Research Article

Determinants of Rice Production in Nepal

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Abstract | Rice as a major cereal crop is getting the attention of policymakers all over the world. Amidst the different changing climatic conditions across the globe, researchers are focusing on the study of determinants of rice production from a different perspective. This study also has made an effort to investigate the determinants of rice production in Nepal taking annual mean temperature, cultivation area, fertilizer used, and precipitation rate as the independent variable by the use of the Auto Regressive Distributed Lag (ARDL) Model. The data analysis from 1990 to 2019 showed that annual mean annual temperature and fertilizers have a long-term, favorable and significant impact on rice production. Whereas cultivation area has a short-term significant impact. Precipitation and cultivation area did not have a long-term effect on rice production. The study recommends prioritizing the expansion of rice cultivation area and area-specific practices for adapting to climate change for increasing rice production in the scenario of an almost stable cultivation area in the last two decades.

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Introduction

Rice is the most important and dominant food crop, consumed by more than 50 percent of the world's population (Nawaz *et al*., 2022). More than 3 billion people get 30-75% of their daily caloric intake from this cereal plant, which is significant on a worldwide scale as a major source of food (Paudel, 2013). For Asian farmers, approximately 90% of the total rice is farmed and eaten throughout the world and it is also considered the primary source of revenue (Chandio *et al*., 2020). Among the top 10 rice-producing countries that cover almost 85% of the world's rice production, India and China contribute more than half of the total (World Economic Forum, 2022). Nepal, however, which is situated between India (in the east, west, and south) and China (in the north) is importing rice since 1970 and is unable to meet the domestic demand of the country (Pant, 2007).

The terai, mid-hills, and high-hills regions of Nepal are favorable for rice production. Together, these three regions account for nearly 50% of all agriculturally cultivated land and all agricultural output in Nepal

(Malla *et al*., 2022). Leaving two high altitude-based districts Manang and Mustang remaining 75 districts grow rice. The majority of rice is produced in the plain land of Terai i.e., 66% followed by Hills and Himalayas (Chandio *et al*., 2021). To promote and uplift the rice production sector, the government of Nepal is giving priority through different plans and programs. Each year government is providing financial support and subsidy for the stakeholders of rice producers to increase rice production and decrease its import though such initiations have not worked well. Similarly, floods in Terai, changes in monsoon time, lack of availability of fertilizer, and improved seed are creating an obstacle to the growth of rice yield. As a result, stakeholders are inspired and pressured to develop innovative techniques and systems to cut down on environmental expenses during the production, or development of new and substitute products (Chaudhry *et al*., 2020).

Parry *et al*. (2013) estimate that by 2060, global cereal production will have decreased by 1% to 7% under the assumption of continuing climate effects. Developing nations are predicted to have the biggest negative effects, ranging from -9% to 11%. Indeed, global temperature is increasing year over year and it is creating adverse impacts in mountainous countries like Nepal. Nepal is experiencing changing temperatures (0.04°C increment in Terai and 0.09°C increase per year within the Himalayas) throughout the year with the highest rate of increment in the winter (Phuyal *et al*., 2017). Such temperature change is creating a threat to the productivity of rice. Along with climate change, sustainable production of rice is undermined by abiotic and biotic stresses (Ayinde *et al*., 2013).

Since the last few decades, greenhouse gas emissions that trap heat in the earth's surface have been largely blamed for climate change and global warming, which have become major worldwide issues (Commer *et al*., 2020). Due to the consequences of climate change, numerous industrialized and developing nations have changed their management strategies (Khanal *et al*., 2018) and Nepal also belongs to such countries. The demand for rice will increase more quickly than that for other crops due to the world population's projected growth of 10 billion people by 2050 (Paudel, 2013). So, small countries like Nepal have to pay more attention to the influencing variables for rice production. In this context, the study has tried to estimate the relationship between precipitation, cultivated area, fertilizer used, and mean temperature with rice production in Nepal.

