Nepal Journal of Biotechnology
Publisher: Biotechnology Society of Nepal
Journal Homepage: https://nepjb.com/index.php/NJB
ISSN (Online): 2467-9313
ISSN (Print): 2091-1130

Assessing Determinants of Maize Yield, Economic Viability and Strategic Framework in Flood Prone Areas of Udayapur, Nepal

Saroj Dhakal, Benif Pandey, Rabindra Yadav, Yuvraj Devkota, Nand Sah, Sandesh Dhakal
Institute of Agriculture and Animal Science (IAAS, TU), Siranchowk, Gorkha, Nepal

Received: 18 Nov 2024; Revised: 05 Jun 2025; Accepted: 13 Jun 2025; Published online: 31 Jul 2025

Abstract

Maize productivity in the flood-prone area of Udayapur, Nepal is influenced by various independent variables. This paper delves deeper into the economic viability and strategic framework for farming in such conditions. The B:C ratio for maize production in flood susceptible areas was 0.986 which imply that enterprise is not profitable. The factors governing crop yield in the study area differ from rest of Nepal due to flood invasion during monsoon, by disrupting the water table. This study investigates different predictors that significantly affect crop yield. Information from farmers were collected through a semi-structured questionnaire. Multiple linear regression model was employed to identify significant independent variables affecting crop yield. The results indicate that irrigation ($p=0.002$) and pesticide application ($p=0.013$) share negative significant relation with the crop yield with unstandardized coefficients of -7.084 and -4.070 respectively. Similarly, the use of synthetic fertilizers demonstrated statistically significant ($p= 0.002$) relation and had positive impact on crop yield. SWOT analysis is done to identify strength, weakness, opportunity and threats to maize farming in the research area. These findings highlight the importance of rapidly nutrient-releasing synthetic fertilizers, especially in anaerobic soil caused by water-logged conditions. Based on our study, site-specific risk management, crop diversification and water management strategies, must be tailored to ensure farmers' resilience and enhanced productivity.

Keywords Anaerobic soil, Flood invasion, Multiple linear regression, Site-specific risk management, Synthetic fertilizers

Corresponding author, email: saaroyz77@gmail.com

Introduction

Maize *(Zea mays)* is the world's most staple food with production of 1134.75 million ton. It ranks second in Asia, after rice, with annual production of 361.84 million tons [1]. Maize supply 365kcal/100 g, 72% starch, 10% protein, and 4% fat approximately [2]. The average maize consumption/head in Nepal is 98g/day [3]. Maize is primarily grown as staple food for human and as feed and fodder for livestock. These diverse uses have led the demand constantly rise from 5% annually [4] to 11% in the last 3 years [5]. The increasing demand of maize especially from poultry industry has reached to 6.46 million mt [6]. The demand exceeds our internal supply, which results in increasing import from neighboring countries. With ever-growing demand and shrunken agricultural land, the only way to meet the soaring demand is by increasing productivity.

Udayapur is a predominately maize-cultivating district with a 17,836-ha cultivation area and 55,239 mt of production. Floods during the monsoon season has affected the crop potential almost every year [7]. Despite the importance of maize in Udayapur, there are no clear understanding of crop yield determinants, especially in flood-prone areas. There is no prior research on these flood-prone areas and farmers are yet to obtain any information on location-specific risk and crop management practices. For economic vulnerability check in the study area, benefit cost ratio is calculated. Multiple linear regression is applied to quantify the effects of predictors on crop productivity. Location-specific crop yield determinants vary primarily because our study region is subjected to disrupted water tables. By examining different predictor variables, the study seeks to identify components to help farmers improve resilience and productivity. The results from the model and SWOT analysis help local farmers aiding with site-specific targeted interventions against flood and water-logged conditions.

Materials and methods

This study used the farm-level data from Triyuga, Chaudandhigadhi and Bel municipalities of Udayapur, Nepal via purposive selection of the study area. These municipalities cover half of the maize farming area and are prone to flood inundation, especially by Triyuga River [8]. The snowball sampling of the respondents was done to collect information. A semi - structured questionnaire was prepared and a sample size of 61 respondents were surveyed. The power to detect at least 95% statistically significant effect would require a sample size of 60 or more, at a significance level of 0.05 [9]. Benefit cost ratio was calculated based on respondents' inputs from their flood invaded field. SPSS (v.27) was applied to figure out the crop yield determinants in the study area. To study and examine the significant relationship among dependent and independent variable [10], a multiple linear regression analysis was employed. Lastly, SWOT analysis was conducted for strategic framework to identify strength, weakness, opportunity and threats for future intervene.

Model Specification

The multiple linear regression model was employed to examine crop yield's statistically significant determinants. The equation for the model is

Crop yield = β_0 + β_1 Irrigation + β_2 Seed Quantity + β_3 Synthetic fertilizers + β_4 Pesticide amount + β_5 Amount of organic amendment + β_6 soil color .... Eqation (i)

Where crop yield (ton) is a dependent variable.

