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Optimizing Potato Productivity in Nepal: Unveiling the Impact of Climate and Farming Practices through Econometric Insights

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Abstract

Potato production in Nepal is essential to its agricultural economy, yet is vulnerable to climatic variability and inefficient practices. This study utilized a Dynamic Ordinary Least Squares (DOLS) approach to analyze data from 1990 to 2022, incorporating variables such as temperature, rainfall, and pesticides. Data were sourced from the FAO and Climate Change Knowledge Portal. Temperature exhibited a significant positive impact on potato yield (β = 35707.52, $p < 0.001$), whereas rainfall's effect was statistically insignificant (β = -28.65, $p > 0.05$). Pesticide use showed a strong positive correlation (β = 81.91, $p < 0.001$), highlighting its critical role. Nutrient management strategies, such as NPK fertilizers, were identified as effective in enhancing yields, particularly in high-altitude regions. The findings reveal the interplay of climatic factors and agronomic practices in shaping potato productivity. The dependency on pesticides raises environmental concerns, while insufficient rainfall adaptation underscores the need for supplementary irrigation systems. Region-specific, adaptive strategies such as precision irrigation and integrated pest management are recommended. Integrating climatic and agronomic factors into policymaking is crucial for enhancing potato production in Nepal. Sustainable farming practices and infrastructural support are key to ensuring economic resilience and food security.

Keywords: Potato yield, climatic variability, DOLS, nutrient management, pest management, sustainable agriculture

JEL Classification: Q54, C32, O13

Introduction

Potato production is a cornerstone of Nepal's agricultural economy, serving as a vital source of livelihood for millions of farmers and contributing significantly to national food security. As a staple crop, potatoes play an essential role in addressing the dual challenges of feeding a growing population and adapting to shifting dietary preferences (Luitel & Bhandari, 2023). This importance is further highlighted by Acharya and Shrestha (2023), who emphasize the crop's role as a primary income source for farmers across diverse regions of Nepal.

However, the productivity and profitability of potato farming in Nepal are under increasing threat from climatic variability and inefficiencies in agricultural practices. These challenges are particularly pronounced in rain-fed agricultural systems, where water stress and temperature fluctuations significantly impact yields (Ojeda et al., 2021; Badr et al., 2022). In high-altitude regions, which are hubs of potato farming, these climate-induced stresses exacerbate the vulnerabilities of traditional farming systems, disrupting yields and threatening economic stability (Thapa & Hussain, 2021; Dawadi et al., 2022).

The adverse impacts of climate change have become more pronounced in recent years, with irregular rainfall and extreme temperatures creating unfavorable growing conditions for potatoes, particularly in rain-fed farming systems (Naz et al., 2021). In addition to climatic challenges, inefficiencies in agricultural practices, such as reliance on traditional methods and limited adoption of modern agronomic techniques, contribute to substantial yield gaps (Adhikari et al., 2023; Khadka et al., 2023). Modern interventions, including the use of high-yielding seed varieties, precision irrigation, and integrated pest management, have demonstrated potential to enhance productivity but remain underutilized in many farming communities (Phulara et al., 2021; Ghimire et al., 2021).

Studies have consistently shown the critical interplay between climatic factors and agricultural practices in determining potato productivity. For instance, Chapagain et al. (2021) identified key traits contributing to higher tuber yields in Nepal's eastern plains, while Kharel (2022) explored the factors affecting marketable surplus in the Kavre district. Similarly, Gotame et al. (2021) evaluated the performance of potato clones in Nepal's central Terai region, emphasizing the importance of region-specific agricultural practices. These findings underscore the need for integrated strategies to address both climatic and agronomic challenges.

Economically, potato farming is a crucial component of rural livelihoods, with substantial contributions to household incomes and food security. However, inefficiencies in resource utilization, high input costs, and limited market access often constrain profitability (Acharya & GC, 2023; Ghimire & Kandel, 2023). Infrastructure deficits and inadequate market linkages further exacerbate these challenges, emphasizing the need for targeted interventions to support farmers (Bolakhe et al., 2022).

This study builds upon existing literature by examining the combined effects of climatic factors and agricultural practices on potato yield in Nepal. Employing the Dynamic Ordinary Least Squares (DOLS) approach, this research seeks to provide robust, policy-relevant insights into optimizing potato production systems. By integrating economic and environmental considerations, the study aims to offer actionable recommendations for policymakers, development practitioners, and stakeholders to enhance the resilience and sustainability of Nepal's potato farming sector.