Rice production, cultivated area, and yield in Nepal

Demand for rice in Nepal is increasing year by year and it is estimated to reach 4.8 to 6.2 million metric tons by 2050 (Timsina *et al*., 2022). In comparison to demand, rice production has not increased as much. Rice cultivated area (Figure 1) fluctuated between 1400 and 1500 thousand hectares during the period 1991 to 2019. The area of cultivation reached its maximum in 2001 (1560 thousand hectares) and the maximum production was in 2019 (5610.01 thousand metric tons). To meet the growing demand for rice using a limited cultivated area is a challenging task though the increasing trend in rice yield (Figure 2) has created a positive environment. The average rice yield for the period 1991 to 2019 is 2.79 me. Ton/ha.

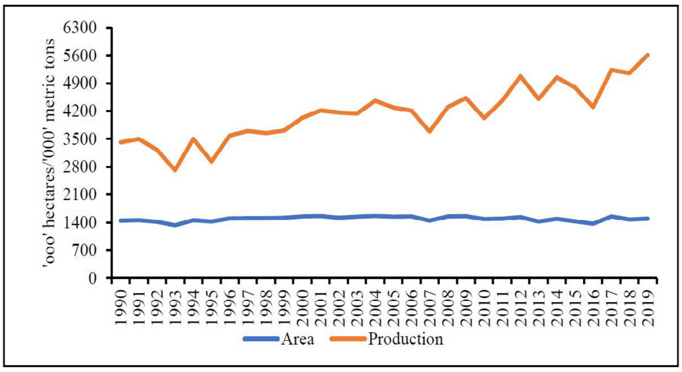

Figure 1: *Rice cultivated area and production.*
Source: *(Nepal Rastra Bank, 2022).*

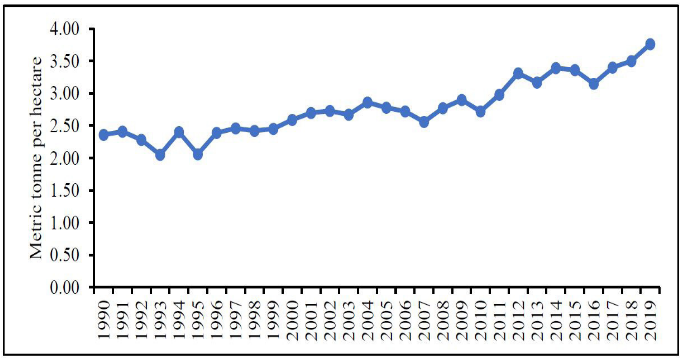

Figure 2: *Rice yield.*
Source: *(Nepal Rastra Bank, 2022).*

Like in other Asian countries, rice is the major cereal crop of Nepal. Among the five major cereal crops (rice, maize, wheat, barley, and millet) grown in Nepal, the percent share of rice in the cultivated area fluctuated around 45.11% (Figure 3). Similarly, the production share of rice among the 5 cereal crops is on average 55% (Figure 4).

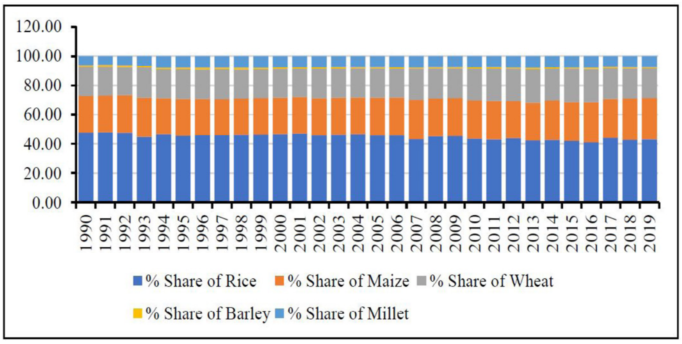

Figure 3: *Cultivated area.*
Source: *(Nepal Rastra Bank, 2022).*

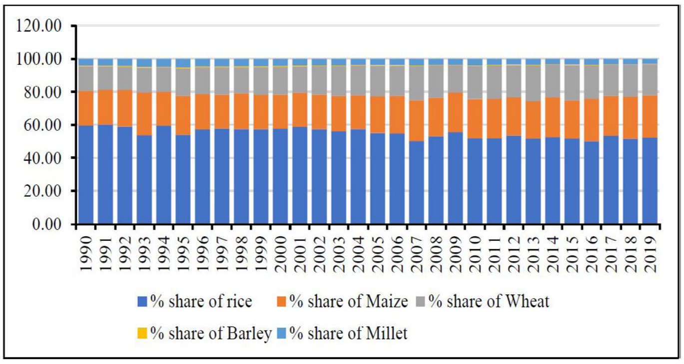

Figure 4: *Production share of rice.*
Source: *(Nepal Rastra Bank, 2022).*

Determinants of rice production

Rice production is influenced by various internal and external factors as per the location of production. However, commonly it is affected by the input factors like cultivated area, fertilizer, irrigation, seeds, and so forth. This section includes the findings of previous research works on determinants of rice production.

