme weather events, sea level rise, changes in CO_2 levels, etc., over a long period are important indications of climate change (WMO 2022). Due to the non-availability of sufficient data on all climate factors during the study period, this study is confined only to the temperature change and per capita CO_2 emissions which are very pertinent to the international level.

The observed data plots of natural log values of the research variables for India are demonstrated in Fig. 1.

Fig. 1 and Fig. 2 show almost stable growth in the share of agriculture in GDP in the long run, both in India and Bangladesh, with some fluctuations in the short run. However, during the 1980s, a deep decrease in the graph was observed for both countries. This may result from the farm crisis in both countries during the 1980s. In India, a gradual increase in CO_2 emission and temperature change is seen over the period. For Bangladesh, except for a deep decline in the early 1980s, a continuous increase in CO_2 emission and temperature change is also noticeable. From Fig. 3, it is visible that all three variables are gradually increasing simultaneously at different rates. The concentration of CO_2 in a country rises due to the Industrial Revolution and the rise in manufacturing activity. The burning of fossil fuels, destruction of forests, and raising of livestock all have a rising impact on the climate and temperature of the planet (European Commission 2022).

The observed data plots of Bangladesh's natural log values for study variables are presented in Fig. 2. The



Note: lnAGDP, $lnCO_2$, and lnTempch denote the natural log value of the share of agriculture in GDP, carbon emissions, and temperature change, respectively.

Fig. 1: Data plots of variables (India).

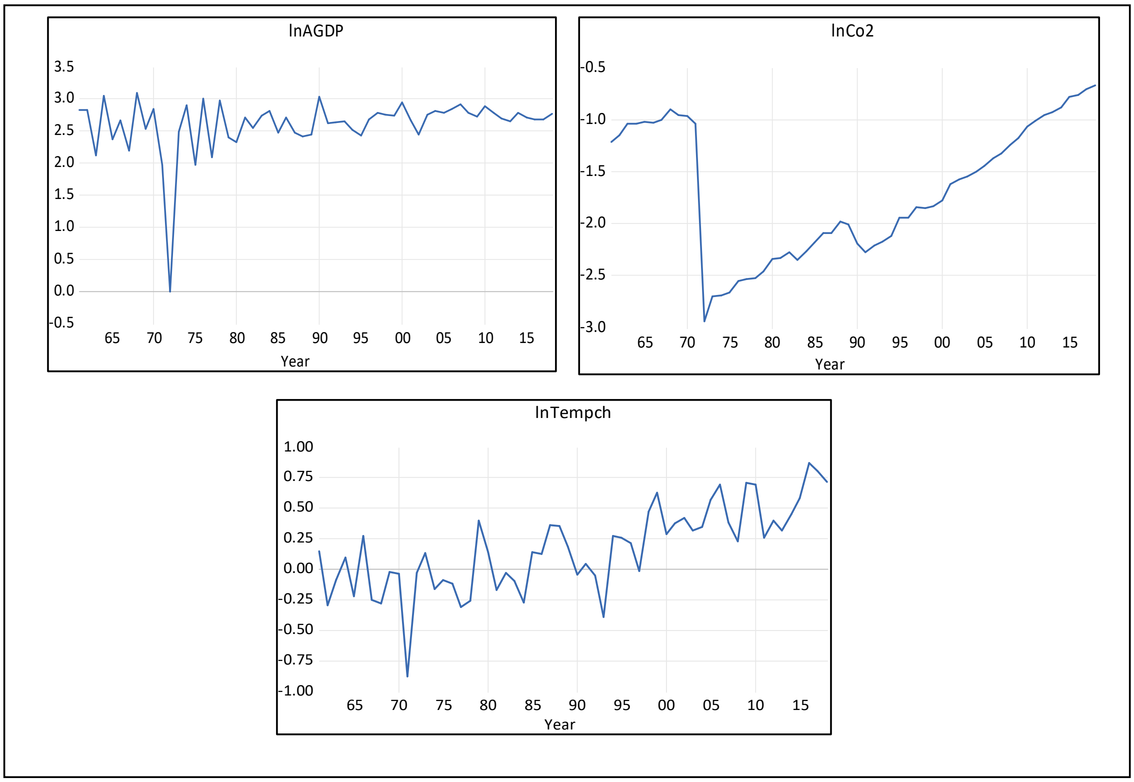


Fig. 2: Data plots of variables (Bangladesh).