Literature Review

Impact of Climatic Factors on Potato Yield

Climate variability has emerged as a critical determinant of agricultural productivity globally, with Nepal's potato sector being no exception. Studies reveal that temperature fluctuations and erratic precipitation patterns adversely affect potato yields, particularly in rain-fed agricultural systems. Mishra et al. (2024) found that rising temperatures shortened the growing season of potatoes in South Asia, leading to diminished tuber development. Similarly, Tooley et al. (2021) emphasized that water stress during critical growth phases significantly reduces yields, highlighting the importance of efficient irrigation systems. In Nepal, extreme weather events and rainfall variability have increasingly posed challenges to potato cultivation, particularly in high-altitude regions where traditional farming methods are prevalent (Jiang et al., 2021). The complex interactions between climate and agricultural systems require adaptive measures to mitigate yield losses (Rijala et al., 2021).

In addition, Rai et al. (2022) provided empirical evidence of the vulnerability of mountain farming systems to climate change, focusing on potato-based systems in Bhutan. Their findings underscore the parallels with Nepal, where high-altitude regions face similar climate-induced stresses. This highlights the importance of adaptive strategies tailored to mountainous terrains.

Role of Sustainable Agricultural Practices

Adopting sustainable agricultural practices has shown significant potential in mitigating the negative impacts of climatic variability on potato yields. Integrated nutrient management, precision irrigation, and high-yielding and pest-resistant potato varieties are among the strategies that have improved productivity in various contexts (Naz et al., 2024). In Nepal, applying micronutrients such as zinc and boron and practices like mulching have enhanced water retention and nutrient uptake in rain-fed systems, leading to better yields (Kohar et al., 2023). Crop simulation models have also been employed to identify region-specific management practices that optimize yields while minimizing resource waste (Divya et al., 2021). Sustainable practices thus play a critical role in addressing climate-induced challenges while fostering economic resilience (Chauhan et al., 2022).

The influence of nutrient management has been further emphasized by Sai and Paswan (2024), who demonstrated that higher levels of NPK fertilizers significantly enhance the growth, yield, and profitability of potato varieties in Nepal's Bajhang district. This reinforces the role of targeted fertilization in addressing regional productivity gaps.

Economic Implications of Potato Farming

Potato farming is a crucial component of Nepal's rural economy, contributing to household incomes and food security. However, inefficiencies in resource utilization and limited market access continue to impede profitability. Studies in Sindhupalchok and Baglung districts show that high input costs often outweigh output prices, reducing profit margins for smallholder farmers (Acharya & GC, 2023; Kandel et al., 2024). Infrastructure deficits and inadequate market linkages further exacerbate these challenges, limiting farmers' ability to fully capitalize on their produce (Bolakhe et al., 2022). These challenges emphasize the need for integrated interventions to support the economic viability of potato farming.

Integration of Climatic and Economic Strategies

Effective integration of climatic and economic strategies is essential for ensuring sustainable potato production in Nepal. Advanced econometric modeling techniques, such as Dynamic Ordinary Least Squares (DOLS), provide robust frameworks for analyzing the long-term and short-term effects of climatic and agricultural variables on yield. Region-specific interventions, such as promoting drought-resistant varieties, enhancing irrigation infrastructure, and facilitating market access, have been proposed to address these dual challenges (Nasir & Toth, 2022). Such strategies emphasize the importance of a holistic approach to agricultural development, integrating both environmental resilience and economic efficiency to optimize potato production systems.

Literature Gap

Despite extensive research on climatic impacts and agricultural practices influencing potato yields, several critical gaps remain unaddressed. While studies such as those by Jannat et al. (2021) and Adekanmbi et al. (2024) have extensively reviewed global trends, region-specific analysis for Nepal that integrates both climatic and economic variables is limited. The unique topographical and climatic conditions of Nepal require targeted research that considers local agronomic practices and socio-economic contexts (Aryal et al., 2023).

Although sustainable practices like mulching and the use of micronutrients have been shown to enhance productivity, as highlighted by Aryal et al. (2023), their adoption in Nepal remains inconsistent. Limited access to resources and technical knowledge among smallholder farmers exacerbates these challenges (Kc et al., 2021). Understanding the socio-economic barriers to adopting such practices is essential for designing effective interventions.

Additionally, studies employing advanced predictive and econometric models like DOLS to evaluate the combined effects of climatic and agronomic variables on potato yield in Nepal are scarce. Research such as that by Dadrasi et al. (2022) and Lin et al. (2023) underscores the value of integrating geospatial and econometric approaches, yet their application remains underutilized in Nepal’s context.

Finally, while the economic implications of climate-smart agricultural practices have been reviewed globally (Waaswa et al., 2022; Vannoppen & Gobin, 2022), their specific impact on the livelihoods of Nepalese farmers is insufficiently documented. This study aims to address these gaps by employing a DOLS framework to analyze the interplay between climatic factors, agricultural practices, and economic outcomes, thereby offering actionable insights for enhancing potato production and resilience in Nepal.

Methods and Materials

Research Design

This study adopts a quantitative research design to investigate the interplay between climatic factors, agricultural practices, and potato yield in Nepal. By employing the Dynamic Ordinary Least Squares (DOLS) model, the research aims to capture long-term relationships among the variables of interest. The DOLS approach is particularly suitable for this study as it accommodates variables integrated at different orders, providing robust and unbiased estimates of the relationships.