Tun and Kang (2015) used 195 farmers as the sample and showed that use of mechanical tools increased efficiency of rice production in Myanmar. The input used, number of labor used, material cost of rice production and the operational cost were used as the major determinants of rice production. Shaikh *et al.* (2016) discovered that factors such as labor, capital, education of farmers, access to financing, and farm size have a positive influence on rice production in Pakistan. The study was based on a judgment sampling of 120 respondents. Similarly, a study by Ali *et al.* (2022) found increased rice productivity in Pakistan through the use of labor hours, irrigation and fertilizer. The study was based on the Cobb-Douglas production function.

Based on the study of major Asian rice-producing countries, Chandio *et al.* (2022) found that temperature and CO_2 emissions significantly decreased rice production. However, area under cultivation, fertilizer, and the rural worker increased rice production. The study used the dynamic ordinary least square method and covered the period 1961-2016.

Koirala *et al.* (2014) used and supported the notion that land area, planting season, land rent, fertilizer, and fuel all had an impact on the Philippines' rice output, as well as the technical efficiency of that production. The findings were based on the stochastic frontier production method. By applying the regression model for the data of 1970-2012 the yield of rice in Ghana was found to change significantly with fluctuations in the cultivated area, prices of rice and maize received by farmers, fertilizer price, and human effort willing to engage their service in farming (Tanko *et al*., 2016). Similarly, Bashir and Yuliana (2018) used per capita income, human resources, population, labor, wage rate, wetland region, urbanization, rice costs, and agricultural technology as the major determinants of rice production in Indonesia for the period 1990 to 2014. The study found that technology does not affect the production of rice.

In Cambodia's case, Kea *et al.* (2016) found agricultural equipment, the size of the land harvested, the use of fertilizer and irrigation, production methods, and the number of agricultural supports to employees as the factors that affect rice production. According to the study, the most important influencing factors of rice production in Cambodia at the provincial level were capital investment, farming equipment, development of rice production land, technological advancement of fertilizers, production technology of agricultural producers, technical knowledge, and the number of employees for food production.

Based on the data of 160 randomly selected rice farmers in Nigeria Osanyinlusi and Adenegan (2016), it was determined that productivity would grow with an increase in the farm area, fertilizer use, educational attainment, labor cost, and transportation at the current rates. Similarly, by the use of a novel dynamic ARDL method, Emenekwe *et al.* (2022) found positive short-run and long-run impacts of fertilizer on rice production in Nigeria for the period 1971 to 2018.

By the use of the ARDL model for the data over the period 1978-2016, Chandio *et al.* (2018) discovered that the amount of land used for grain crops, better seeds, fertilizer, and water accessibility have a favorable and significant influence on grain crop production in Pakistan. By the use of a nonlinear ARDL model Baig *et al*. (2022) found long term negative impact and short-term positive impact of mean temperature on rice production in India for the period 1991 to 2018.

Khanal *et al*. (2018) surveyed 422 rice farmers in four districts of Nepal (Kaski, Dhading, Chitwan, and Rupandehi) and proved that education of the farmer has a positive and significant effect on climate change adaptation. Rice production is observed to increase by 33% as a result of adaptation, and the majority of the farmers that had adapted would have earned 24% less rice otherwise. Karn (2014) found that a 10 °C rise in daytime maximum temperature in the Terai region of Nepal increases rice harvest by 27 kg/ha during the ripening phase.

