Assessing Soil Nutrient Dynamics and Their Impacts on Crop Yields: A Case Study of Janaki Rural Municipality, Banke, Nepal

Rasila Gautam*[1], Bishwa Prakash Puri[1], and Hari Dahal[1]

[1]College of Applied Sciences-Nepal, Tribhuvan University, Kathmandu, Nepal

*Correspondence Author: rasilagautam2@gmail.com

Abstract

This study represents .

Keywords: Soil Nutrient, Fertiliser Use, Crop Yield, Janaki Rural Municipality, Banke, Nepal

1 Introduction

Nepal, a landlocked mountainous country in South Asia, is situated between 26°22′–30°27′ N latitude and 80°04′–88°12′ E longitude. Nestled in the southern foothills of the Himalayas, Nepal shares its northern border with China, while India surrounds it on the other three sides (**ningLandUseCover**). Out of the total 147,181 square kilometers land area of Nepal (**timilsinaAGRICULTURELANDUSE2019**) and has a population of approximately 28.9 million (**ningLandUseCover**). Nepal's land cover was primarily dominated by forests, croplands, and grasslands. Forests accounted for 49.9% of the total land area, followed by croplands at 29.2% and grasslands at 15.6%. Over time, land-use patterns have undergone significant transformations, with notable shifts between different land types (**ningLandUseCover**). Only the 75% of cropland is cultivated (**timilsinaAGRICULTURELANDUSE2019**).

It is increasingly evident that climate change is a tangible phenomenon, with fluctuations in temperature and precipitation affecting nutrient levels, soil moisture conditions, and, consequently, crop production. These impacts can be particularly severe if they coincide with critical growth stages of crops, potentially leading to devastating yield losses. To mitigate such adverse effects, the adoption of adaptive management practices is essential. Effective implementation of these practices requires a comprehensive understanding of appropriate fertilizer dosages, irrigation regimes, and soil nutrient dynamics (**shresthaAssessmentClimateChange2017**).

Soils in both natural ecosystems and agricultural landscapes exhibit inherent heterogeneity, resulting from a complex interplay of geochemical processes and anthropogenic influences. Agricultural activities, such as crop cultivation and soil management practices, further contribute to this variability by altering soil properties across spatial scales. Consequently, farm soils display inconsistent fertility and productivity levels, driven by differences in soil parameters and the availability of natural resources. However, the lack of detailed information regarding the levels and spatial distribution of soil nutrients at specific locations and fields often leads to the application of uniform fertilizer recommendations. This blanket approach frequently causes imbalanced nutrient supply, diminished crop productivity, and progressive soil degradation. To mitigate these issues, assessing the spatial distribution of soil nutrients is imperative for enabling precise nutrient management, optimizing crop yields, and fostering sustainable agricultural practices (**dahalNewApproachMeasure2024a**). A large proportion of the population engaged in agriculture follows a subsistence farming system. Only 25.1% of farmers are engaged in commercial farming, while the remaining 75.9% practice subsistence farming (**simkhadaReviewNepalsIncreasing2019**). Agriculture in Nepal is based on subsistence farming for the majority of the population and this can never be underestimated. The growth of Nepalese agriculture was low and very vulnerable in recent decades (Gyawali & Khanal, 2021). Despite the excellent production potential, farmers continue to face enormous challenges. Poverty, land degradation, low agricultural productivity, wrong use of budget and subsidies, shortage. The development of agriculture was hindered by the number of agricultural inputs, poor government support, etc. The challenge of maintaining food security was the simultaneous growth of the population on the one hand and the reduction of cultivated land on the other (Gyawali & Khanal, 2021).