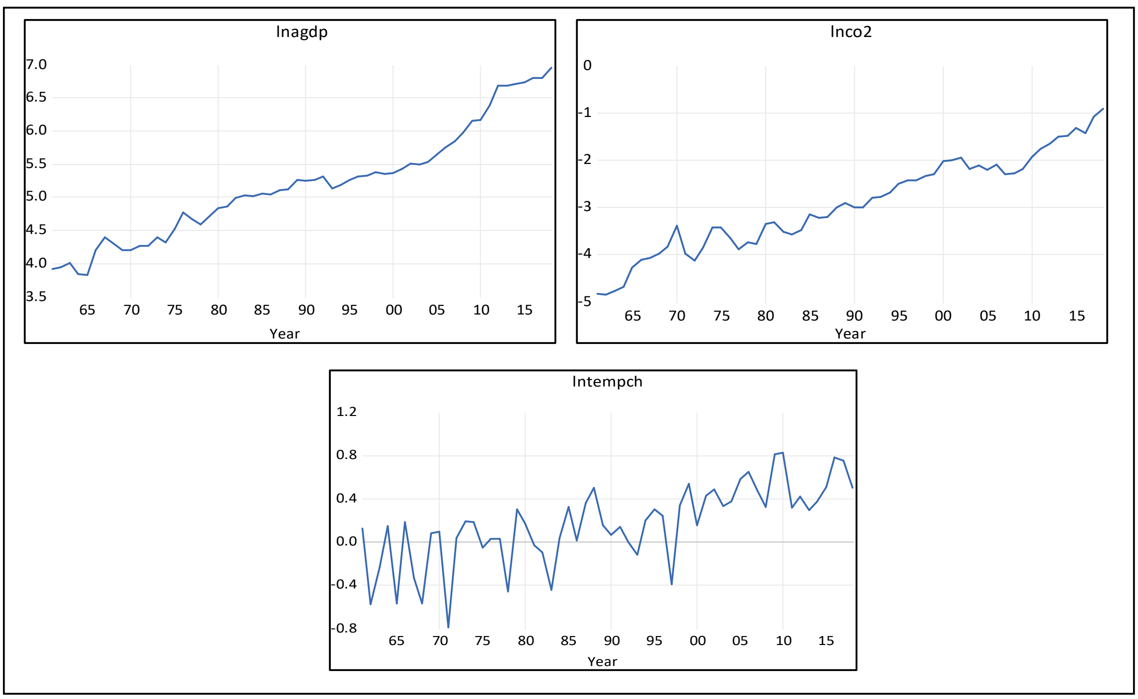


Fig. 3: Data plots of variables (Nepal).

observed data plots of the natural log values of study variables for Nepal are presented in Fig. 3.

MATERIALS AND METHODS

Data Sources

The data on per-head carbon dioxide (CO_2) emission in metric tons and the share of agriculture in GDP (percentage growth) were obtained from the World Bank's data portal (https://data.worldbank.org/). In contrast, the data on temperature change (^oC) are collected from the Food and Agricultural Organisation (https://www.fao.org/faostat/) for the period spanning from 1961 to 2018.

Methodology

Climate change's impact on agriculture may be studied using a variety of methodologies. To estimate the long-run relationship between the percentage share of agriculture in GDP and climatic conditions, we used the Auto-regressive Distributed Lag (ARDL) bounds method. Eviews12's automatic lag section option uses the Akaike information criterion (AIC) to determine the best lag sequence. Charemza and Deadman (1992) introduced the ARDL test, which was further developed by Pesaran and Shin (1999) and Pesaran et al. (2001). This approach is advantageous as compared to other methods in some cases. First, even when independent variables have different integration orders, the ARDL approach can be used. Secondly, it gives more consistent results for small samples as compared to other techniques.