Irrigation (0=no, 1=yes), seed variety (0= improved, 1= local), synthetic fertilizers (kg), pesticides amount (kg), amount of organic amendment (kg), and soil color (0= dark soil, 1= light soil) are predictor variables in the model.

The major factors affecting the crop yield in maize are fertilizer management [11] including both synthetic and organic sources [12], pesticide application [13] location-specific seed varieties [14] and irrigation supply [15].

Table 1. Benefit cost ratio for maize production in flood prone areas of Udayapur, Nepal

A. Average Cost of Production	Maize
1. Average variable cost	(ha)
Human Labor	31,678
Bullock Labor	8,766
Machinery cost	2,108
Seed cost	1,836
Manure Cost	1,387
DAP Cost	1,233
Urea Cost	1,100
Pesticide Cost	467
Other Cost	1,121
2. Fixed cost	
Land Cost	43
Farm Equipment, Depreciation and Maintenance	95
Total cost of production	49,834
B. Marketing at nearest market	
Yield	2367
Market Price	20.76
Income	49,139
B.C ratio	**0.986**

Results

Benefit Cost ratio

The **table 1** presents the benefit cost ratio for maize production in the flood inundation in Udayapur district of Nepal. The B:C ratio for maize cultivation in flood prone area of Udayapur was found to be 0.986. This indicate that the return from the crop is not sufficient enough to cover the costs incurred. Thus, the production enterprise in not profitable.

Multiple Linear Regression

Table 2. A Multiple Linear Regression for maize yield determinants in flood-prone areas of Udayapur, Nepal

Model	Unstandardized coefficient		Standardized coefficient	t value	Sig.	VIF
	B	Std Error	***B***			
(Constant)	5.314	2.086		2.548	.038	
Irrigation	-7.084	1.469	-1.389	-4.822	.002	5.960
Type of Seed	.053	.066	.248	.796	.452	6.972
Quantity of Synthetic fertilizers	.294	.061	.857	4.792	.002	2.299
Pesticide use	-4.070	1.221	-.798	-3.333	.013	4.118
Quantity of organic amendments	1.745E-5	.001	.005	.023	.983	2.946
Soil color	5.996	1.630	.859	3.677	.008	3.916

Dependent Variable: Crop Yield R=0.950; R^2=0.903 Adjusted R^2 = 0.819; F (6,7) = 10.804; P = 0.03

Table 2. summarizes the results of a multiple linear regression model for crop yield in Udayapur, Nepal. The dependent variable for the model is crop yield (quintal) and the independent variables are irrigation (yes= 0, no =1), seed quantity (kg), amount of synthetic fertilizers used (kg), pesticide use (yes = 0, no = 1), quantity of organic amendments (kg) and soil color (0= light soil, 1 = dark soil). After analyzing individual predictors, it was found that irrigation had a -7.084 unstandardized beta coefficient suggesting that with an increase in irrigation supply, there was a notable decrease in crop yield. It has a p-value of 0.02 suggesting statistically significant. The preference for improved seed variety over local variety has a positive but insignificant relation with crop yield with an unstandardized beta value of 0.053. Similarly, the unstandardized coefficient for the quantity of synthetic fertilizers and its p-value were 0.294 and 0.02 respectively, indicating that this predictor value positively affects crop yield and is statistically significant. It was also found that with increased pesticide use, the crop yield decreased significantly (p-value = 0.013) by 4.07 units. Further, the quantity of organic amendments has a positive but insignificant relation with crop yield. Lastly, light-colored soil has a positive and significant association with crop yield with a p-value of 0.008 and

increased yield by 5.9998 units compared to dark soil. Among the variables, irrigation, quantity of synthetic fertilizers and soil color were highly significant at 1% level of significance. Whereas, pesticide application was significant to crop yield at 5% level of significance.

This model indicates a high level of fit with R= 0.950 meaning that 95 % correlation exists between independent and dependent variables. Since R^2 = 0.903, 90.3% of the variation in crop yield is explained by the model. Similarly, the adjusted R^2 is slightly lesser than R^2, to prevent overfitting. The f statistics of 10.804 and p-value of 0.03 suggest that the model is statistically significant. The VIF values for each predictor variable are less than 10, suggesting that the model is free from multicollinearity.

Lastly, irrigation and pesticide use were both negatively correlated and statistically significant with crop yield. Amount of synthetic fertilizers and lighter soil color share positive and statistically significant relation to crop yield. With a decent R^2 value, large proportion of variance is explained by this model. The model also possesses no violation of linear regression assumptions (no multicollinearity).

SWOT Analysis

Table 3 presents the Strength, Weakness, Opportunities and Threats of farming in the flood prone area of Udayapur for maize cultivation.