2 Study area, Data and Methods

2.1 Study Area

The study was conducted in Janaki Rural Municipality, Banke, Nepal. The study area is located in the mid-western region of Nepal. The study area is situated between 28° 00' 00" N to 28° 15' 00" N latitude and 81° 45' 00" E to 82° 00' 00" E longitude. The study area is located at an altitude of 200 to 500 meters above sea level. The study area is characterized by a subtropical climate with a mean annual temperature of 25°C and a mean annual rainfall of 1500 mm. The study area is characterized by a monsoon climate with a wet season from June to September and a dry season from October to May. The study area is characterized by a hilly terrain with steep slopes and deep valleys. The study area is characterized by a dense forest cover with a variety of flora and fauna. The study area is characterized by a diverse population

3 Results and Discussion

4 Nutrient and Fertilizers

4.1 Nutrient

The analysis of soil properties based on Soil and Fertilizer data revealed that the majority of soil samples exhibited neutral pH levels (79.2%). Additionally, organic matter content was predominantly medium to high, with 83.3% falling within the medium range and 12.5% classified as high. Nitrogen levels varied, with a significant proportion (45.8%) in the medium range, conducive to healthy plant growth. Phosphorus levels were notably high, with 50% of samples classified as high and the remaining 50% as very high, suggesting adequate phosphorus availability for plant nutrition. Potash levels also demonstrated a diverse distribution, with the majority falling within the medium to high range. These results enhance our understanding of soil quality by highlighting subtle differences in important agricultural metrics that can guide targeted actions for optimal crop management (Table 1).

Table 1: Soil Properties and Their Interpretation

Variables	Scale	Interpretation	Percent (%)
pH	1–6.5	Acidic	20.8
	6.5–7.5	Neutral	79.2
	7.5–14	Basic	0
Organic Matter	<0.1	Very Low	0
	1.1–2.5	Low	4.2
	2.6–5	Medium	83.3
	5.1–10	High	12.5
	>11	Very High	0
Nitrogen	<0.05	Very Low	0
	0.051–0.10	Low	4.2
	0.11–0.20	Medium	45.8
	0.21–0.4	High	50
	>0.41	Very High	0
Phosphorus	<10	Very Low	0
	11–30	Low	0
	31–55	Medium	0
	56–110	High	50
	>110	Very High	50
Potash	0–55	Very Low	0
	56–110	Low	0
	111–280	Medium	41.7
	281–500	High	54.2
	>501	Very High	4.2

Descriptive statistics of soil nutrients (pH, Organic Matter, Nitrogen, Phosphorus, and Potash) are presented in Table 2, showing the Minimum, Maximum, Mean, and Standard Deviation of each nutrient. This table complements the findings of Table 1 by providing measures of central tendency and variability for each soil nutrient.

Table 2: Descriptive statistics of soil nutrients and total yield

Variable	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
pH	5.200	7.500	6.746	0.687
Organic Matter (%)	1.930	6.100	4.019	0.941
Nitrogen (%)	0.090	0.300	0.195	0.049
Phosphorus (ppm)	60.000	589.000	200.167	175.676
Potash (ppm)	116.000	608.000	277.667	94.304
Total Yield (kg/ha)	3000.00	19571.53	6372.066	3639.386

4.2 Nutrient and Production

Correlation analysis revealed significant correlations between pH, organic matter, nitrogen levels, and crop yield (Table 3). Negative correlations between pH, organic matter, nitrogen, and yield indicate that yield tends to decrease as these components increase. This inverse association may result from imbalances caused by excessive amounts or restrictions on nutrient availability. Notably, no significant association was found between yield and phosphorus and potash, indicating that these elements might not have a substantial impact on yield variability. Overall, managing pH, organic matter, and nitrogen levels in soil management techniques is crucial for increasing crop productivity and yield potential.