To study the relationship between the percentage of agriculture in GDP and climatic variables, notably temperature change and carbon dioxide emissions in India, Bangladesh, and Nepal from 1961 to 2018, a model can be expressed as given in the equation (1).

$$AGDP_t = f\ (Tempch, CO_2) \qquad \ldots(1)$$

In equation (1), $AGDP_t$ indicates the share of agriculture in GDP for a specific country over time, Tempch represents the temperature change, and CO_2 denotes per capita carbon dioxide emissions. Equation (1) can also be written as:

$$AGDP_t = \beta_0 + \beta_1 Tempch + \beta_2 CO_2 + \mu_t \qquad \ldots(2)$$

To decrease multicollinearity and instability in the time series data, the study used all variables in their natural logarithmic form. The natural logarithm is applied to equation (2) to create a log-linear model as given below:

$$LnAGDP_t = \beta_0 + \beta_1\ LnTempch + \beta_2\ LnCO_2 + \mu_t \qquad \ldots(3)$$

There are two steps in the ARDL method. The initial step is to check the long-run cointegrating connection using either the Wald-coefficient test or F-statistics, as suggested by Pesaran et al. (2001). Lower limits and upper bounds are two sorts of critical values, according to Pesaran et al. (2001). Lower-level critical values are assigned to the I (0) variables, whereas upper-level critical values are assigned to the I (1) variables. Suppose the estimated value of the F-Statistic is greater than the upper boundaries. In that case, the null hypothesis of no co-integration among the variables will be rejected, suggesting a long-run cointegration connection, irrespective of their integration order. We cannot reject the null hypothesis if the estimated value of the F-statistic is below the lower bound crucial value, showing the absence of a long-run equilibrium connection. A clear inference cannot be made if the computed F-statistic comes between the lower and upper-level bound. The mathematical representation of the ARDL bounds-testing model for this study can be expressed as follows:

$$\Delta\ \mathrm{LnAGDPti}\ = \beta_0 + \beta_1 \sum_{i=1}^{n} \Delta\ \mathrm{LnAGDPt}_{t-i} + \beta_2 \sum_{i=1}^{n} \Delta\ \mathrm{LnTempch}_{t-i} + \beta_3 \sum_{i=}^{n} \Delta\ \mathrm{LnCO2}_{t-i} + \gamma_1 \mathrm{LnAGDP}_{t-1} + \gamma_2\ \mathrm{LnTepch}_{t-1} + \gamma_3 \mathrm{LnCO2}_{t-1} + \varepsilon_t \qquad \ldots(4)$$

Where Δ means change, β_0 is the intercept, n denotes the lag order and $\mathcal{E}_t$ Reflects the error term. The significance of the lagged levels of the study variables is evaluated using the F-statistic to see if there is a cointegration connection between variables from Equation (4). Pesaran et al. (2001) recommend the test: H_0: $\gamma_1 = \gamma_2 = \gamma_3 = 0$, which indicates we can't rule out the hypothesis of no cointegration, but we can rule out the alternative hypothesis H_1: $\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq 0$, which means the possibility of such a connection can't be ruled out. The error correction model (ECM), based on the ARDL approach, is used to examine the short-term connections between the variables shown in the equation (5).

$$\Delta \mathrm{LnAGDPt} = \gamma_0 + \gamma_1 \sum_{i=1}^{n} \Delta\ \mathrm{LnAGDPt}_{t-i} + \gamma_2 \sum_{i=1}^{n} \Delta\ \mathrm{LnTempch}_{t-i} + \gamma_3 \sum_{i=1}^{n} \Delta\ \mathrm{LnCO2}_{t-i} + \gamma_4 ECM_{t-1} + \varepsilon_t \qquad \ldots(5)$$

Where, ECM_{t-1} is the residual lagged value in the model from which the long-term connection is derived? ECM_{t-1} is expected to be a negative value for the speed of adjustment parameter.

