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Research Paper

Impact of GHG emission, temperature, and precipitation on rice production in Nepal

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ABSTRACT

Climate variables mainly greenhouse gas (GHG) emissions, temperature, precipitation, and rainfall are affecting crop production across the world. Nepal as a vulnerable country in terms of climate change, has raised the attention of researchers and policymakers in recent years. In this scenario, this study has attempted to find the impact of GHG emissions, temperature, and precipitation on rice production in Nepal. The study is based on time serried data from 1990 to 2019. The findings show that GHG emission has a significant positive impact on rice production. However, the annual average mean temperature has a significant negative impact on rice production. Besides having a negative coefficient, precipitation did not affect rice production significantly. The study recommends concrete climate change adaptation practices in the major rice production areas of Nepal, mainly in the Terai and Hilly belts.

Keywords: GHG emission, Mean temperature, Precipitation, Fertilizer use, Rice production, Urban population

Global warming caused GHG emissions have become a serious threat to agricultural activities worldwide (Gul *et al.,* 2022). In addition to having an indirect effect on food quality and supply networks, climate change has directly affected food security by reducing agricultural production (Raihan *et al.,* 2023). Different regions of the world have faced different effects on crops due to climate change (Onyeneke *et al.,* 2022). It is predicted that continuing increase in GHG emissions will have severe impacts on the world climate system, affecting every aspect of society. So, the study of climatic variables has become a pertinent issue in the agricultural sector as every crop has its climatic requirements (Dakhore *et al.,* 2024). Agriculture is regarded as a crucial sector for food production, as it must increase food production to feed an expanding population while also addressing environmental pressure like energy and water scarcity, climate change, and the lack of new agricultural land. For the production of grain, livestock, grassland, forestry, and bioenergy, agricultural land is used, making up around 40% of the planet's total surface area (Rehman *et al.,* 2020).

About two-thirds of the Nepalese population works in agriculture, which makes up a significant portion of the country's GDP (Karn, 2014). A large number of rural families in the Terai area rely on rice production for their livelihood. During the past 20 years, production growth has been modest, averaging 1.4% annually. Approximately 70% of the total amount of rice produced is consumed at home. However, only a small portion of the annual household food needs are satisfied by rice production for the majority of subsistence farmers (Ghimire *et al.,* 2013). Nepal features a variety of agricultural zones, including plain hills, high hills, mid-hills, and mountains. Agri-zone changes caused by climate change affect the zone's cropping pattern. The distribution of crops ecologically can be altered by climate factors. Although there have been numerous attempts to mitigate the effects of climate change, Nepalese agricultural continuous faces challenges. The country's temperature increased by 1.8 ^{0}C between 1975 to 2006, or 0.06 ^{0}C each year, on average.

Devkota and Paija (2020) shows that the output of rice production is significantly impacted by rainfall. Chandio *et al.,* (2021) find that average temperature and average precipitation enhanced rice output by 0.72% and 0.01%, respectively, but CO_2 emission lowered rice productivity by 0.13% over the long term. In the long-term rice, output was increased by 2.26%, 0.05%, and 0.02%, respectively, by rice cultivated area, fertilizer used, and agricultural credit. The relationship between rice output farmed land, fertilizers, seeds, temperature, and CO_2 emission has been proven unconditional.

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Table 1: Description and sources of variables used in the study

Variable	Symbol	Description	Units	Source
Rice production	RICE	Rice produced in a year	Thousand metric ton	NRB (2022)
Greenhouse gas emission	GHG	CO_2 emission	Din Kiloton	WDI (2022)
Cultivated area	CA	Rice cultivated area in a year	Thousand hectares	NRB (2022)
Urban population growth	UPOP	Urban population growth	Annual %	WDI (2022)
Precipitation	PREC	Precipitation	Millimeters	World Bank (2022a)
Domestic credit	DCPS	Domestic credit to the private sector by banks (% GDP)	% GDP	WDI (2022)
Fertilizer	FERT	Fertilizer used	Metric ton	World Bank (2022b)
Temperature	TEM	Annual mean temperature	Celsius degree centigrade	

Bashir and Yuliana (2019) uses an econometric model to discover the factors that might affect rice production including human capital, labor, wages, wetland, urban population, and rice prices; on the other hand, technology has little impact on rice output. Rayamajhee *et al.,* (2021) use econometric analysis to discover that both average and severe precipitation and temperature have a major adverse effect on rice output. Furthermore, he concludes that long-term increases in average temperature and increasingly abnormal extreme rainfall patterns pose serious challenges to rice production. According to Koirala *et al.,* (2013) research in the Philippines, the value of rice production is positively correlated with land area, planting season, fuel cost, fertilizer cost, and land rent.