Table 3. SWOT Analysis of Maize Production in Flood-Prone Areas of Udayapur, Nepal

Strength	**Weakness**
▪ Framers use shorter maturation period maize variety ▪ Availability of inputs ▪ Favorable climatic condition ▪ Experienced farmers ▪ Water availability	▪ Soil Degradation ▪ Inefficient drainage management ▪ Lack of crop diversification ▪ Input inefficiency due to flood invasion ▪ Depletion of soil nutrients ▪ Depletion of pesticides
Opportunity	**Threats**
▪ Government support with river embankments and dams ▪ Growing maize demand especially by poultry industry ▪ NGO and INGOs intervention ▪ Risk management and crop diversification trend	▪ Flood invasion ▪ Higher managerial cost ▪ Input inefficiency ▪ Increasing trend of importing maize

Discussion

The B:C ratio for maize in flood prone area is 0.986 which clearly suggests that the firms aren't operating with profitable margin. The B:C ratio for maize farming in the same district was 1.21 [16]. The study areas had clearly hinderance factors affecting the crop economics. Further results so obtained are somewhat counterintuitive, as irrigation, pesticide application, and dark-colored soils are usually associated with promoting crop yield. However, in flood-prone areas, better drainage, lessened pesticide application, and light soils might have better characteristics in supporting crop growth.

In flood-prone areas, the accumulated water limits the oxygen supply to plant roots by creating anaerobic soil. This can dismantle the usual movement of pesticides and can accumulate in the soil profile. This harms biotic soil and nutrient cycle leading to retarded plant growth [17]. Additionally, the pesticides can run-off or leach in such soil making plants more vulnerable to pests. Research suggests that anaerobic soil can alter the dynamics of pesticides and cause them to act as stressors rather than protectors [18]. Hence pesticide application is not always associated with a higher yield [19] as evident in our study.

Essential plant nutrients such as nitrogen and phosphorous leach deeper into the soil profile resulting paucity of nutrient [20]. Prolonged saturation due to flood and further irrigating the field aid in oxygen depletion, root decay, and pest infestation [21]. The application of synthetic fertilizers is statistically significant on crop yield [22] which was evident in our study. This aligns with the fact that synthetic fertilizers by their nature of rapid-release of nutrients can aid in crop yield [23]. In such anaerobic soil, the slow discharge of nutrients from organic amendment explains why synthetic fertilizers are significant and organic fertilizers are not [24]. To cope with the water abundance in the field, water-resistant varieties, drainage, river embankments, and dams [25] along with location-specific risk management alternatives [26] must be employed to enhance productivity.

Conclusion

The research area holds significant disadvantage in crop production, evident through B:C ratio < 1. In flood-prone areas, the crop yield determinants are different possibly due to anaerobic soil conditions. Among predictors, irrigation, quantity of synthetic fertilizers, pesticide use, and soil color were significant factors governing crop yield in Udayapur. With an increase in irrigation and pesticide application, the crop yield was found to be significantly reducing. Lighter-colored soil was associated with higher yield than darker-colored soils. These results are somewhat counterintuitive. However, in the flood-prone areas, this can happen due to anaerobic soil, nutrient leaching, changes like pesticides becoming stressors, root decay, and so on. To accommodate the depleted soil nutrients, the application of synthetic fertilizers can rapidly release primary nutrients in the soil. The depleted nutrient soil profile upon supply of synthetic fertilizers leads to enhanced productivity. Lastly, better drainage management, dams and embankment should be prioritized. Delayed irrigation and eco-friendly alternatives to pesticide application should be adopted to mitigate the adverse effects of excessive soil moisture.

Declarations

We declare that the research entitled "Assessing determinants of maize yield, economic viability and strategic framework in flood prone areas of Udayapur, Nepal" is my original work. It has not been submitted or published else were. We declare my report as free from plagiarism. We understand that our research may be used as a reference in future research or publications, and we have no objection to its use in that context.

Author contribution statement

Conceptualization: S.D and S.D.; Methodology: S.D; Software and validation: R.Y., Y.D. and B.P.; Analysis: S.D.; Resources: S.D.; Data curation: R.Y.; Writing—original draft preparation: S.D. and Y.D.; Writing—review and editing: S.D. and N.S.; Visualization: N.S.; Supervision: S.D.; Project administration: B.P.; Funding acquisition: S.D and Y.D.; All of the authors agreed on submission of this research article.

Conflicts of interest

No conflict of interest among authors.

Ethics approval

All participants provided informed consent before their inclusion in the study, ensuring their voluntary participation. The confidentiality and anonymity of participants were maintained throughout the research process, and all data were securely stored.

Consent for publication

I consent to the publication of materials related to my participation in the research study titled 'Assessing determinants of maize yield, economic viability and strategic framework in flood prone areas of Udayapur, Nepal'. I understand that my information will be used for research purposes and that my identity will remain confidential. I am aware that I can withdraw my consent at any time before the publication

Data availability

Additional data will be made available on request.

Funding statement

Self-managed.

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