Data Collection and Sources

Secondary data spanning 1990 to 2022 were sourced from reliable databases such as the Food and Agriculture Organization (FAO) and the Climate Change Knowledge Portal (CCKP). The dataset includes annual observations of potato yield, temperature, rainfall, and pesticide usage. Table 1 provides a summary of the variables, symbols, units, and sources.

Table 1

Variables, Symbols, Units, and Data Sources Used in the Study

Variable Names	Symbols	Units	Source
Potato Yield	Potato Yield	Hectograms per hectare (hg/ha)	FAO
Average Temperature	Temperature	Degrees Celsius (°C)	CCKP
Total Rainfall	Rainfall	Millimeters (mm)	CCKP
Pesticide Usage	Pesticides	Tonnes	CCKP

Model Specification

The DOLS model is specified as follows:

$$(\text{Potato Yield})_t = \beta_0 + \beta_1(\text{Temperature})_t + \beta_2(\text{Rainfall})_t + \beta_3(\text{Pesticides})_t + \sum_{j=-q}^{q} \alpha j \, \Delta X_{t-j} + \epsilon_t \quad (1)$$

Where,

Dependent Variable:

- (Potato Yield)t: The potato yield in year t.

Independent Variables:

- (Temperature)t: The temperature in year t.
- (Rainfall)t: The rainfall in year t.
- (Pesticides)t: The pesticide usage in year t.

First-Differenced Independent Variables with Leads and Lags:

- ΔX_{t-j}: The first difference of the independent variables (temperature, rainfall, and pesticides), included with both leads and lags.
- Leads (+j) and lags (−j) help address endogeneity (potential correlation between regressors and the error term) and correct for serial correlation.

Constant Term (β_0):

- Represents the intercept, capturing the average level of (Potato Yield)t when all independent variables are zero.
- **Error Term ($\in_t$)**:
- Captures the unobservable factors that affect potato yield, assumed to be white noise (i.e., normally distributed with constant variance).

Leads and Lags (q):

- The number of years before (j<0) or after (j>0) the current year t for which the first differences of independent variables are included.

Hansen Parameter Instability Test

To assess the stability of the long-run relationships among the variables, we employ the Hansen Parameter Instability Test. This test is specifically designed to detect any parameter instability within cointegrated relationships over time, making it ideal for assessing the robustness of our model in the presence of potential structural breaks or shifts (Poudel et al., 2024). By applying this test, we can determine if the parameters of the cointegrating equation remain stable or if they exhibit significant changes due to factors like economic shocks, policy adjustments, or other external influences over the sample period.

The Hansen test involves estimating a cointegrating vector and then examining whether this vector is stable across the sample period. The procedure utilizes the residuals from the cointegrating regression, testing for any systematic deviation that would indicate instability. For this purpose, we use the following hypotheses:

Null Hypothesis (H_0): The parameters in the cointegrating relationship are stable over time.

Alternative Hypothesis (H_1): There is instability in the parameters of the cointegrating relationship.

Normality Test

The Jarque-Bera test was used to check whether the residuals from the estimated models followed a normal distribution. The results indicated that the model residuals were normally distributed, confirming the reliability of the regression estimates (Khatri et al., 2025)

Software and Tools

The statistical analyses, including stationarity tests, cointegration tests, and DOLS estimation, are conducted using statistical software Eviews 12, which provide robust implementations of the DOLS method and related diagnostics.

Data Analysis and Results

Trends in Key Variables for the Analysis

The trends in key variables, including potato yield, temperature, rainfall, and pesticide usage, highlight significant fluctuations over the study period (1990-2022). These variations reflect the interplay between climatic factors and agricultural practices, underscoring their impact on potato productivity in Nepal.

Figure 1

Trends in Potato Yield, Temperature, Rainfall, and Pesticide Usage (1990-2022)