The study of Nepal by Rayamajhee *et al*. (2021) used labor, capital, fertilizer, seed, irrigated land, temp extreme, rain extreme, temp average, rain average, social capital, Agri extension, river, and road availability as the major determinants of rice production in Nepal. Though the study did not establish a connection between increases in typical monsoon precipitation and rice production yet the result showed severe variations in rainfall harm rice productivity. The outcome demonstrates that both average and excessive temperatures and precipitations have a significant adverse effect on paddy cultivation, and rice yield in Nepal is seriously threatened by increasingly abnormal intense rainfall structures and long-term increases in mean temperature.

A study by Chandio *et al*. (2021) used cultivated land, CO_2 emissions, annual mean temperature, average precipitation, fertilizer consumption, agricultural loan, and improved seeds as the determinants of rice yield in Nepal. It was discovered that CO_2 emissions adversely influence rice yield in both the short run and long run. Similarly, average temperature and average precipitation positively influenced rice production in the long run. These findings were based on the ARDL model for the period of 1990 to 2016.

By realizing the growing issue of food security past studies have shown the climate and non-climate related factors affecting rice production in different countries and regions. However, in the case of Nepal, as per the researcher's knowledge, there is a lack of research on determinants of rice production at the national level based on secondary data. This gap is fulfilled by this study. As Nepal is a highly climate change-vulnerable country, the findings could be helpful for concerned stakeholders.

Materials and Methods

Data

For an empirical investigation, time series data from 1990 to 2019 were analyzed. Total rice production, total cultivated area, annual mean temperature, fertilizer consumption, and precipitation are the major variables used for the study. The data source and measurement unit are mentioned in the Table 1.

Methodology

To test the determinants of rice production following simple model is developed based on the study of Chandio *et al*. (2018).

$$RP = f\,(CA, FT, MT, PRC) \quad \ldots(1)$$

Where, RP = rice production, CA = rice cultivated area, FT = fertilizer consumption, MT= annual mean temperature, PRC = precipitation.

The model is further expressed in the form of the following linear form.

$$RP = \beta 0 + \beta_1 CA + \beta_2 FT + \beta_3 MT + \beta_4 PRC + \varepsilon_t \quad \ldots(2)$$

Table 1: *Variable definition and sources of data.*

Variable name	Rice production	Precipitation	Mean temperature	Cultivate area	Fertilizer consumption
Abbreviations	RP	PRC	MT	CA	FT
Unit of measurement	Thousand metric tons	Millimeters	Celsius degree centigrade	Thousand hectares	Metric Ton
Source	(Nepal Rastra Bank 2022)	(World Bank Nepal, 2022)	(Climate Change Knowledge Portal for Development practitioners and Policy Makers, 2022)	(Nepal Rastra Bank, 2022)	(Nepal Rastra Bank, 2022)

Table 2: *Descriptive statistical analysis (1990 to 2019).*

	Rice production	Precipitation	Fertilizer	Cultivated area	Annual mean temperature
Mean	4207.428	1266.485	110154.3	1487.661	14.18767
Median	4212.500	1292.635	55580.00	1496.500	14.22500
Maximum	5610.010	1652.360	400541.0	1560.000	14.97000
Minimum	2712.000	730.6600	3157.000	1324.000	13.13000
Std. Dev.	725.5332	167.5739	122396.8	61.02516	0.423375
Skewness	0.061131	-0.779451	1.176057	-0.816325	-0.326094
Kurtosis	2.550638	5.236831	2.864344	3.134337	3.239061
Jarque-Bera	0.271093	9.291989	6.938554	3.354493	0.603124
Probability	0.873238	0.009600	0.031140	0.186888	0.739662
Sum	126222.8	37994.54	3304629	44629.84	425.6300
Sum Sq. Dev.	15265556	814349.5	434,000,000,000	107998.0	5.198137
Observations	30	30	30	30	30

Compared to the simple linear model, the log-linear model, which was created from the linear combination, produces findings that are acceptable and competent. Equation 2 can be converted into a log form as:

$$lnR_P=\beta_0+\beta_1 lnCA+\beta_2 lnFT+\beta_3 lnMT+\beta_4 lnPRC+\varepsilon_t \quad ....(3)$$

Based on Equation 3 following ARDL model is used to test the determinants of rice production in Nepal.