RESULTS AND DISCUSSION

Unit Root Tests

A pre-requisite condition for the ARDL test is to check the stationarity and the integration order for study variables. The Augmented Dickey-Fuller (ADF) test was employed in the present study to determine the stationarity and the integration order. As stated in Table 1, the stationarity test was applied by taking a natural log to each variable in level and first

Table 1: Results of Unit Root Tests.

Variables	ADF Unit Root Test		Order of integration
	Level	First Difference	
India			
LNAGDP	-9.863573* (-3.490662)	-	I (0)
$LNCO_2$	-1.591749 (-3.490662)	-9.694125* (-3.492149)	I (1)
LNTEMPCH	-7.475508* (-3.492149)	-	I (0)
Bangladesh			
LNAGDP	-7.491959* (-3.490662)	-	I (0)
$LNCO_2$	-1.675092 (-3.490662)	-7.969308* (-3.492149)	I (1)
LNTEMPCH	-5.685645* (-3.492149)	-	I (0)
Nepal			
LNAGDP	-3.864800* (-3.508508)	-	I (0)
$LNCO_2$	-3.350035 (-3.504330)	-6.824868* (-3.495295)	I (1)
LNTEMPCH	-7.160386* (-3.492149)	-	I (0)

Note: 0 represents critical values in the t-statistic of the intercept and trend model with a 5% significance level; *indicates statistical significance at a 5% level of significance.

difference forms. The integration order is a combination of I (0) and I (1).

Cointegration Testing Results

Table 2 shows the results of the ARDL bound test. At a 5 percent level of significance, the estimated F statistic values are determined to be above the critical values. The F statistic values for India, Bangladesh, and Nepal are 24.02841, 11.17842, and 6.28523, respectively, whereas the critical value is 3.87 at a 5 percent level of significance. These results suggest a long-term association among the variables for all three countries from 1961 to 2018.

Table 2: Cointegration Test Results of ARDL (1, 0, 1), ARDL (3, 4, 4), and ARDL (3, 2, 3) for India, Bangladesh, and Nepal, respectively.

Test statistic	Estimated Values		k
F Statistics	24.02841* 11.17842* 6.28523*	AGDP of India AGDP of Bangladesh AGDP of Nepal	2
Critical Values of Bounds			
Significance	Lower Bound (I0)		Upper Bound (I1)
10%	2.63		3.35
5%	3.1		3.87
1%	4.13		5

Note: * refers to the rejection of the null hypothesis at a 5% significance level.

Long-Run ARDL Estimates

Table 3 displays long-term coefficients obtained using the estimation results of the ARDL (1, 0, 3), ARDL (3, 4, 4), and ARDL (3, 2, 3) models for India, Bangladesh, and Nepal, respectively. The results show that per capita CO_2 emission and temperature change have a positive but statistically insignificant association with the percentage of agriculture in the GDP of India in the long term. However, CO_2 has a significant and positive association with the share of agriculture in Bangladesh's GDP, whereas temperature change has a significant and positive association with the share of agriculture in Bangladesh's GDP in the long run. In the case of Nepal, both CO_2 and temperature changes do not show any statistically significant relationship with the share of agriculture in GDP. The coefficient of temperature change for Bangladesh indicates that a 1% increase in temperature would result in a 0.31 percent growth in the percentage of agriculture in GDP over time. These results are also supported by Fig. 1 and Fig. 2, where time series data are plotted.

Short-Run ARDL Estimates

Table 4 shows the results of the short-run ARDL estimations and the coefficients of error terms. The computation of the

Table 3: Long-Run ARDL estimates.

Regressor	Coefficient	T-statistics	P- value
India			
Dependent variable: D(LNAGDP), ARDL (1, 0, 3)			
$LNCO_2$	0.101384	0.440994	0.6612
LNTEMPCH	0.198494	0.363848	0.7176
C	2.744065	14.09615*	0.0000
Bangladesh			
Dependent variable: D(LNAGDP), ARDL (3, 4, 4)			
$LNCO_2$	-0.007592	-0.207120	0.8370
LNTEMPCH	0.319830	3.583387*	0.0009
C	4.162481	6.045027*	0.0000
Nepal			
Dependent variable: D(LNAGDP), ARDL (3, 2, 3)			
LNCO2	-0.395185	-0.333304	0.7405
LNTEMPCH	5.981115	1.055079	0.2971
C	4.090269	1.203129	0.2354

* Indicates significance at a 5 % level of significance.