Table 3: Correlation between yield and soil nutrients

Variable	**pH**	**Organic Matter**	**Nitrogen**	**Phosphorus**	**Potash**
Yield (kg/ha)	-0.289*	-0.203*	-0.368*	-0.018	0.200
p-value	0.055	0.017	0.038	0.466	0.175

*Correlation is significant at the 0.05 level (2-tailed)

5 Model Summary for Nutrient and Crop Yield

Table 4 represents the model summary for nutrient and crop yield in the study area. With an R value of 0.822, the model summary indicated a significant positive correlation, showing a strong relationship between the independent and dependent variables. The R^2 value of 0.675 suggested that 67.5% of the variability in average yield was explained by these independent variables. After adjusting for the number of predictors, the independent variables accounted for approximately 58.5% of the variance in crop production. The model's significance level (p-value) of 0.001

suggested that at least one of the independent variables significantly affected crop output, implying a substantial and strong overall impact on crop productivity.

Table 4: Linear Regression Model Summary for Nutrients and Crop Yield

Dependent Variable	Yield
Adjusted R^2	0.585
Model	Linear Regression
R	0.822
Significance (p-value)	0.001
F-statistic	7.484
R^2	0.675
Predictors	Potash, Phosphorous, pH, Organic Matter, Nitrogen

5.1 Coefficient Table

Table 5: Coefficient Table for the Model

Model	Unstandardized Coefficient	Std. Error	Beta	t	Sig.
(Constant)	15263.881	5559.539	-	2.746	0.013
pH	-1451.159	719.515	-0.274	-2.017	0.059
Organic Matter	10554.882	2253.806	2.728	4.683	0.000
Nitrogen	-222409.190	42458.901	-3.021	-5.238	0.000
Phosphorous	-1.166	2.993	-0.056	-0.390	0.701
Potash	7.169	5.221	0.186	1.373	0.187

The high coefficients of organic matter and nitrogen showed their strong influence on the expected yield. Although phosphorus and potash are essential for plant growth, their smaller coefficients suggested a lower impact on yield. pH had a moderate impact by influencing nutrient availability.

The linear regression equation from the analysis explains the variability in crop yields based on soil nutrients:

$$\text{Yield} = 15263.881 - 1451.159(\text{pH}) + 10554.882(\text{Organic Matter}) - 222409.190(\text{Nitrogen}) - 1.166(\text{Phos} \tag{1}$$

6 Fertilizers and Production

Farmers used fertilizers to enhance crop yield. The major inorganic fertilizers used were urea, di-ammonium phosphate, and potash (Annex 6.3). Descriptive statistics between average yield and fertilizer use showed that the mean average yield observed was 5612.85 kg/ha with a standard deviation of 2659.38 kg/ha. The average amount of fertilizer used was 102.5218 kg with a standard deviation of 48.47575 kg (Annex 6.4).

Table 6: Correlation Between Average Fertilizer Use and Crop Yield

Yield (kg/ha)	0.349**
Significance (*p*-value)	¡0.001

The model's combined predictive value was demonstrated by the significant F-statistic ($p < 0.001$), supporting the explanation of 11.5% of the variability in crop production by fertilizer use.

The regression equation for fertilizers and yield is given by:

$$\text{Yield} = 3648.185 + 19.163 \times (\text{Fertilizers}) \tag{2}$$

7 Land and Irrigation Details

Table 7 presents the landholding and irrigation characteristics of the study area. The majority (54.5%) of families held between 5-15 Katha of land, followed by marginal landholders (28.4%) with less than 5 Katha.

8 Land Use Change Analysis

Land use change analysis for Janaki Rural Municipality and Banke District was conducted using ICIMOD data. The results are presented in Table 8 and Figure ??.