$$\Delta lnRp_t = \propto_0 + \beta_1 \Delta lnRp_{t-1} + \beta_2 \Delta lnCA_{t-1} + \beta_3 \Delta lnFT_{t-1} + \beta_4 \Delta lnMT_{t-1} + \beta_5 \Delta lnPRC_{t-1} + \sum_{i=1}^{n} \delta_{1i} \Delta lnRp_{t-i} + \sum_{i=1}^{n} \delta_{2i} \Delta lnCA_{t-i} + \sum_{i=1}^{n} \delta_{3i} \Delta lnFT_{t-i} + \sum_{i=1}^{n} \delta_{4i} \Delta lnMT_{t-i} + \sum_{i=1}^{n} \delta_{5i} \Delta lnPRC_{t-i} \quad ...(4)$$

The variables under the log-linear model (3) are tested for stationarity by using Dicky fuller test which suggested the use of the ARDL model.

Autoregressive distributed lag model

Pesaran has greatly popularized the autoregressive distributed lag (ARDL) method, which has many benefits compared to earlier cointegration techniques like EG (Engle and Granger, 1987) and JJ's maximum likelihood-based tests (Ghimire *et al*., 2021). It is easy to determine whether a long-term relationship is close by using the ARDL approach without taking into account the series that is stationary at levels [I (0)] or first difference [I (1)], or a combination of both (Chandio *et al*., 2018). Likewise, ARDL model is used to derive error correction model which shows the speed of adjustments from short to long-run equilibrium (Nkoro and Uko, 2016). ARDL strategy is extremely dependable when there is a small sample size and maintains the strategic distance from the issue of endogeneity and makes a difference to look at the long-term coefficients. In other words, the ARDL technique is free from residual correlation (Nkoro and Uko, 2016). ARDL F-stat is utilized to look at the relationship over time between the study variables chosen. By rejecting the null hypothesis, we infer that the cointegration occurs if the value of F-statistic is significantly larger than the upper bound (Chandio *et al*., 2021). Eviews software automatically selects the ARDL model lag order.

Results and Discussion

Table 2 shows the summary statistics of the selected variables. During the study period (1990-2019), the average rice production is 4207.428 thousand metric tons. Maximum precipitation and annual mean temperature are 1652.360 millimeters and 14.97 Celsius degree centigrade respectively. Similarly, the mean cultivated area and fertilizer are 1487.66 thousand hectare scale and 110154.3 metric tons respectively.

Unit root test

Augmented dickey-fuller test (ADF Test) was used for testing the stationarity of the variables at the level and first difference including both intercepts as well as trend and intercept (see Table 3).

The result shows that except fertilizer (stationary at first difference), all other variables including rice production, cultivated area, mean temperature, and precipitation rate were stationary at level. This allows us to test the long-run relation between the variables.

Table 3: *Results of unit root test.*

Variables	ADF test statistic (Intercept)	Trend and intercept
At level		
LnRP	-1.018250	-5.135141***
LnPRC	-4.592250***	-4.508338***
LnCA	-3.605731**	-3.525576*
LnFT	-1.052124	-1.410568
LnTM	-3.060212**	-3.566657*
At first difference		
DLnRP	-7.714315***	-7.510783***
DLnPRC	-3.259070**	-2.595941
DLnCA	-7.002443***	-7.511038***
DLnFT	-6.261219***	-6.530419***
DLnTM	-6.344016***	-6.479210***

Note: *The variables having signs *, ** and *** are statistically significant at the level of 10,5 and 1 percent respectively.*

ARDL F-bounds test

ARDL F bound test is utilized to identify the existence of long-term relationships between variables under study. The result of the ARDL bound test indicates that calculated F-statistics (6.157775) is greater than the lower and upper bound values at a 5% level of significance as shown in Table 4. It suggests that there is a long-run relationship between the chosen variables.

Table 4: *F-bounds test.*

Test statistics	Value	Signif.	I (0)	I (1)
		Asymptotic: n = 1000		
F-statistics	6.157775	10%	2.2	3.09
K	4	5%	2.56	3.49
		2.50%	2.88	3.87
		1%	3.29	4.37

Null Hypothesis: There are no levels of relationship.