Rayamajhee *et al.,* (2021) find that the output of rice is reduced by 4183 kg for every 1^0C rise in summertime temperatures. Rice productivity is negatively impacted by severe rainfall fluctuation, even though there is no clear correlation between the increase in average monsoon rainfall and rice yield. The output also demonstrates that rice production is significantly negatively impacted by both average and extreme precipitation and temperature, and both persistently abnormal severe rainfall patterns and a long-term increase in average temperature pose a serious challenge to rice production. The result has also been supported by Chandio *et al.,* (2021) where rice output increased by 0.72% and 0.01% with average temperature and precipitation respectively.

MATERIAL AND METHODS

Data

The study has used GHG emission, rice cultivated area, urban population growth, precipitation, fertilizer used, annual mean temperature, and domestic credit to the private sector by banks as the major independent variables to study the impact of climate change on rice production in Nepal. Carbon dioxide emission (CO_2) has been used as a proxy for greenhouse gas emissions. CO_2 emission, annual mean temperature, and precipitation are the major variables of concern used as climate variables. Others are the supportive variables that affect rice production. A description of the selected variables along with measurement scale and the source is mentioned in Table 1. Trends of the selected time-series variable for the study period 1990 to 2019 are shown in the Fig. 1.

Empirical model

The study has used the following regression equation to find the impact of greenhouse gas emissions, temperature, and precipitation on rice production in Nepal.

RICE = f (GHG, CA, UPOP, PREC, DCPS, FERT, TEM)……(i)

In general, theoretically, it is expected that cultivated area (CA), fertilizer use (FERT), and domestic credit to the private sector by banks (DCPS) influence rice production positively. Similarly, an increase in GHG emissions, temperature, and precipitation is expected to influence rice production negatively. The econometric model of equation (i) in natural logarithm form is expressed as follows:

$$lnRICE = \alpha_0 + lnGHG + lnCA + lnUPOP + lnPREC + lnDCPS + lnFERT + lnTEM + \varepsilon i \ldots\ldots (ii)$$

Where, ln = natural logarithm and εi = random variable

Stationarity test

Stationarity test is necessary for the time series variables to avoid flawed regression (Raihan, 2023). The stationarity test also helps to identify the order of integration for selecting the method of cointegration that shows long-run associations between the variables. For this purpose, Augmented Dickey-Fuller (ADF) test has been used.

Cointegration test

Autoregressive distributed lag model (ARDL) bound test has been used for the cointegration test. It can be used for the variable with the same order or mixed order of integration and for even a small sample (Raihan, 2023). Based on ARDL F statistics decision on the existence of a long-run relationship between the variables can be confirmed. If calculated F statistics is greater than upper and lower bound values we verify the existence of a long-run relationship between the selected variables and vice versa. For testing the long run relationship between variables Fully Modified Ordinary Least Square (FMOLS) method has been used. This method is suitable for small size sample and corrects the problem of endogeneity and serial correlation as well as gives long-run reliable co-integrating estimates (Ejemeyovwi *et al.,* 2018).