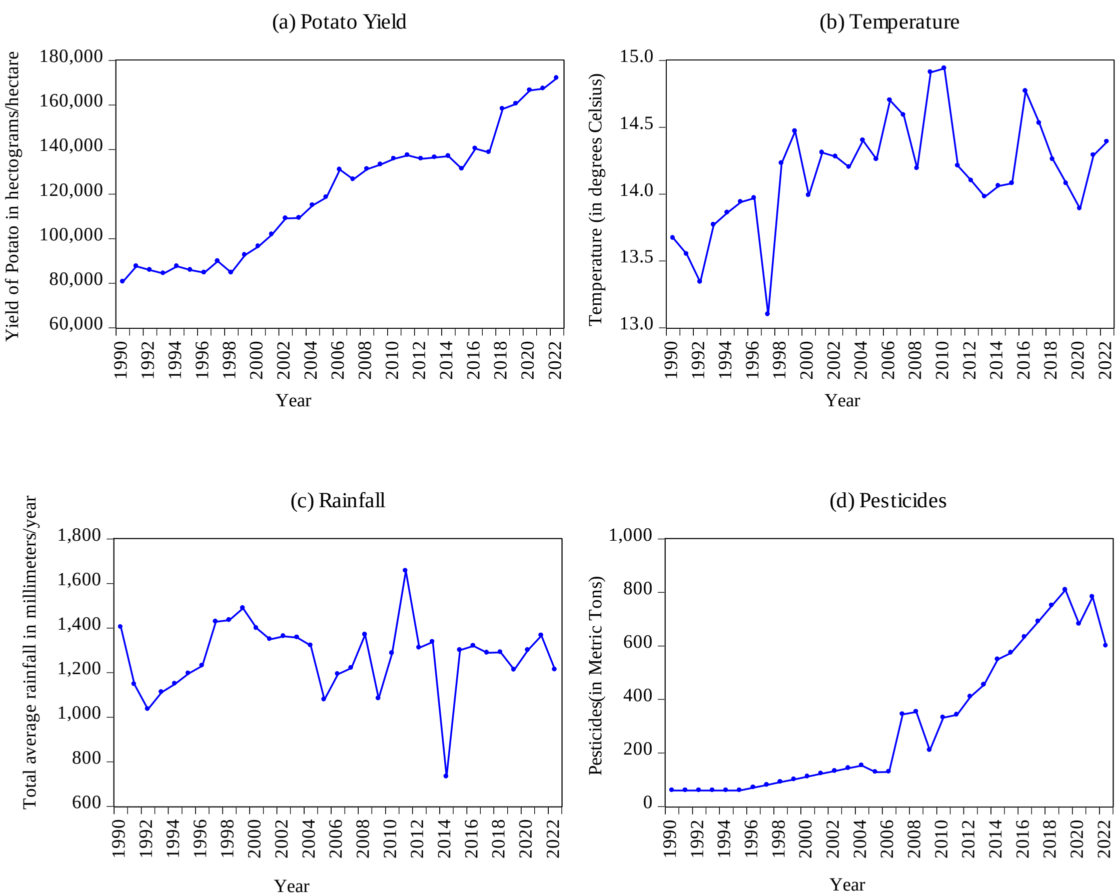

Figure 1 presents four subplots that illustrate the trends in potato yield, temperature, rainfall, and pesticide usage in Nepal between 1990 and 2022. Panel (a) shows the trend of potato yield, which exhibits a general upward trajectory over the years, reaching nearly 180,000 hectograms per hectare by 2022. However, the rate of increase appears to fluctuate, possibly reflecting the impact of variable climatic conditions and agricultural practices. Panel (b) depicts temperature trends, indicating a gradual rise in average temperatures over the study period, which aligns with global patterns of climate change. This rise in temperature could negatively impact potato growth by shortening the growing season, leading to reduced yields in certain years, particularly when coupled with extreme weather events.

Panel (c) shows the fluctuations in rainfall, which are critical for rain-fed agriculture in Nepal. The rainfall data indicate substantial variability, with some years experiencing significant rainfall while others face dry spells, likely influencing the stability of potato production. Panel (d) depicts the increasing trend in pesticide usage, which seems to align with the efforts to protect potato crops from pests and diseases. This increase in pesticide use may reflect rising pest pressures, but it could also indicate an over-reliance on chemical inputs, which can escalate farming costs and have environmental consequences. These trends collectively underline the complex interaction between climatic factors and agricultural practices, and they highlight the economic implications for potato farming in Nepal, where climatic variability, increased input costs, and fluctuating yields directly influence farmer income and food security.

Descriptive Statistics

The descriptive statistics, as shown in Table 2, highlight significant variability in key variables such as potato yield, temperature, rainfall, and pesticide usage over the study period.

Table 2

Descriptive Statistics of Key Variables

	Potato Yield	Temperature	Rainfall	Pesticides
Mean	119768.70	14.16	1271.93	307.31
Median	126568.00	14.20	1300.03	153.00
Maximum	172044.00	14.94	1656.02	809.09
Minimum	80601.00	13.10	732.86	60.11
Std. Dev.	28208.49	0.41	161.20	256.90
Skewness	0.17	-0.35	-0.83	0.66
Kurtosis	1.86	3.39	5.62	1.93
Observations	33	33	33	33

Table 2 presents descriptive statistics for the key variables—potato yield, temperature, rainfall, and pesticide usage—over the period from 1990 to 2022. For each variable, the mean, median, maximum, minimum, standard deviation, skewness, kurtosis, and the number of observations (33) are provided, offering an overview of the data's central tendency, variability, and distribution.