Table 5: *The long-run relationship between variables.*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
lnPRC	0.548009	0.445876	1.22906	0.2393
lnCA	0.882474	1.6059	0.54952	0.5913
lnMT	8.269543	1.783971	4.63547	0.0004
lnFT	0.100049	0.02375	4.212511	0.0009
C	-24.99765	8.532936	-2.929549	0.011

Table 5 displays the findings of the long-run association between the variables. The optimal lag order of the model is ARDL (2, 2, 2, 1). The result of the model indicates that coefficients of mean temperature and fertilizer are positive and statistically significant at a 1% level. It means a 1 percentage increase in fertilizer and annual mean temperature causes to about 0.1% and 8.269% rise in rice production, respectively. The research finding on temperature contradicts the study of Rayamajhee *et al.* (2021) and is similar to that of Chandio *et al.* (2018) and (Karn, 2014). But as Nepal is a vulnerable country in terms of climate change in the coming years rice production could be affected by annual mean temperature. Similarly, findings on fertilizer match the study of (Emenekwe *et al*., 2022). Though rice production has a long-run positive relationship with the cultivated area and precipitation rate yet their coefficient is not found statistically significant. This contradicts the findings of past studies (Osanyinlusi and Adenegan, 2016; Tanko *et al*., 2016). As the rice cultivated area has remained almost constant during the study period, fertilizer and other factors might have played a significant role to increase rice production.

Results of Short-run error correction model (ECM)

The short-term dynamics were examined by the use of a short-run error correction model. It is employed to find the short-term relation between rice production and is exogenous variables. The outcome of the ECM is shown in Table 6.

Table 6: *Error correction model.*

Variable	Coefficient	Std. Error	T-Statistic	P value
ΔlnRP (-1)	-0.250028	0.131517	-1.901103	0.0781
ΔlnPRC	-0.004980	0.039510	-0.126037	0.9015
ΔlnPRC (-1)	-0.236579	0.057513	-4.113453	0.0011
ΔlnCA	2.477229	0.249818	9.916117	0.0000
ΔlnCA (-1)	0.988136	0.323006	3.059184	0.0085
ΔlnTM	0.633335	0.288554	2.194857	0.0455
ΔlnTM (-1)	-1.779909	0.323727	-5.498185	0.0001
ΔlnFT	0.012735	0.011513	1.106103	0.2873
CointEq (-1)	-0.348188	0.049172	-7.081093	0.0000

R-squared 0.943761; Adjusted R squared 0.920082; Durbin-Watson stat 2.404441

The result shows that in the short run cultivated area has a positive as well as significant influence on rice production. This finding is similar to the study of Chandio *et al.* (2018). In the long run, the annual mean temperature was positively correlated with rice production in the short run. A similar outcome was found by Bage *et al.* (2022) in Nigeria. However, fertilizer does not have a significant impact in the short run. Every year there is a shortage and late supply of fertilizer during the season of rice farming in Nepal. So, a significant short-run impact is not found in rice production though it has a positive impact. It contradicts the study of Emenekwe *et al.* (2022). The coefficient of ECM is negative (-0.348188) and significant at a one percent level of significance. ECM coefficient indicates that long-run equilibrium is being adjusted at a rate of 0.35% per year. The value of R-squared (0.943761) indicates that the model is strongly well-fitted.

Diagnostic test

Results of diagnostic tests, including serial correlation LM test, heteroskedasticity, and normality test (Table 7 and Figure 5), reveal no problem with the selected model. As the P value of all the diagnostic tests is more than 5% the selected model is a good one.

Table 7: *Diagnostic test.*

Test statistics	Probability
Serial correlation LM test (Breus ch Godfrey)	0.2556
Heteroskedasticity (Breusch-Pagan-Godfrey)	0.0592
Normality (Jarque-Bera)	0.9672