RESULTS AND DISCUSSION

Unit root test

The findings of the ADF unit root test are shown in the

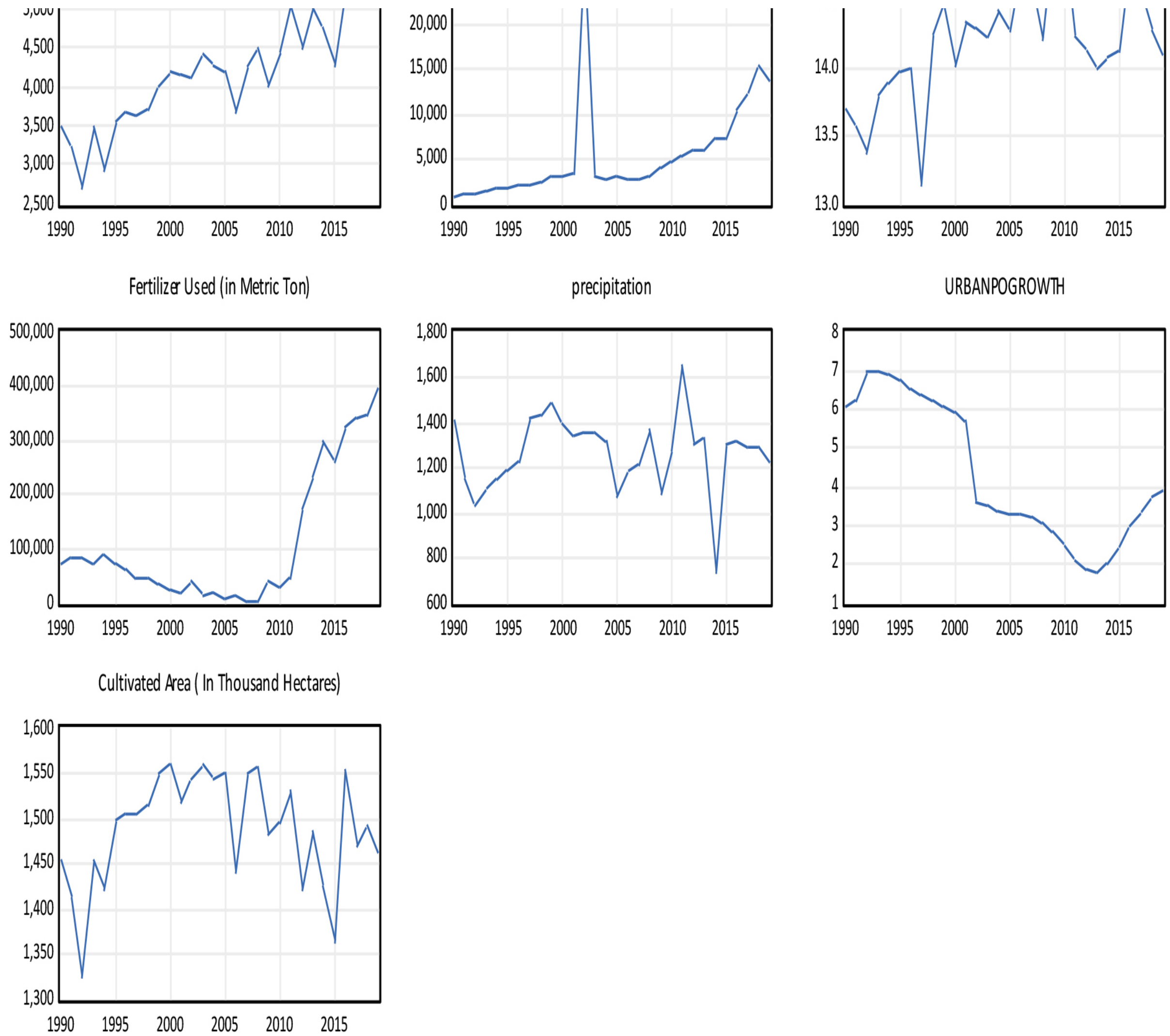

Fig. 1: Rice production, cultivated are, CO_2 emission, precipitation, temperature fertilizer used and urban growth in Nepal during 1990-2019

Table 2. The table shows that urban population growth, fertilizer, and domestic credit to the private sector are stationary at the first difference and other remaining variables are stationary at level. It means there is mix order of integration, i.e., I (0) and I (1). This allows us to have ARDL bound test.

Result of F bound test

Table 3 shows the result of the ARDL F-bounds test. The result shows that calculated F-statistics (17.61) is greater that the upper and lower bound values. It indicates the long-run association between the selected variables.

Fully modified ordinary least square (FMOLS)

Table 4 shows that GHG emission, cultivated area, domestic credit to the private sector by banks, and fertilizer consumption have significant positive impacts on rice production in Nepal. Likewise, urban population growth and annual mean temperature have a significant negative impact on rice production.