Source: Authors' own calculation using EViews12.

ECM (-1) coefficient is an important result of the short-run dynamics. For all three nations, the ECM coefficients are negative and significant. For example, the coefficient of ECMt-1 for the percentage of agriculture in the GDP of India is -1.253095. This means that in the current year, about 125 percent of the disequilibria from the prior year's shock have adjusted back to the long-term equilibrium. Similarly, the coefficient of ECMt-1 for Bangladesh's percentage of agriculture in GDP is -1.641099, meaning that the short-run disequilibria are correcting back to the long-run equilibrium at a pace of 164 percent in the current year. For Nepal, the coefficient of ECMt-1 is -0.059861, which means that the short-run disequilibria are correcting back to the long-run equilibrium at a rate of 5 percent.

Table 4: Short-run ARDL estimate.

INDIA			
Dependent variable: D(LNAGDP), ARDL (1, 0, 3)			
Variable	Coefficient	T-statistics	P- value
D(LNTEMPCH)	-0.940106*	-3.401473	0.0014
D (LNTEMPCH (-1))	0.006901	0.027163	0.9784
D (LNTEMPCH (-2))	-0.802004*	-3.123978	0.0030
ECM (-1)	-1.253095*	-10.10548	0.0000
Bangladesh			
Dependent variable: D(LNAGDP), ARDL (3, 4, 4)			
Variable	Coefficient	T-statistics	P- value
D (LNAGDP (-1))	0.410331*	2.155088	0.0372
D (LNAGDP (-2))	0.334046*	2.893972	0.0061
D ($LNCO_2$)	1.330953*	11.05392	0.0000
D ($LNCO_2$ (-1))	0.2269772	1.305786	0.1991
D ($LNCO_2$ (-2))	0.088597	0.453282	0.6528
D ($LNCO_2$ (-3))	0.566551*	3.203279	0.0027
D (LNTEMPCH)	-0.071907	-0.654086	0.5168
D (LNTEMPCH (-1))	-0.753033*	-4.925982	0.0000
D (LNTEMPCH (-2))	-0.353038*	-2.288117	0.0275
D (LNTEMPCH (-3))	-0.418429*	-3.237696	0.0024
ECM (-1)	-1.641099*	-6.933051	0.0000
Nepal			
Dependent variable: D(LNAGDP), ARDL (3, 2, 3)			
D (LNAGDP (-1))	0.036537	0.309789	0.7582
D (LNAGDP (-2))	-0.354683*	-3.085855	0.0035
D (LNCO2)	0.068902	0.968849	0.3379
D (LNCO2 (-1))	0.163920*	2.437778	0.0189
D (LNTEMPCH)	0.009992	0.209020	0.8354
D (LNTEMPCH (-1))	-0.321236*	-4.884497	0.0000
D (LNTEMPCH (-2))	-0.165443*	-3.2463333	0.0022
ECM (-1)	-0.059861*	-5.182189	0.0000

* Indicates significance at a 5 % level of significance.

Source: Authors' own calculation using EViews12.

In the short run, temperature change has a significant and negative association with a share of agriculture in GDP, but CO_2 has no significant relationship with this in India. In the case of Bangladesh, CO_2 has a significant and positive association with the share of agriculture in GDP. For Nepal, different CO_2 and temperature change lag values have significant relationships with the share of GDP in agriculture.