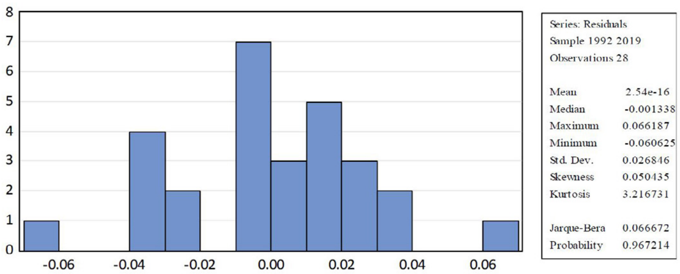

Figure 5: *Normality test.*

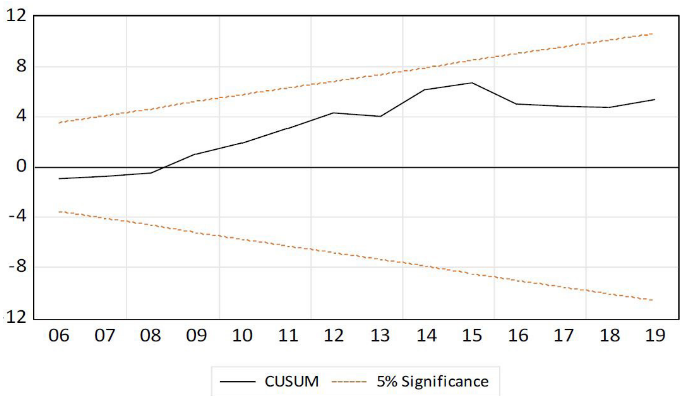

Figure 6: *A plot of the CUSUM test.*

Likewise, the CUSUM and CUSUM square tests are shown in Figures 6 and 7. They indicate the stability of the model as the plot of CUSUM and CUSUM of squares line lie between the two dotted lines.

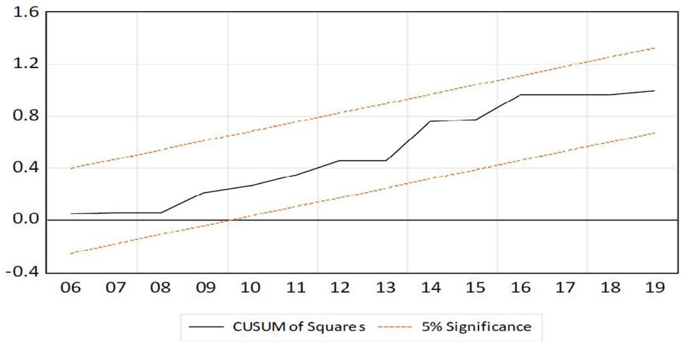

Figure 7: *CUSUM square test.*

Conclusions and Recommendations

The increasing food deficit caused by the slow growth of rice production has become a serious issue of concern in Nepal. Realizing this fact this study has analyzed the determinants of rice production in Nepal for the period 1990 to 2019. For this purpose, the cointegration method: Autoregressive Distributed Lag Model has been used. The study found both the short-run and long-run relationhip between the selected variables: rice production, cultivation area, fertilizer used, mean temperature, and precipitation. The findings further demonstrated the significant and positive influence of mean temperature and fertilizer on rice production. Though rice cultivation area and precipitation have a positive influence on production they do not have a significant impact. Rice production, however, is positively and significantly impacted by the area under cultivation. The study revealed that annual mean temperature and precipitation have not negatively impacted rice production in Nepal. However, area-specific climate change adaptation practices are to be encouraged. The government of Nepal should formulate and implement a rice farming policy to protect major rice-cultivated areas. This policy should be linked with land policy and discourage plotting of rice cultivated areas for housing mainly in the terai belt and major city areas of Nepal. Furthermore, the study suggests further research on province and local-level micro-study on the determinants of rice production in different seasons.

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Links Researchers

Novelty Statement

As per the researcher's knowledge, this is the first paper analysing determinants of rice production including climate change variables by the use of time series data in the Nepalese scenario. The findings might be useful for rice-growing small countries.

Author's Contribution

Hari Prashad Joshi: Conceptualization, methodology, visualization, resources, and writing— original draft preparation.
Kuaanan Techato: Conceptualization, data curation, and writing—review & editing.
Khamphe Phoungthong: Funding acquisition, project administration, conceptualization, supervision, and writing—review & editing.
Keshav Raj Panthee: Formal analysis, resources, data curation, and writing—review & editing.
All authors have read and agreed to the published version of the manuscript.

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Conflict of interest
The authors have declared no conflict of interest.

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