The mean potato yield is 119,768.70 hectograms per hectare, with a median of 126,568. This suggests that, on average, potato yields have been quite high, although the presence of variability is evident due to the large standard deviation of 28,208.49. The skewness value of 0.17 indicates that the distribution is relatively symmetrical, meaning that there are not extreme outliers on either side. However, the kurtosis value of 1.86 shows a relatively flat distribution compared to a normal distribution, which implies that while extreme values are less common, they still occur occasionally. For temperature, the mean is 14.16°C with a slight negative skew of -0.35, indicating that lower temperature values are more frequent. Rainfall shows more variability with a standard deviation of 161.20 and a negative skewness of -0.83, meaning that higher rainfall values are less common, and there is a tendency for more dry years. Pesticide usage has a mean of 307.31 tonnes, with substantial variability, indicated by the standard deviation of 256.90, and a positive skewness of 0.66, pointing to a few years with high pesticide usage.

From an economic perspective, the data highlight the unpredictability of agricultural conditions and input costs. The large variability in potato yield and pesticide usage reflects the risks farmers face, particularly in years of low yield or high pesticide dependence, which can increase production costs. The analysis of skewness and kurtosis provides insights into the stability of potato farming: a more symmetrical yield distribution with fewer extreme outliers suggests that, on average, yields are moderately stable, but extreme weather events or pest outbreaks could still lead to significant losses. Therefore, understanding these statistical measures is critical for developing strategies that enhance yield stability and reduce the economic risks associated with unpredictable weather patterns and rising input costs.

Table 3

Correlation Analysis

	Potato Yield	Temperature	Rainfall	Pesticides
Potato Yield	1.00	0.48	-0.02	0.90
Temperature	0.48	1.00	0.07	0.30
Rainfall	-0.02	0.07	1.00	-0.02
Pesticides	0.90	0.30	-0.02	1.00

Table 3 presents the correlation analysis for the key variables—potato yield, temperature, rainfall, and pesticide usage—over the period from 1990 to 2022. The table provides the correlation coefficients between each pair of variables, which reveal the strength and direction of their relationships.

The correlation between potato yield and temperature is 0.48, indicating a moderate positive relationship. This suggests that as temperature increases, potato yield tends to rise, although the relationship is not strong enough to be purely deterministic. This finding aligns with the idea that higher temperatures may contribute to more favorable growing conditions for potatoes, but the impact is not entirely linear, implying that other factors, such as rainfall or agricultural practices, could also influence yields. The correlation between potato yield and pesticides is much stronger, at 0.90, indicating a very strong positive relationship. This suggests that increased pesticide usage is closely associated with higher potato yields, possibly due to the role of pesticides in protecting crops from pests and diseases, which could otherwise reduce yield. However, this also highlights a dependency on chemical inputs, which raises concerns about the economic and environmental sustainability of this practice.

On the other hand, the correlation between potato yield and rainfall is almost negligible at -0.02, indicating no significant linear relationship. This may suggest that, despite variations in rainfall, other factors like temperature or agricultural practices have a more direct influence on potato yield. The correlation between temperature and pesticides is 0.30, showing a mild positive relationship, which might indicate that as temperatures rise, farmers may increase pesticide usage to counteract pests that thrive in warmer conditions. Overall, these correlation results underscore the complex interplay between climatic variables and agricultural practices, highlighting how temperature and pesticide usage are closely linked to potato yield, while rainfall appears to have a less direct effect. From an economic perspective, these insights stress the need for policies that balance the use of pesticides with sustainable practices to ensure long-term productivity and profitability for farmers.

Unit Root Testing

Table 4 presents the results of unit root tests conducted to examine the stationarity of key variables. The tests confirm that all variables are either stationary at level or become stationary after first differencing, satisfying the requirements for DOLS modeling (Poudel et al., 2024).

Table 4
Unit Root Test Results

UNIT ROOT TEST TABLE (PP)					
At Level		Potato Yield	Temperature	Rainfall	Pesticides
With Const.	t-Stat.	0.52	-3.07**	-4.61***	-0.52
With Const.& T.	t-Stat.	-2.12	-3.58**	-4.56***	-2.34
None	t-Stat.	3.52	0.67	-0.56	0.82
At First Difference		d(Potato Yield)	d(Temperature)	d(Rainfall)	d(Pesticides)
With Const.	t-Stat.	-7.25***	-10.26***	-19.97***	-6.69***
With Const. & T.	t-Stat.	-7.45***	-15.50***	-19.44***	-6.56***
None	t-Stat.	-5.90***	-9.73***	-20.36***	-6.19***
UNIT ROOT TEST TABLE (ADF)					
At Level		Potato Yield	Temperature	Rainfall	Pesticides
With Const.	t-Stat.	0.28	-3.22**	-4.61***	-0.67
With Const.& T.	t-Stat.	-2.80	-3.64**	-4.56***	-2.46
None	t-Stat.	3.67	0.23	-0.24	0.55
At First Difference		d(Potato Yield)	d(Temperature)	d(Rainfall)	d(Pesticides)
With Const.	t-Stat	-7.52***	-6.56***	-8.16***	-6.68***
With Const. & T.	t-Stat.	-7.75***	-6.66***	-8.00***	-6.55***
None	t-Stat.	-2.08**	-6.59***	-8.30***	-6.17***

Notes: (*) = 10%; (**) = 5%; and (***)=1% Significant respectively

Table 4 presents the results of the Unit Root Tests (PP and ADF) conducted on the key variables—potato yield, temperature, rainfall, and pesticide usage—to assess their stationarity at both the level and first difference. The table provides t-statistics for each variable under different conditions: with constant, with constant and trend, and none.