CONCLUSION

In recent years, climate change has become popular in agricultural research, as climate change is predicted to adversely impact agricultural productivity and the share of agriculture in GDP across different countries. The present study investigated the long-run associations and short-run dynamics of the share of agriculture in GDP and climate variables, particularly temperature change and CO_2 emission, in India, Bangladesh, and Nepal. The study finds the presence of long-run association among the study variables over the period spanning from 1961 to 2018 for all three nations. The results indicate that per capita CO_2 emission and temperature change have a positive but insignificant association with agriculture's contribution to India's GDP in the long run. However, a positive and significant connection is observed between temperature change and the percentage of agriculture in Bangladesh's GDP in the long run. In Nepal, CO_2 and temperature changes do not show any statistically significant relationship with the share of agriculture in GDP in the long run. In the short run, temperature change has a negative and significant association with the share of agriculture in India's GDP, but CO_2 has no significant impact. The CO_2 emission is positively and significantly connected with the percentage of agriculture in the GDP, while the temperature is negatively and significantly related to the contribution of agriculture to Bangladesh's GDP in the short run. For Nepal, Different lag values of both CO_2 and temperature change have significant relationships with the share of GDP in agriculture in the short run. The agriculture sector is the major source of GDP for all three countries. Therefore, governments need to make suitable mitigation policies and encourage farmers to take appropriate adaptation approaches to combat the adverse effects of climate change on agriculture.

REFERENCES

Charemza, W.W. and Deadman, D.F. 1992. New Directions in Econometric Practice: General to Specific Modelling. Cointegration and Vector Autoregressions, Edward Elgar Publication, England.

Cline, W.R. 2007. Global Warming and Agriculture: Impact Estimates by Country. Centre for Global Development and Peterson Institute for International Economics, Washington, DC.

Dinar, A., Mendelsohn R., Evenson R., Parikh J., Sanghi A., Kumar K. and Lonergan S. 1998. Measuring the Impact of Climate Change on Indian Agriculture. WB Technical Paper no. 402, The World Bank, Washington DC.

European Commission (EC) 2022. Causes of Climate Change. https://ec.europa.eu/clima/climate-change/causes-climate-change_en (Accessed 15 June 2022)

Guiteras, R. 2009. The impact of climate change on Indian agriculture. Manuscript, Department of Economics, University of Maryland, College Park, Maryland.

Karki, R. and Gurung, A. 2012. An overview of climate change and its impact on agriculture: A review from least developing country, Nepal. Int. J. Ecosyst., 2(2): 19-24. DOI: 10.5923/j.ije.20120202.03

Mendelsohn, R.O. and Dinar, A. 2009. Climate Change and Agriculture: An Economic Analysis of Global Impacts, Adaptation, and Distributional Effects. Edward Elgar Publishing. Cheltenham, UK.

Nastis, S.A., Michailidis, A. and Chatzitheodoridis, F. 2012. Climate change and agricultural productivity. Afr. J. Agric. Res., 7(35): 4885-4893.

Pesaran, M.H. and Shin, Y. 1998. An autoregressive distributed-lag modeling approach to cointegration analysis. Econ. Soc. Monogr., 31: 371-413.

Pesaran, M.H., Shin, Y. and Smith, R.J. 2001. Bounds testing approaches to the analysis of level relationships. J. Appl. Econ., 16(3): 289-326.

Senapati, M.R., Behera, B. and Mishra, S.R. 2013. Impact of climate change on Indian agriculture & its mitigating priorities. Am. J. Environ. Protect., 1(4): 109-111.

Sikder, R. and Xiaoying, J. 2014. Climate change impact and agriculture of Bangladesh. J. Environ. Earth Sci., 4(1): 35-40.

Trinh T.A., Feeny S. and Posso A. 2021. The Impact of Natural Disasters and Climate Change on Agriculture: Findings from Vietnam – Economic Effects of Natural Disasters. Academic Press, Cambridge, MA, pp. 261-280. https://doi.org/10.1016/B978-0-12-817465-4.00017-0.

WMO 2022. Climate Data. https://climatedata-catalogue.wmo.int/climate_indicators (Accessed 20 June 2022).

Xie, B., Brewer, M.B., Hayes, B.K., McDonald, R.I. and Newell, B.R. 2019. Predicting climate change risk perception and willingness to act. J. Environ. Pyschol., 65: 101331.

ORCID DETAILS OF THE AUTHORS

Mashud Ahmed: https://orcid.org/0000-0002-0092-7282