As shown in Table 4, 1% increase in CO_2 emission has 0.03% increase in rice production in Nepal for the period 1990 to 2019. It indicates that CO_2 emission has significant impact in rice production in the long run though the coefficient is small one. The major climatic variable annual mean temperature has negative impact in rice production in Nepal. Rise in temperature has caused severe impact in cropping pattern in rice producers of Nepal in recent years. Rayamajhee *et al.,* (2021) had found a 4183 kg reduction in rice production caused by 1^{O}C increase in summer temperature. The finding is further supported by Dawadi *et al.,* (2022) who found shifting cropping pattern due to change in temperature in Rasuwa district of Nepal. Negative impact of temperature on rice production is further supported by the study of Pandey (2023) who found decrease in rice yield from 7.8 % to 19.9 % in Narmada belt of Gujrat, India. Such negative effects of temperature can be minimized by following energy efficiency improvements in agriculture sector (Panthee and Noppradit, 2024). The negative impact of urban population growth in rice production could mean shift of rural farming population to urban for non-farm work which might have caused a decline in rice production. However, the significant positive impact of domestic

Table 2: Results of unit root test

Variable	Augmented Dickey-Fuller (ADF)			
	Level		First difference	
	Intercept	Trend and intercept	Intercept	Trend and intercept
lnRICE	0.7320	0.0014	0.0000	0.0000
lnGHG	0.2316	0.0186	0.0000	0.0000
lnCA	0.0119	0.0552	0.0000	0.0000
lnUPOP	0.5237	0.8155	0.0485	0.1274
lnPREC	0.0010	0.0063	0.0292	0.2849
lnDCP	0.7765	0.4514	0.0023	0.0123
lnFERT	0.7206	0.8362	0.0000	0.0001
lnTEM	0.0411	0.0508	0.0000	0.0001

Table 3: F bound test

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	17.61185	10%	1.92	2.89
K	7	5%	2.17	3.21
		2.5%	2.43	3.51
		1%	2.73	3.9

Table 4: The long run coefficient determined by the use of FMOLS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
lnGHG	0.0313	0.0065	4.805	0.0001
lnCA	2.1910	0.1091	20.068	0.0000
lnUPOP	-0.1163	0.0104	-11.093	0.0000
lnPREC	-0.0229	0.0235	-0.973	0.3413
lnDCPS	0.1785	0.0110	16.164	0.0000
lnFERTI	0.0357	0.0037	9.655	0.0000
lnTEMP	-1.1274	0.1427	-7.898	0.0000
C	-5.6303	0.7882	-7.142	0.0000
R-squared	0.9090	Mean dependent var		8.3356
Adjusted R-squared	0.8787	S.D. dependent var		0.1772
S.E. of regression	0.0617	Sum squared resid		0.0800
Long-run variance	0.0002			

Dependent variable: lnRICE; Cointegrating equation deterministic: C; Long-run covariance estimate (Pre whitening with lags = 2 from AIC
maxlags = 2, Bartlett kernel, Newey-West fixed bandwidth = 3.0000)

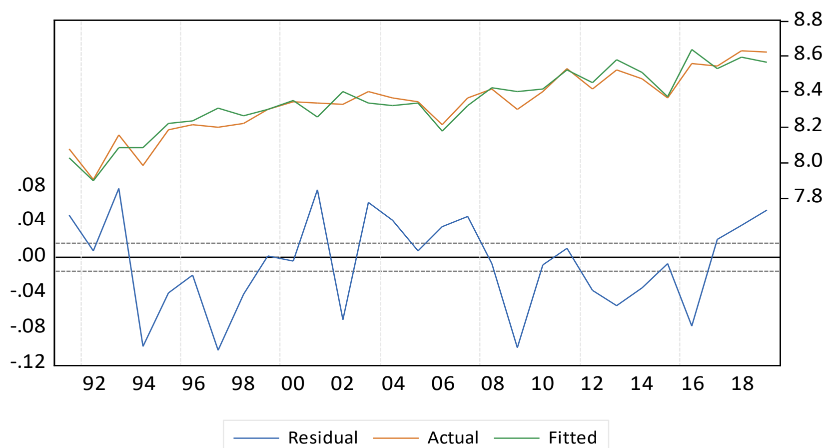

Fig. 2: Actual, estimated and residual values of the model

credit to the private sector by banks indicates the increase of access of rice producer to the loan provided by banking institutions.