For the PP test at the level, potato yield, temperature, and pesticide usage are non-stationary, as their t-statistics do not exceed the critical values for stationarity (with the exception of temperature, which shows a significant t-statistic of -3.07 at the 5% level). This suggests that these variables have a unit root at the level and do not exhibit stationary behavior, meaning their mean and variance change over time. Rainfall, however, shows stationarity at the 1% level, with a t-statistic of -4.61, indicating that it is stationary at the level. When the variables are differenced (first difference), all the variables, including potato yield, temperature, rainfall, and pesticide usage, show significant stationarity (at the 1% level), with t-statistics well below the critical values. This confirms that the variables become stationary once their first differences are taken, making them suitable for the Dynamic Ordinary Least Squares (DOLS) modeling.

From an economic perspective, the results indicate that the relationships between potato yield and climate-related factors (temperature, rainfall) as well as agricultural inputs (pesticides) may not be constant over time. The non-stationary nature of these variables suggests that factors such as long-term climate changes and evolving agricultural practices could influence potato yield dynamics. The first difference stationarity confirms that the variables can be analyzed for their long-term relationships in econometric models, allowing for a more accurate understanding of how changes in climate and agricultural practices impact potato productivity and profitability. These insights are critical for policy development, as they emphasize the need for long-term strategies that account for the evolving nature of agricultural conditions and the adaptive responses required to sustain the potato farming sector in Nepal.

Lag Length Selection

Table 5 displays the criteria of lag length selection for the DOLS model, with the AIC identifying an optimal lag of 1. This ensures the inclusion of appropriate lag structures for robust long-run and short-run analysis (Poudel, 2022; Poudel, 2023).

Table 5

Criteria of Lag Length Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-710.9561	NA	3.05e+16	49.30731	49.49591	49.36638
1	-642.4167	113.4444*	8.25e+14*	45.68391*	46.62687*	45.97923*
2	-633.2176	12.68836	1.42e+15	46.15294	47.85027	46.68452
3	-618.7250	15.99187	1.90e+15	46.25690	48.70860	47.02474
4	-600.7254	14.89624	2.49e+15	46.11899	49.32507	47.12309

Dynamic Ordinary Least Squares

The dependent variable in this analysis is potato yield, which is modeled using the Dynamic Ordinary Least Squares (DOLS) method. The model includes 30 observations after necessary adjustments and incorporates fixed leads and lags (lead=1, lag=1) to account for potential endogeneity. The long-run variance estimate is calculated using the Bartlett kernel with a Newey-West fixed bandwidth of 4.0000, ensuring robust and unbiased estimates of the relationships between the variables.

Table 6
Results of DOLS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Temperature	35707.52	6031.077	5.920587	0.0000
Rainfall	-28.65089	18.82673	-1.521820	0.1464
Pesticides	81.90794	6.966194	11.75792	0.0000
C	-371657.7	80656.92	-4.607883	0.0003
R-squared	0.954620	Mean dependent var		120405.1
Adjusted R-squared	0.922588	S.D. dependent var		26357.77
S.E. of regression	7333.535	Sum squared resid		9.14E+08
Long-run variance	63235313			

Table 6 presents the results from the Dynamic Ordinary Least Squares (DOLS) model, analyzing the relationships between potato yield (the dependent variable) and key independent variables: temperature, rainfall, and pesticide usage.

The coefficient for temperature is 35,707.52, with a t-statistic of 5.92 and a p-value of 0.0000, indicating a strong and statistically significant positive relationship between temperature and potato yield. This suggests that higher temperatures are associated with increased potato yields, likely due to more favorable growing conditions. The coefficient for rainfall is -28.65, but the t-statistic of -1.52 and the p-value of 0.1464 indicate that this relationship is not statistically significant at conventional levels. This implies that while rainfall may have some impact on potato yield, its effect is not strong enough to be considered a significant driver of yield variability in this model. On the other hand, pesticide usage shows a highly significant positive relationship with potato yield, with a coefficient of 81.91, a t-statistic of 11.76, and a p-value of 0.0000. This suggests that increased pesticide usage correlates with higher yields, reflecting its role in protecting crops from pests and diseases, but also signaling a dependence on chemical inputs.