Table 7: Frequency Table for Land and Irrigation Data

Characteristics	Variables	Percentage
Total Land Holding	Small (¡5 Katha)	28.4
	Marginal (5-15 Katha)	54.5
	Large (¿15 Katha)	17.2
Land Type	Lowland	80.6
	Both	19.4
Land Adequacy	Yes	97.8
	No	2.2
Soil Type	Clay	100.0
Soil Fertility Rating	Good Quality	26.9
	Medium	67.9
	Not Good Quality	5.2

Table 8: Slope of Land Cover Change (2000-2019) in Banke District

Land Cover	Slope
Forest	264.8
Other Wooded Land	111.7
Grassland	-279.3
Cropland	-210.4
Built-up	92.3
Waterbody	15.6
Riverbed	5.4

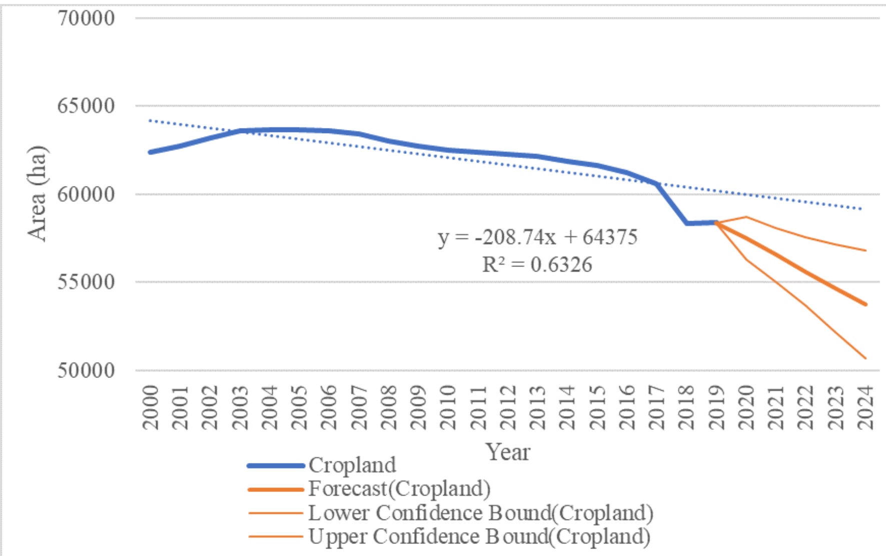

Figure 1: Land Use Change Trend in Banke District (2000-2019)

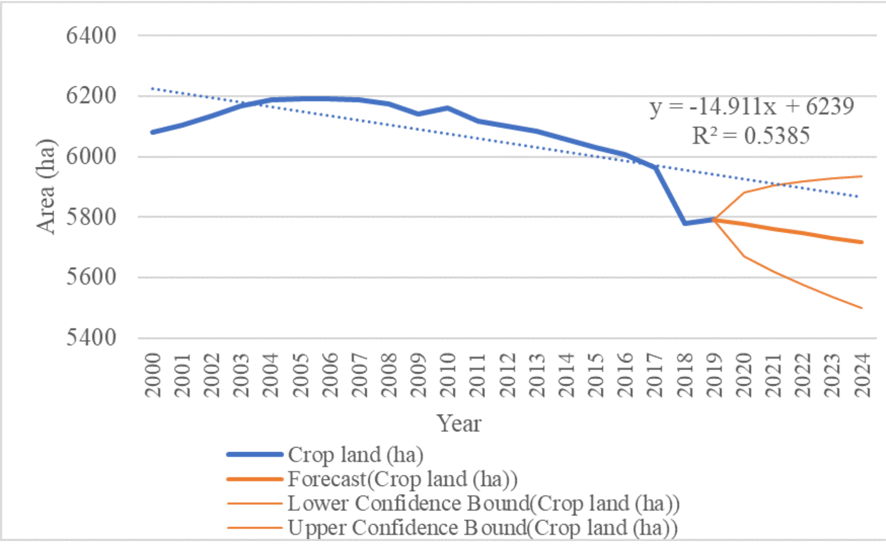

Figure 2: Land Use Change Trend in Janaki Rural Municipality (2000-2019)

9 Discussion

10 Summary

References

References

Gyawali, P., & Khanal, S. (2021). Overview of Agriculture in Nepal: Issues and strategies to cope with. *Fundamental and Applied Agriculture*, (0), 1. https://doi.org/10.5455/faa.89753