The significant impact of fertilizer to rice production is found as expected. Such findings is similar to the study done by Chandio *et al.,* (2018) and (Rayamajhee *et al.,* 2021). The result of significant positive relation of rice cultivated area with rice production is as expected and similar to the study of (Tanko *et al.,* 2016) and Osanyinlusi and Adenegan (2016). The relation of precipitation with rice production is negative and insignificant. It means precipitation has not significantly affected rice production in Nepal though negative relation have indicated to adopt precaution in the sector of rice farming. As majority of the farmers rely on precipitation in Nepal (Karki and Gurung, 2012), seasonal shift in precipitation might create new challenge (Zhang *et al.,* 2012) in the coming years.

Diagnostic test

For testing the validity of the model actual, estimated, and residual values; test of Q- statistics and normality test is performed. As shown in Table 5 estimated values of rice are close to the actual values except in 1994, 1997 and 2009 indicating less fluctuations in the rice production.

Similarly, Table 5 represents the test of autocorrelation represented by the Q-statistics correlogram. As all levels of significance are more than 5 % the model is free from autocorrelation. It means the residuals of the model are stable.

Similarly, the Jarque-bera normality test (Fig. 3) is performed to test the normality of residuals. As the significance of the Jarque-bera coefficient is greater than 5 %, it justifies that residuals are normally

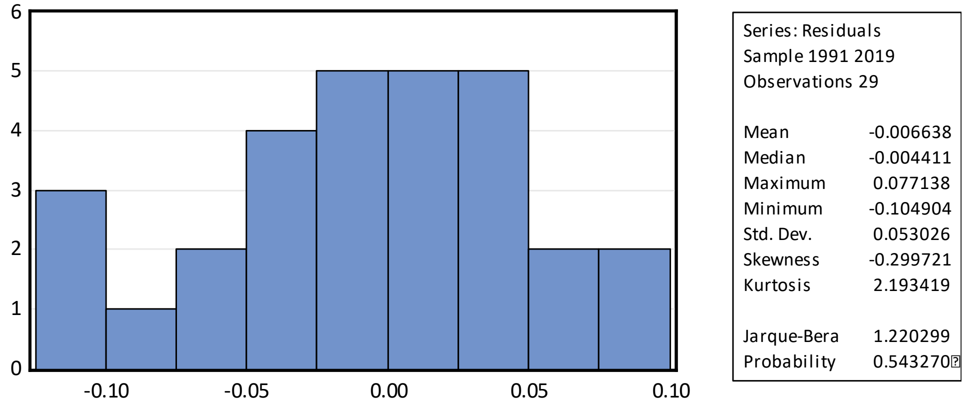

Fig. 3: Normality test

Table 5: Q-Statistic for auto correlation

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.048	0.048	0.0730	0.787
		2	0.070	0.068	0.2352	0.889
		3	0.070	0.064	0.4023	0.940
		4	-0.083	-0.095	0.6527	0.957
		5	-0.143	-0.147	1.4163	0.923
		6	-0.318	-0.312	5.3718	0.497
		7	-0.056	-0.018	5.5016	0.599
		8	-0.045	0.013	5.5896	0.693
		9	-0.413	-0.435	13.269	0.151
		10	-0.137	-0.293	14.151	0.166
		11	0.031	-0.076	14.198	0.222
		12	0.117	0.065	14.917	0.246

*Probabilities may not be valid for this equation specification.

distributed. Hence, the tested model is free from econometric problems.

CONCLUSION

Rice is a major food crop grown in Nepal and its productivity is being affected by climate change in recent years. So, by taking GHG emissions, annual mean temperature, and precipitation as the major climatic variable, the study has tried to reveal their impact on rice production in Nepal. For this purpose, the FMOLS method was applied to the time series data from 1990 to 2019. The outcomes show the significant positive of GHG emission, mainly by CO_2 emissions, and the significant negative impact of annual mean temperature on rice production. Though precipitation has a negative impact yet the influence is not found significant. Similarly, fertilizer use and domestic credit to the private sector by banks and cultivated area have a significant positive impact on rice production. However, the negative impact of urban population growth on rice production has raised serious concerns along with the impact of climate change. So, the policy makers have to focus on climate change adaptation measures for increasing rice production. Urban migration has to be discouraged by developing rural sector and engaging people in agricultural activities. Similarly, there is the need of continuous research on the impact of temperature, CO_2 emission, and precipitation on rice plant growth and productivity.

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