The model's R-squared value of 0.9546 and adjusted R-squared of 0.9226 indicate that the model explains a large portion of the variability in potato yield, with the adjusted R-squared accounting for the degrees of freedom. The standard error of regression (7333.535) and sum of squared residuals (9.14E+08) suggest a relatively low level of unexplained variation, further supporting the model’s robustness. The long-run variance estimate of 63,235,313 reflects the estimated variability in potato yields over the long term. From an economic standpoint, these results emphasize the importance of temperature and pesticide use in influencing potato yield, highlighting the potential costs and trade-offs associated with pesticide reliance, while also suggesting the need for strategies that address climate change's impact on temperature and rainfall patterns. Understanding these dynamics is crucial for optimizing productivity and ensuring the sustainability of potato farming in Nepal, which is central to the article’s aim of improving agricultural practices and economic outcomes.

Cointegration Test - Hansen Parameter Instability

The Hansen Parameter Instability test examines the cointegration relationship between potato yield, temperature, rainfall, and pesticide usage. The null hypothesis posits that the series are cointegrated, meaning they share a long-term equilibrium relationship. The cointegrating equation includes a constant term (C), and the test evaluates the stability of the relationship across the study period.

Table 7

Cointegration Test - Hansen Parameter Instability

Lc statistic	Stochastic Trends (m)	Deterministic Trends (k)	Excluded Trends (p2)	Prob.*
0.062934	3	0	0	> 0.2

*Hansen (1992b) Lc(m2=3, k=0) p-values, where m2=m-p2 is the number of stochastic trends in the asymptotic distribution

Table 7 presents the results of the Hansen Parameter Instability test for the cointegration relationship between potato yield, temperature, rainfall, and pesticide usage. The test assesses the stability of the long-term relationship between these variables by evaluating the likelihood of structural changes over time.

The Lc statistic value of 0.0629, with a p-value greater than 0.2, indicates that there is no significant evidence of parameter instability in the cointegrating relationship. In other words, the relationship between the variables (potato yield, temperature, rainfall, and pesticide usage) appears to remain stable throughout the study period from 1990 to 2022. This stability is important for understanding the long-term dynamics of potato farming, as it suggests that the factors influencing potato yield, such as temperature and pesticide usage, maintain a consistent influence over time. Economically, this stability implies that policy interventions and agricultural practices aimed at enhancing potato productivity can be based on reliable long-term trends, without the need for frequent adjustments due to structural breaks or shifts in the relationship between variables.

The Wald Test

The Wald Test in Table 9 evaluates the joint significance of temperature, rainfall, and pesticide usage in the model. It assesses whether these variables collectively contribute to explaining variations in potato yield over time.

Table 8

Wald Test Results for Joint Significance of Variables

Test Statistic	Value	df	Probability
F-statistic	87.30486	(3, 17)	0.0000
Chi-square	261.9146	3	0.0000
Null Hypothesis: C(1)=C(2)=C(3)=0		Null Hypothesis Summary:	
Normalized Restriction (= 0)		Value	Std. Err.
C(1) = Tempereture		35707.52	6031.077

C(2) = Rainfall	-28.65089	18.82673
C(3) = Pesticides	81.90794	6.966194

Table 8 presents the results of the Wald Test for the joint significance of the variables temperature, rainfall, and pesticides in explaining potato yield. The null hypothesis, which states that the coefficients for temperature, rainfall, and pesticides are all zero (C(1)=C(2)=C(3)=0), is tested against the alternative that at least one of these coefficients is non-zero.

The F-statistic of 87.30, with degrees of freedom (3, 17), and the chi-square value of 261.91, both have p-values of 0.0000, indicating that the null hypothesis is strongly rejected. This suggests that all three variables—temperature, rainfall, and pesticide usage—significantly contribute to explaining variations in potato yield. The coefficients for each variable are also presented: temperature (35,707.52), rainfall (-28.65), and pesticides (81.91), with standard errors indicating their precision. From an economic standpoint, these results emphasize that climate and agricultural input variables play a crucial role in determining potato yield. Policymakers and farmers should focus on optimizing these factors—temperature regulation through adaptive measures, efficient water management, and careful pesticide use—to enhance productivity and mitigate risks in potato farming.

Histogram of Residuals for Normality Test

Figure 2

Histogram of Residuals for Normality Test

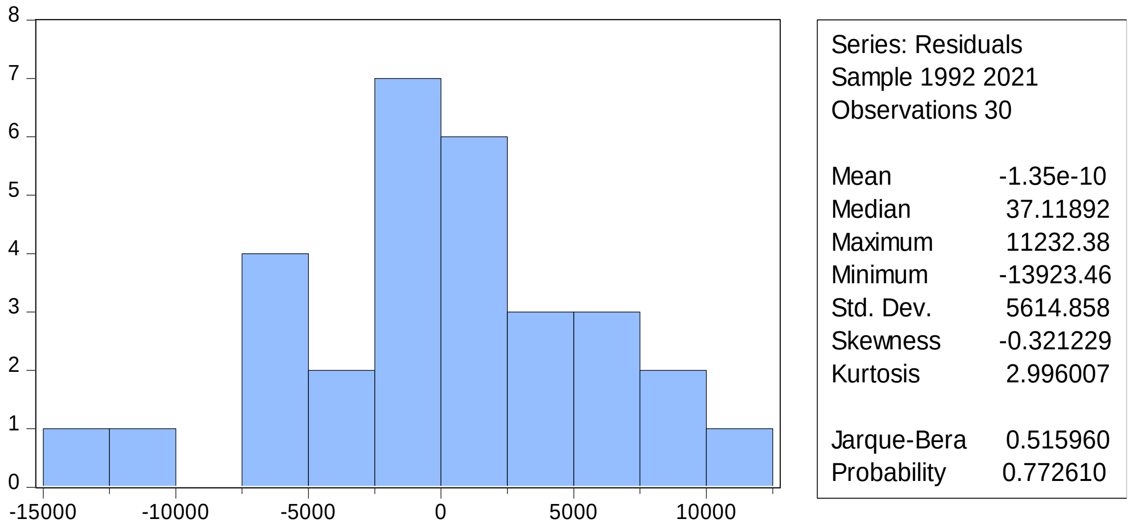

Figure 2 provides the results of diagnostics and stability tests, confirming the reliability of the econometric model used in this study. The JB test (p=0.77) indicates that the residuals are approximately normally distributed, ensuring valid statistical inference.

Discussion

This study investigates the influence of climatic factors and agricultural practices on potato yield in Nepal using a Dynamic Ordinary Least Squares (DOLS) approach. The findings highlight that temperature and pesticide usage are significant drivers of potato yield, while rainfall's impact is statistically insignificant. Specifically, the positive and significant relationship between temperature and yield underscores the adaptive potential of potato farming under moderate temperature increases. However, the strong dependence on pesticide usage reveals vulnerabilities associated with current farming practices, such as environmental and economic sustainability challenges. These results address the study's objectives by providing robust evidence of the interplay between climatic and agronomic variables, contributing valuable insights to the existing body of literature.

The significant positive relationship between temperature and potato yield aligns with prior studies, such as Mishra et al. (2024a), which highlighted the role of optimal temperature ranges in enhancing tuber development. This study further contextualizes these findings in Nepal, suggesting that moderate temperature increases in specific regions may extend the growing season and improve yields. However, extreme temperature fluctuations, as documented by Thapa and Hussain (2021), could undermine these gains, particularly in high-altitude areas vulnerable to climate-induced stress.

Contrary to expectations, rainfall showed no significant impact on potato yield. This may be attributed to the predominance of rain-fed systems in Nepal, where irregular rainfall patterns lead to inconsistent water availability, as noted by Neupane et al. (2022). The results imply that supplementary irrigation systems could mitigate this variability, aligning with findings by Tooley et al. (2021), which advocate for precision irrigation to stabilize yields.

The strong correlation between pesticide usage and potato yield highlights the critical role of pest management in sustaining productivity. However, this dependency raises concerns about the overuse of chemical inputs, echoing the warnings of Kohar et al. (2023) regarding environmental degradation and rising production costs. The findings underscore the need for integrated pest management strategies to balance productivity with sustainability.

Conclusion

This study provides comprehensive insights into the interplay between climatic factors and agricultural practices in determining potato yield in Nepal. The findings underscore the significant roles of temperature and pesticide usage, while highlighting the limited impact of rainfall under current farming systems. By employing a robust DOLS methodology, this research fills critical gaps in the literature and provides evidence-based recommendations to optimize potato production. Addressing the challenges of climate variability and unsustainable agricultural practices requires a multi-pronged approach, integrating adaptive, technological, and policy-driven solutions to ensure food security and economic resilience. Policymakers should prioritize investments in precision irrigation systems and heat-tolerant crop varieties to help farmers adapt to climatic variability, ensuring stable and increased productivity. Concurrently, extension services must educate farmers on sustainable pest management practices to reduce dependency on chemical inputs, promoting environmentally friendly farming. Development practitioners should support these efforts by implementing targeted interventions, such as providing subsidized access to modern agricultural tools and organizing training programs that enhance both productivity and sustainability. Additionally, long-term planning should incorporate environmental considerations into agricultural policies, fostering resilience in Nepal's potato farming sector against the challenges posed by climate change.

The novelty of this study lies in its application of the DOLS approach to analyze the combined effects of climatic and agronomic variables on potato yield in Nepal, a region with unique agricultural and climatic challenges. Unlike previous studies that often consider these factors in isolation, this research provides an integrated analysis, offering a nuanced understanding of their interplay. Additionally, the study's focus on Nepal addresses a critical gap in region-specific research, contributing to the global discourse on sustainable agriculture under climate change. A new future research area has been added, focusing on analyzing the environmental impacts of current pesticide usage patterns and assessing the feasibility of transitioning to eco-friendly pest management solutions.

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